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DARPA Spectrum Challenge

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SPECTRUM CHALLENGE

The final event took place at DARPA's offices in Arlington, VA. Ninety teams registered from around the world as entrants to the Spectrum Challenge and eighteen teams were selected to participate as finalists. Academic institutions from around the country comprised 14 of the 18 teams, with the remaining 4 teams composed of individual radio hobbyists and practitioners working on their own time.

We would like to thank all the participants for their hard work and dedication. Congratulations to all the teams that made it to the finals and a special congratulation to the teams that won.

More information on the event and winners can be found under [News and Updates](#)

What is the DARPA Spectrum Challenge?

The DARPA Spectrum Challenge was a competition to demonstrate a radio protocol that can best use a given communication channel in the presence of other dynamic users and interfering signals. The Challenge was not focused on developing new radio hardware, but instead was targeted at finding strategies for guaranteeing successful communication in the presence of other radios that may have conflicting co-existence objectives. The Spectrum Challenge entailed head-to-head competitions between each team's radio protocol and an opponent's in a structured testbed environment. The Challenge awarded first place teams in the preliminary event, and first and second place teams in the final event with cash prizes totaling \$200,000.

Why is DARPA interested in spectrum usage?

Radios are used for a wide range of tasks, from the most mundane to the most critical of communications, from garage door openers to military operations. As the use of wireless technology proliferates, radios can often compete with, interfere with, and disrupt the operations of other radios. DARPA seeks innovative approaches that ensure robust communications in such congested and contested environments. Other factors that motivate the need for intelligent use of spectrum include:

- High priority radios in the military and civilian sectors must be able to operate regardless of the ambient electromagnetic environment, to avoid disruption of communications and potential loss of life.
- Response operations, such as disaster relief, further motivate the desire for multiple radio networks to effectively and efficiently share the spectrum without requiring direct

coordination or spectrum preplanning.

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Spectrum Challenge Final Event (March 19th -20th, 2014)

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Spectrum Challenge Final Event Helps Pave the Way for More Robust, Resilient and Reliable Radio Communications

Three teams take home prizes for innovative software techniques designed to enable radios to automatically sense and adapt to congested and contested electromagnetic environments

OUTREACH@DARPA.MIL

4/2/2014



Reliable wireless communications today requires careful allocation of specific portions of the electromagnetic spectrum to individual radio networks. While pre-allocating spectrum is effective in benign environments, radios remain vulnerable to inadvertent interference from other emitters and intentional jamming by adversaries.

On March 19-20, 2014, 15 teams from around the country demonstrated new ways to help overcome these challenges by participating in the final event of the DARPA [Spectrum Challenge](#)—a national competition to develop advanced radio techniques capable of communicating in congested and contested electromagnetic environments without direct coordination or spectrum preplanning. After two intense days of competition, teams from Tennessee Technological University and Georgia Tech Research Institute and an independent team of individuals emerged as the overall winners, earning a

total of \$150,000 in prize money.

“The sophistication of the solutions that the teams developed really impressed us,” said [Yiftach Eisenberg](#), DARPA program manager. “The teams showed that radios can learn to coexist and communicate reliably by autonomously sensing and adapting to congested electromagnetic environments—paving the way for new spectrum-sharing applications for the Department of Defense and commercial industry.”

The final event took place at DARPA’s offices in Arlington, Va. Eighteen teams had previously participated in the Spectrum Challenge preliminary event in September 2013. Three teams that participated in the preliminaries were unable to complete their ambitious designs in time for the final event. The competitors at the final event represented the top 15 teams out of the 90 teams that initially registered. Academic institutions from around the country comprised 12 of the 15 teams, while the remaining three teams were individual radio hobbyists and practitioners working on their own time.

Both the preliminary and final events included two separate tournaments, each with its own goals:

Cooperative tournament: In each match, three teams attempted to effectively share the spectrum while transmitting random data files from their source radio to their destination radio over the same 5 MHz UHF band. A team’s match score was its total packets delivered plus the higher of the two other teams’ delivered packets—thus motivating cooperative behavior. Teams could not coordinate in advance on how to share the spectrum; instead, they had to develop and implement algorithms to enable their assigned software-defined radios to dynamically communicate at a high rate while leaving spectrum available for the other two teams to do the same. This event tested conditions encountered during military operations involving multiple units and coalition partners, and also has possible future commercial applications.

Tennessee Tech Telecom, a team from Tennessee Technological University, won the cooperative tournament and a \$50,000 prize. Efficient Spectrum, a team of individuals from Centreville, Va., came in second and earned a \$25,000 prize:

DARPA Spectrum Challenge Final Event, Coopera...



Competitive tournament: In each match, two teams sought to dominate the spectrum, with the winner being the first to transmit all its files of random data (or to successfully transmit the most packets in three minutes) from a source radio to a destination radio. Teams had to develop and implement algorithms to enable their assigned software-defined radio to dynamically communicate at a high rate in the presence of competitors' signals within the same 5 MHz UHF band. This event tested conditions directly applicable to military communications, where radios must deliver high-priority data in congested and often contested electromagnetic environments. Efficient Spectrum—the runner-up in the cooperative tournament—won the competitive tournament and added another \$50,000 to its earnings. A team from Georgia Tech Research Institute (GTRI) took home \$25,000 as the second-place finisher:

DARPA Spectrum Challenge Final Event, Competi...



As in the preliminaries, DARPA provided all teams with the same radio hardware to ensure that each team would win or lose based on its software algorithms alone. All the matches again occurred on the ORBIT testbed at Rutgers University's WINLAB, which streamed the proceedings live to big screens in DARPA's conference center, where contestants as well as representatives from across the government and industry eagerly watched the event unfold.

"The Spectrum Challenge exceeded expectations for stimulating new technologies and attracting new talent," said Dan Kaufman, director of DARPA's Information Innovation Office, which oversaw the Spectrum Challenge. "As competitors alternately battled over and worked to share the spectrum, it was easy to see how these advanced capabilities could prove invaluable in a wide range of military and civilian applications that seek to maximize the value of this precious and finite resource."

"It was immensely satisfying to see the enthusiasm of the participants and how quickly they grasped the complexities of operating in dynamic spectrum environments," Eisenberg said. "We want to continue to work with industry and academia to build upon the achievements we have seen so far."

More information about the Spectrum Challenge is available at

<http://www.darpa.mil/program/spectrum-challenge>.

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Spectrum Challenge

COOPERATIVE TOURNAMENT



Group B		Cumm. Score
WSL-NEU		58326
WINBOT		61371
Wireless Infidels		47532
Notre Spectrum		62582
First:	Notre Spectrum	
Second:	WSL-NEU	

Group C		Cumm. Score
Efficient Spectrum		53404
VT-Hume		49629
Orange WiWar		38968
KPE		49612
First:	Efficient Spectrum	
Second:	VT-Hume	

Group D		Cumm. Score
Purdue		39489
wasabi		41990
VT CogRad		40355
Tenn Tech Tel		46840
First:	Tenn Tech Tel	
Second:	wasabi	

Group E		Cumm. Score
MarmotE		57298
Gator Wings		61051
GTRI		51885
Wildcats		54359
First:	Gator Wings	
Second:	MarmotE	

Group F		Cumm. Score
Notre Spectrum (3)		55581
VT-Hume (3)		51982
Tenn Tech Tel (3)		64359
MarmotE (3)		65481
First:	MarmotE	
Second:	Tenn Tech Tel	

Group G		Cumm. Score
Efficient Spectrum (3)		70132
WSL-NEU (3)		58845
Gator Wings (3)		55852
wasabi (3)		51342
First:	Efficient Spectrum	
Second:	WSL-NEU	

Group H		Cumm. Score
MarmotE (3)		59895
Tenn Tech Tel (3)		69350
Efficient Spectrum (3)		63472
WSL-NEU (3)		44815
WINNER:	Winnner:	Tenn Tech Tel
SECOND PLACE:	Second Place:	Efficient Spectrum



COOPERATIVE MATCH SCORES

Preliminaries

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
WSL-NEU	WINBOT	Wireless Infidels	18990	18990	14166
WINBOT	WSL-NEU	Notre Spectrum	18703	18703	18271
Wireless Infidels	Notre Spectrum	WINBOT	16739	23678	23678
Notre Spectrum	Wireless Infidels	WSL-NEU	20633	16627	20633

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
Efficient Spectrum	VT-Hume	Orange WnWar	18738	18738	18457
VT-Hume	Efficient Spectrum	KPE	18793	26840	26840
Orange WnWar	KPE	VT-Hume	14946	14946	12098
KPE	Orange WnWar	Efficient Spectrum	7826	5565	7826

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
Purdue	wasabi	VT CogRad	10343	12091	12091
wasabi	Purdue	Tenn Tech Tel	18551	16783	18551
VT CogRad	Tenn Tech Tel	wasabi	15926	15926	11348
Tenn Tech Tel	VT CogRad	Purdue	12363	12338	12363

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
MarmotE	Gator Wings	2	15000	18343	18343
Gator Wings	MarmotE	Wildcats	27298	27298	20817
GTRI	Wildcats	Gator Wings	17144	17144	15410
Wildcats	GTRI	MarmotE	16398	16398	15000

Semifinals

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
Notre Spectrum (3)	VT-Hume (3)	Tenn Tech Tel (3)	20291	15077	20291
VT-Hume (3)	Notre Spectrum (3)	MarmotE (3)	18993	21413	21413
Tenn Tech Tel (3)	MarmotE (3)	VT-Hume (3)	24471	24471	17912
MarmotE (3)	Tenn Tech Tel (3)	Notre Spectrum (3)	19597	19597	13877

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
Efficient Spectrum (3)	WSL-NEU (3)	Gator Wings (3)	17903	13125	17903
WSL-NEU (3)	Efficient Spectrum (3)	wasabi (3)	30000	30000	18111
Gator Wings (3)	wasabi (3)	WSL-NEU (3)	15720	15012	15720
wasabi (3)	Gator Wings (3)	Efficient Spectrum (3)	18219	22229	22229

Finals

Player 1	Player 2	Player 3	P1 Score	P2 Score	P3 Score
MarmotE (3)	Tenn Tech Tel (3)	Efficient Spectrum (3)	19608	27016	27016
Tenn Tech Tel (3)	MarmotE (3)	WSL-NEU (3)	23011	23154	23154
Efficient Spectrum (3)	WSL-NEU (3)	Tenn Tech Tel (3)	19323	11992	19323
WSL-NEU (3)	Efficient Spectrum (3)	MarmotE (3)	9669	17133	17133



Spectrum Challenge

COMPETITIVE TOURNAMENT

Group A	Team Total	Group B	Team Total	Group C	Team Total	Group D	Team Total	Group E	Team Total	Group F	Team Total
Purdue	4910	WSL-NEU	45038	Gator Wings	60000	Efficient Spectrum	30000	MarmotE	60000	-	0
GTRI	30000	Orange WiWar	47991	wasabi	42544	Wireless Infidels	553	VT CogRad	8913	VT-Hume	2081
-	0	Tenn Tech Tel	12802	Notre Spectrum	4689	-	0	KPE	23721	Wildcats	23
First:	GTRI	First:	Orange WiWar	First:	Gator Wings	First:	Efficient Spectrum	First:	MarmotE	First:	VT-Hume
Second:	Purdue	Second:	WSL-NEU	Second:	wasabi	Second:	Wireless Infidels	Second:	KPE	Second:	Wildcats

Group ABC2	Team Total
Purdue	9296
WSL-NEU	33112
wasabi	50522
First:	wasabi

Group DEF2	Team Total
Wireless Infidels	1310
KPE	37981
Wildcats	28088
First:	KPE

Group G	Team Total
GTRI (6)	84712
Orange WiWar (6)	71815
Gator Wings (6)	57393
KPE (6)	32293
First:	GTRI

Group H	Team Total
Efficient Spectrum (6)	79629
MarmotE (6)	59998
VT-Hume (6)	4241
wasabi (6)	47362
First:	Efficient Spectrum

Finals	Team Total
GTRI	9912
Efficient Spectrum	30000
WINNER:	Efficient Spectrum
SECOND PLACE:	GTRI



Spectrum Challenge

COMPETITIVE MATCH SCORES

Preliminaries

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Purdue	GTRI	2300	15000	2610	15000	4910	30000
Purdue	---	0	0	0	0	0	0
GTRI	---	0	0	0	0	0	0

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
WSL-NEU	Orange WiWar	38	15000	15000	2991	15038	17991
WSL-NEU	Tenn Tech Tel	15000	3780	15000	4070	30000	7850
Orange WiWar	Tenn Tech Tel	15000	2609	15000	2343	30000	4952

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Gator Wings	wasabi	15000	10859	15000	1685	30000	12544
Gator Wings	Notre Spectrum	15000	311	15000	0	30000	311
wasabi	Notre Spectrum	15000	4058	15000	320	30000	4378

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Efficient Spectrum	Wireless Infidels	15000	0	15000	553	30000	553
Efficient Spectrum	---	0	0	0	0	0	0
Wireless Infidels	---	0	0	0	0	0	0

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
MarmotE	VT CogRad	15000	1009	15000	0	30000	1009
MarmotE	KPE	15000	2226	15000	1985	30000	4211
VT CogRad	KPE	3	9760	5901	9750	5904	19510

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
---	VT-Hume	0	0	0	0	0	0
---	Wildcats	0	0	0	0	0	0
VT-Hume	Wildcats	703	23	1358	0	2061	23

Semifinals

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Wireless Infidels	KPE	0	9755	0	9497	0	19252
Wireless Infidels	Wildcats	1310	7721	0	7285	1310	15006
KPE	Wildcats	9412	12930	9317	152	18729	13082

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Purdue	WSL-NEU	1616	15000	2743	2039	4359	17039
Purdue	wasabi	2269	15000	2668	14999	4937	29999
WSL-NEU	wasabi	1073	15000	15000	5523	16073	20523

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
GTRI (B)	Orange WiWar (B)	9712	15000	15000	2280	24712	17280
Gator Wings (B)	KPE (B)	15000	8748	15000	4130	30000	12878
GTRI (B)	Gator Wings (B)	15000	5035	15000	4915	30000	9950
Orange WiWar (B)	KPE (B)	13042	9524	15000	1371	28042	10895
GTRI (B)	KPE (B)	15000	6638	15000	1882	30000	8520
Orange WiWar (B)	Gator Wings (B)	11493	15000	15000	2443	26493	17443

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Efficient Spectrum (B)	MarmotE (B)	4629	15000	15000	14998	19629	29998
VT-Hume (B)	wasabi (B)	891	15000	1140	12461	2031	27461
Efficient Spectrum (B)	VT-Hume (B)	15000	1099	15000	485	30000	1584
MarmotE (B)	wasabi (B)	0	15000	0	23	0	15023
Efficient Spectrum (B)	wasabi (B)	15000	4222	15000	656	30000	4878
MarmotE (B)	VT-Hume (B)	15000	306	15000	320	30000	626

Finals

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
GTRI	Efficient Spectrum	4686	15000	5226	15000	9912	30000

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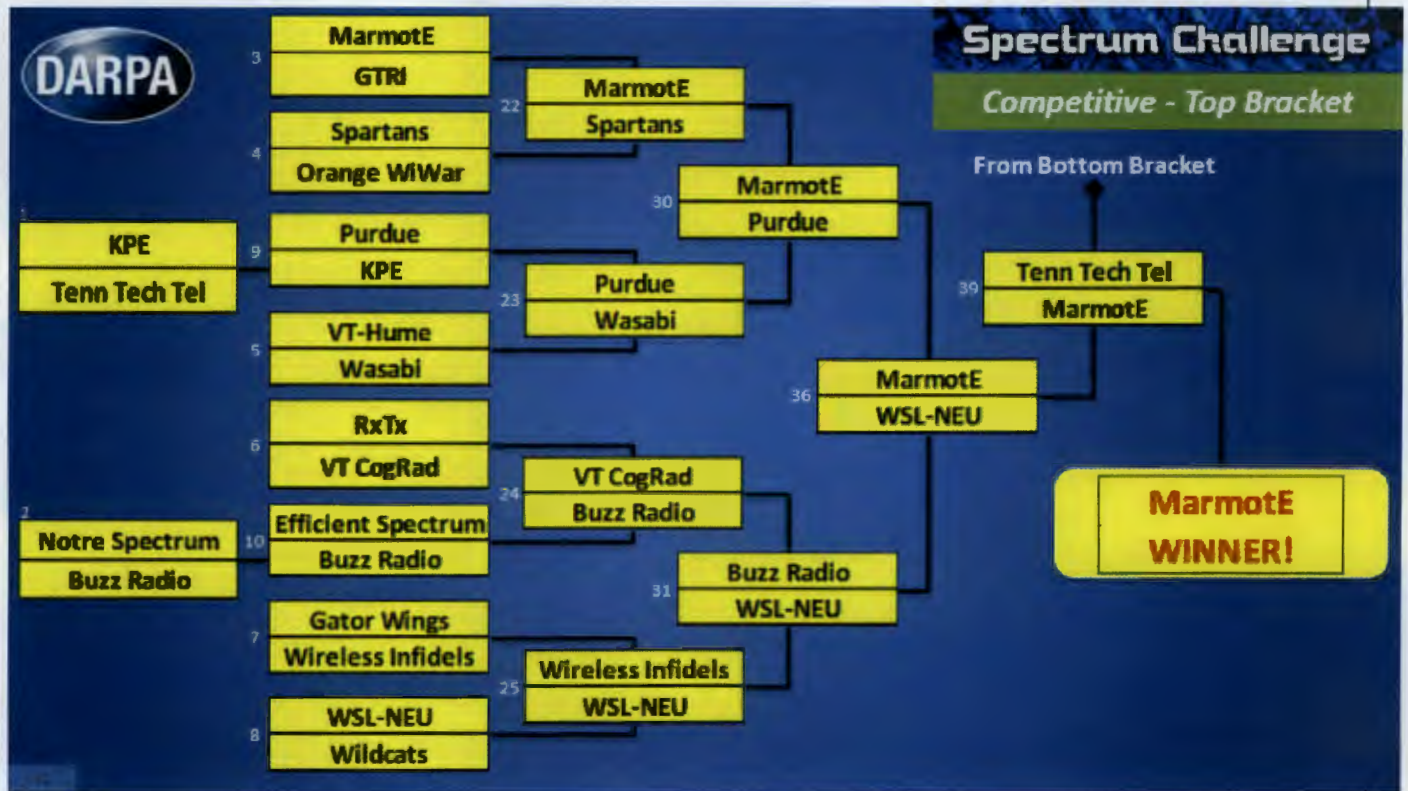
Congratulations to the Preliminary Tournament winners!

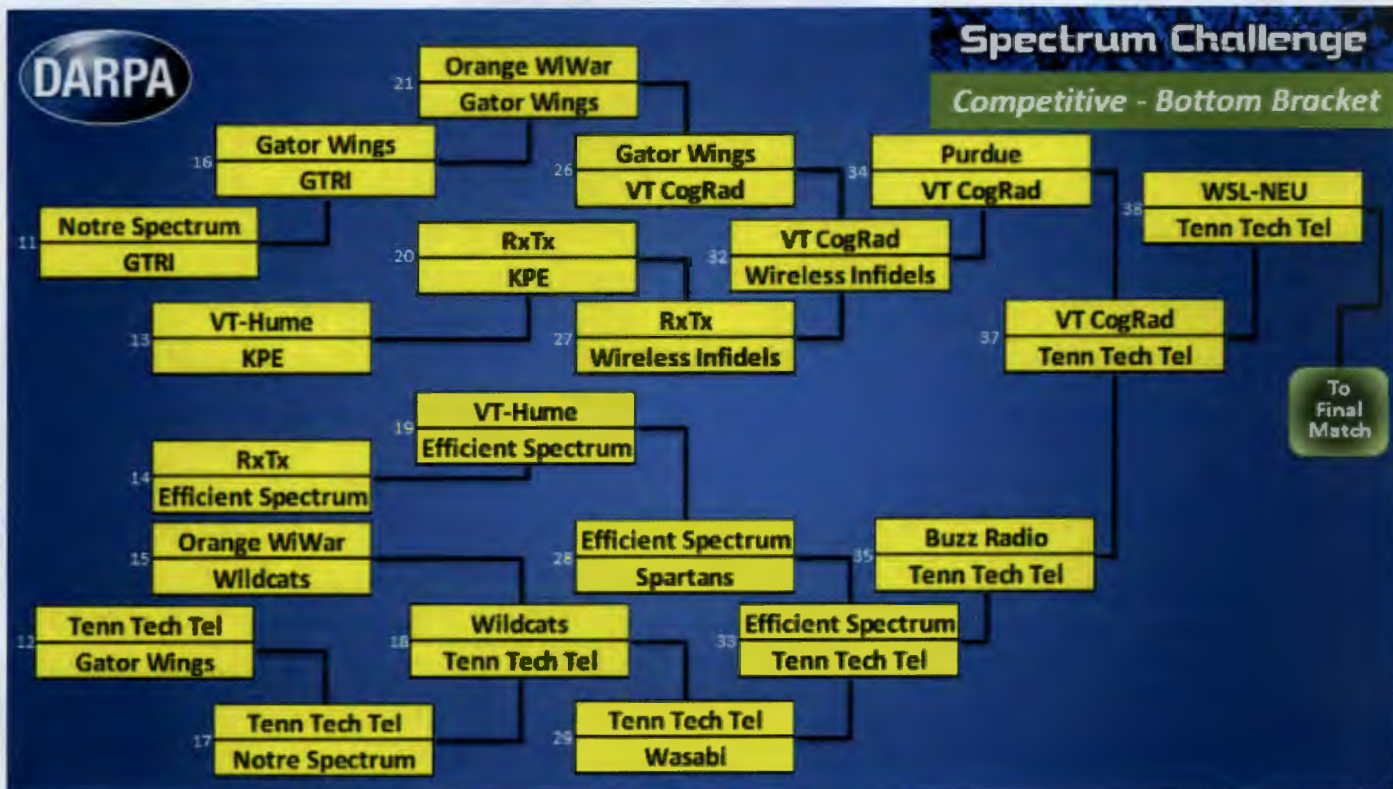
Team MarmotE from Vanderbilt University
Team WSL-NEU from Northeastern University

Team MarmotE has won the Competitive tournament in a close match against Tennessee Tech Telecom.

Team WSL-WEU's final match in the Cooperative tournament went down the final few seconds to clinch its win over team wasabi.

Here are the complete tournament ladders for the Competitive tournament.





Here are the scores for the final round of the Cooperative tournament.

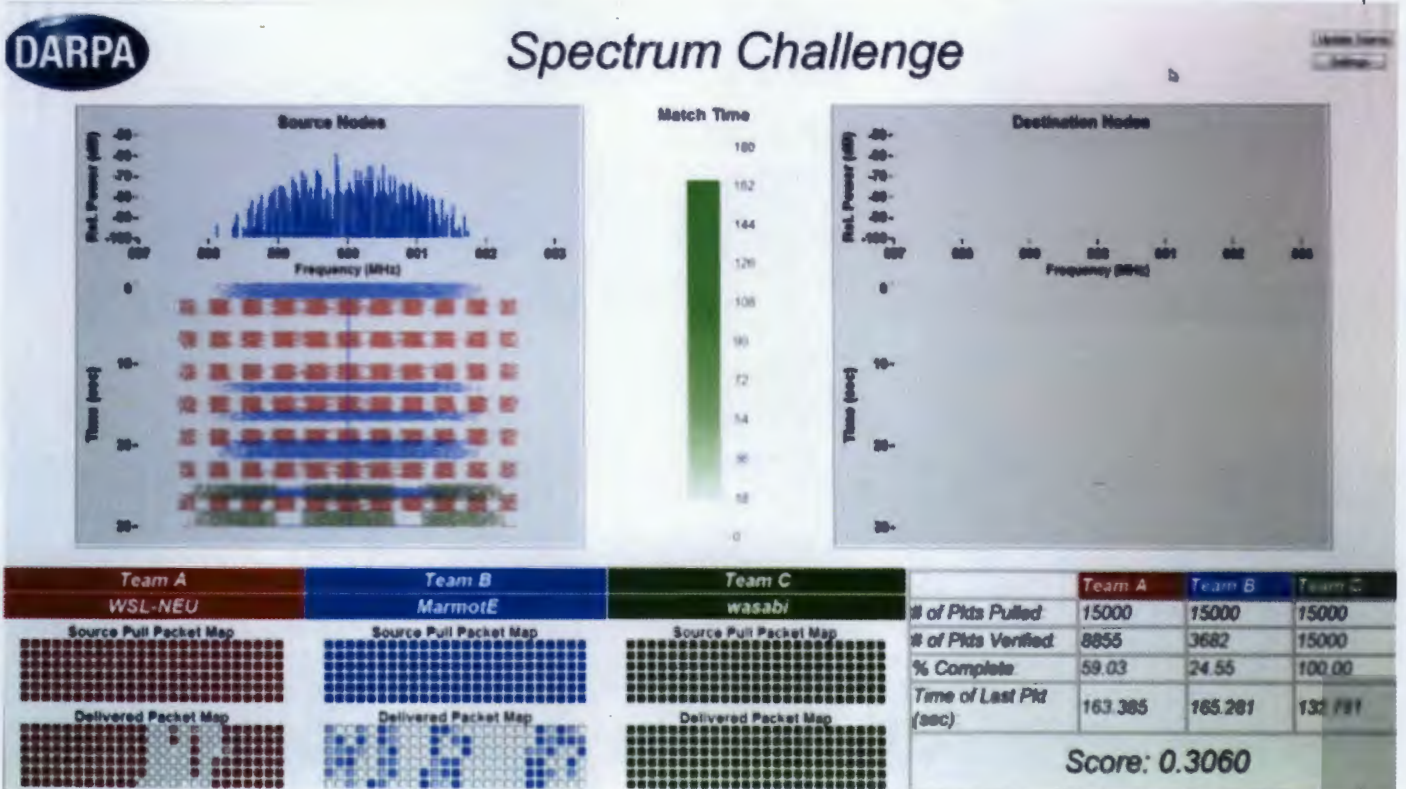
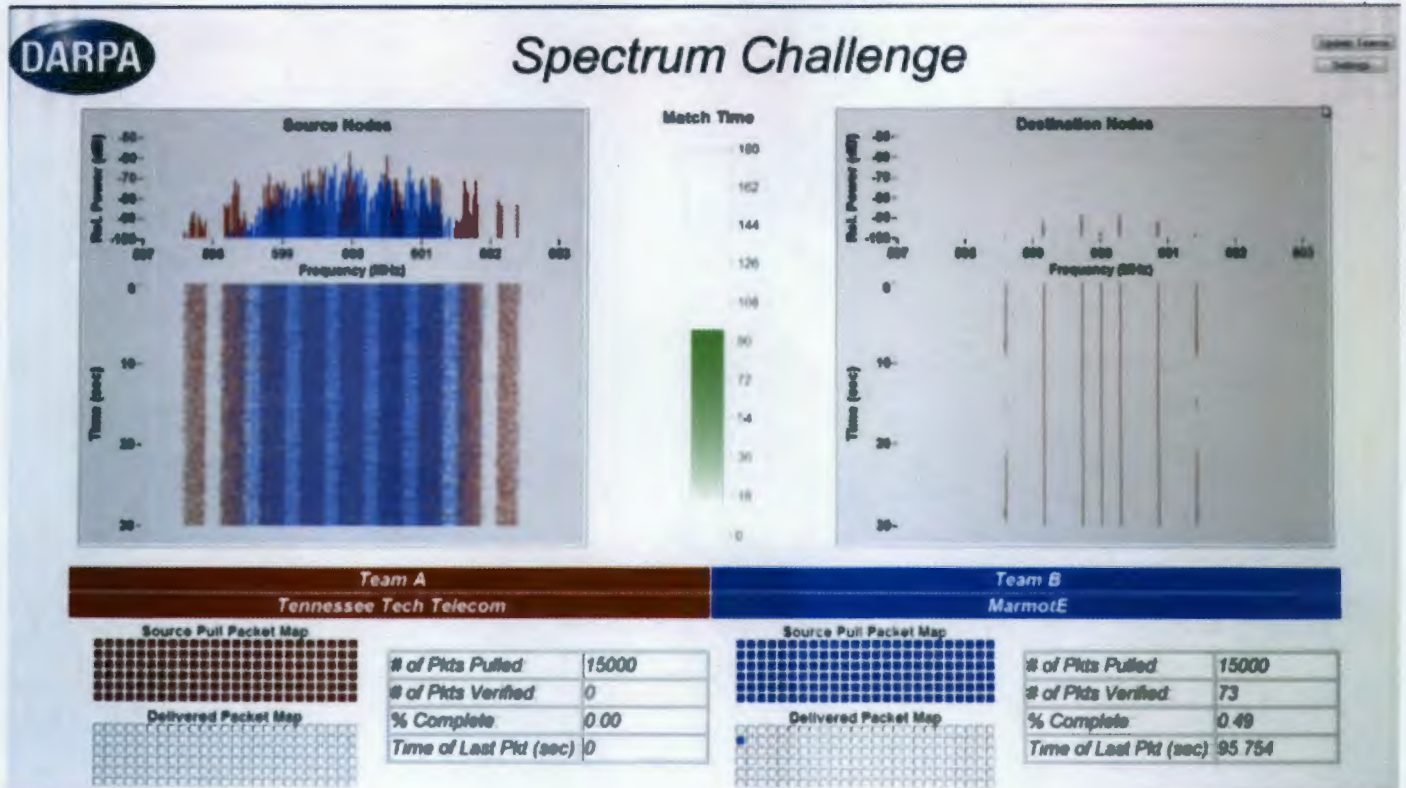
Spectrum Challenge
Cooperative Finals

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!**

The tournament utilized real-time data visualization software that attendees viewed at the DARPA Conference Center. While the radios were operating on the ORBIT testbed at Rutgers University's WINLAB, attendees viewed spectrograms and the data packet transfer progress as it was happening. The images below are screen shots of the visualization output. The first is a screen shot from the final competitive match between Tennessee Tech Telecom and the second is a screen shot from the final cooperative match involving WSL-NEU, MarmotE and wasabi.



The winners pose with the Dr. Arati Prabhakar, DARPA Director and Dr. Yifty Eisenberg, Program Manager.



Congratulations to all the participants. We look forward to the Final Tournament in March 2014.

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Why is DARPA interested in spectrum usage?

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- High priority radios in the military and civilian sectors must be able to operate regardless of the ambient electromagnetic environment, to avoid disruption of communications and potential loss of life.

- Response operations, such as disaster relief, further motivate the desire for multiple radio networks to effectively and efficiently share the spectrum without requiring direct coordination or spectrum preplanning.

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COOPERATIVE TOURNAMENT

Spectrum Challenge

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WSL-NEU (3)		58845
Gator Wings (3)		55852
wasabi (3)		51342
First:	Efficient Spectrum	
Second:	WSL-NEU	

Group H		Cumm Score
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Tenn Tech Tel (3)		69350
Efficient Spectrum (3)		63472
WSL-NEU (3)		44815
WINNER:	Tenn Tech Tel	
SECOND PLACE:	Efficient Spectrum	

DSC Final Challenge March 19-20, 20



COOPERATIVE MATCH SCORES

Preliminaries

Player_1	Player_2	Player_3	P1_Score	P2_Score	P3_Score
WSL-NEU	WINBOT	Wireless Infidels	18990	18990	14166
WINBOT	WSL-NEU	Notre Spectrum	18703	18703	18271
Wireless Infidels	Notre Spectrum	WINBOT	16739	23678	23678
Notre Spectrum	Wireless Infidels	WSL-NEU	20633	16627	20633
Player_1	Player_2	Player_3	P1_Score	P2_Score	P3_Score
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VT-Hume	Efficient Spectrum	KPE	18793	26840	26840
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MarmotE	Gator Wings	2	15000	18343	18343
Gator Wings	MarmotE	Wildcats	27298	27298	20817
GTRI	Wildcats	Gator Wings	17144	17144	15410
Wildcats	GTRI	MarmotE	16398	16398	15000

Semifinals

Player_1	Player_2	Player_3	P1_Score	P2_Score	P3_Score
Notre Spectrum (3)	VT-Hume (3)	Tenn Tech Tel (3)	20291	15077	2029
VT-Hume (3)	Notre Spectrum (3)	MarmotE (3)	18993	21413	2141
Tenn Tech Tel (3)	MarmotE (3)	VT-Hume (3)	24471	24471	1791
MarmotE (3)	Tenn Tech Tel (3)	Notre Spectrum (3)	19597	19597	1387
Player_1	Player_2	Player_3	P1_Score	P2_Score	P3_Score
Efficient Spectrum (3)	WSL-NEU (3)	Gator Wings (3)	17903	13125	1790
WSL-NEU (3)	Efficient Spectrum (3)	wasabi (3)	30000	30000	1811
Gator Wings (3)	wasabi (3)	WSL-NEU (3)	15720	15012	1572
wasabi (3)	Gator Wings (3)	Efficient Spectrum (3)	18219	22229	2222

Finals

Player_1	Player_2	Player_3	P1_Score	P2_Score	P3_Score
MarmotE (3)	Tenn Tech Tel (3)	Efficient Spectrum (3)	19608	27016	27011
Tenn Tech Tel (3)	MarmotE (3)	WSL-NEU (3)	23011	23154	23154
Efficient Spectrum (3)	WSL-NEU (3)	Tenn Tech Tel (3)	19323	11992	19323
WSL-NEU (3)	Efficient Spectrum (3)	MarmotE (3)	9669	17133	17133

COMPETITIVE TOURNAMENT

Group A	Team Total	Group B	Team Total	Group C	Team Total	Group D	Team Total	Group E	Team Total	Group F	Team Total
Purdue	4910	WSL-NEU	45038	Gator Wings	60000	Efficient Spectrum	30000	MarmotE	60000		0
GTRI	30000	Orange WiWar	47991	wasabi	42544	Wireless Infidels	553	VT CogRad	6913	VT-Hume	206
	0	Tenn Tech Tel	12802	Notre Spectrum	4689		0	KPE	23721	Wildcats	23
First:	GTRI	First:	Orange WiWar	First:	Gator Wings	First:	Efficient Spectrum	First:	MarmotE	First:	VT-Hu
Second:	Purdue	Second:	WSL-NEU	Second:	wasabi	Second:	Wireless Infidels	Second:	KPE	Second:	Wildc

Prelims

Group ABC2	Team Total
Purdue	9296
WSL-NEU	33112
wasabi	50522
First:	wasabi

Group DEF2	Team Total
Wireless Infidels	1310
KPE	37981
Wildcats	28088
First:	KPE

Semifinals

Group G	Team Total
GTRI (6)	84712
Orange WiWar (6)	71815
Gator Wings (6)	57393
KPE (6)	32293
First:	GTRI

Group H	Team Total
Efficient Spectrum (6)	79629
MarmotE (6)	59998
VT-Hume (6)	4241
wasabi (6)	47362
First:	Efficient Spectrum

Finals

Finals	Team Total
GTRI	9912
Efficient Spectrum	30000
WINNER:	Efficient Spectrum
SECOND PLACE:	GTRI

COMPETITIVE MATCH SCORES

Preliminaries

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Purdue	GTRI	2300	15000	2610	15000	4910	30000
Purdue	---	0	0	0	0	0	0
GTRI	---	0	0	0	0	0	0

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
WSL-NEU	Orange WiWar	38	15000	15000	2991	15038	17991
WSL-NEU	Tenn Tech Tel	15000	3780	15000	4070	30000	7850
Orange WiWar	Tenn Tech Tel	15000	2609	15000	2343	30000	4952

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Gator Wings	wasabi	15000	10859	15000	1685	30000	12544
Gator Wings	Notre Spectrum	15000	311	15000	0	30000	311
wasabi	Notre Spectrum	15000	4058	15000	320	30000	4378

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Efficient Spectrum	Wireless Infidels	15000	0	15000	553	30000	553
Efficient Spectrum	---	0	0	0	0	0	0
Wireless-Infidels	---	0	0	0	0	0	0

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
MarmotE	VT CogRad	15000	1009	15000	0	30000	1009
MarmotE	KPE	15000	2228	15000	1985	30000	4211
VT CogRad	KPE	3	9780	5901	9750	5904	19510

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
---	VT-Hume	0	0	0	0	0	0
---	Wildcats	0	0	0	0	0	0
VT-Hume	Wildcats	703	23	1358	0	2061	23

Semifinals

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Wireless Infidels	KPE	0	9755	0	9497	0	19252
Wireless Infidels	Wildcats	1310	7721	0	7285	1310	15006
KPE	Wildcats	9412	12930	9317	152	18729	13082

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Purdue	WSL-NEU	1616	15000	2743	2039	4359	17039
Purdue	wasabi	2269	15000	2668	14999	4937	29999
WSL-NEU	wasabi	1073	15000	15000	5523	16073	20523

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
GTRI (6)	Orange WiWar (6)	9712	15000	15000	2280	24712	17280
Gator Wings (6)	KPE (6)	15000	8748	15000	4130	30000	12878
GTRI (6)	Gator Wings (6)	15000	5035	15000	4915	30000	9950
Orange WiWar (6)	KPE (6)	13042	9524	15000	1371	28042	10895
GTRI (6)	KPE (6)	15000	6638	15000	1882	30000	8520
Orange WiWar (6)	Gator Wings (6)	11493	15000	15000	2443	26493	17443

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
Efficient Spectrum (6)	MarmotE (6)	4629	15000	15000	14998	19629	29998
VT-Hume (6)	wasabi (6)	891	15000	1140	12461	2031	27461
Efficient Spectrum (6)	VT-Hume (6)	15000	1099	15000	485	30000	1584
MarmotE (6)	wasabi (6)	0	15000	0	23	0	15023
Efficient Spectrum (6)	wasabi (6)	15000	4222	15000	656	30000	4878
MarmotE (6)	VT-Hume (6)	15000	306	15000	320	30000	626

Finals

Player 1	Player 2	Game 1 P1	Game 1 P2	Game 2 P1	Game 2 P2	P1 Total	P2 Total
GTRI	Efficient Spectrum	4686	15000	5226	15000	9912	30000

NEWS

Spectrum Challenge Final Event Helps Pave the Way for More Robust, Resilient and Reliable Radio Communications

April 02, 2014

Three teams take home prizes for innovative software techniques designed to enable radios to automatically sense and adapt to congested and contested electromagnetic environments

Reliable wireless communications today requires careful allocation of specific portions of the electromagnetic spectrum to individual radio networks. While pre-allocating spectrum is effective in benign environments, radios remain vulnerable to inadvertent interference from other emitters and intentional jamming by adversaries.

On March 19-20, 2014, 15 teams from around the country demonstrated new ways to help overcome these challenges by participating in the final event of the DARPA Spectrum Challenge—a national competition to develop advanced radio techniques capable of communicating in congested and contested electromagnetic environments without direct coordination or spectrum preplanning. After two intense days of competition, teams from Tennessee Technological University and Georgia Tech Research Institute and an independent team of individuals emerged as the overall winners, earning a total of \$150,000 in prize money.

“The sophistication of the solutions that the teams developed really impressed us,” said Yiftach Eisenberg, DARPA program manager. “The teams showed that radios can learn to coexist and communicate reliably by autonomously sensing and adapting to congested electromagnetic environments—paving the way for new spectrum-sharing applications for the Department of Defense and commercial industry.”

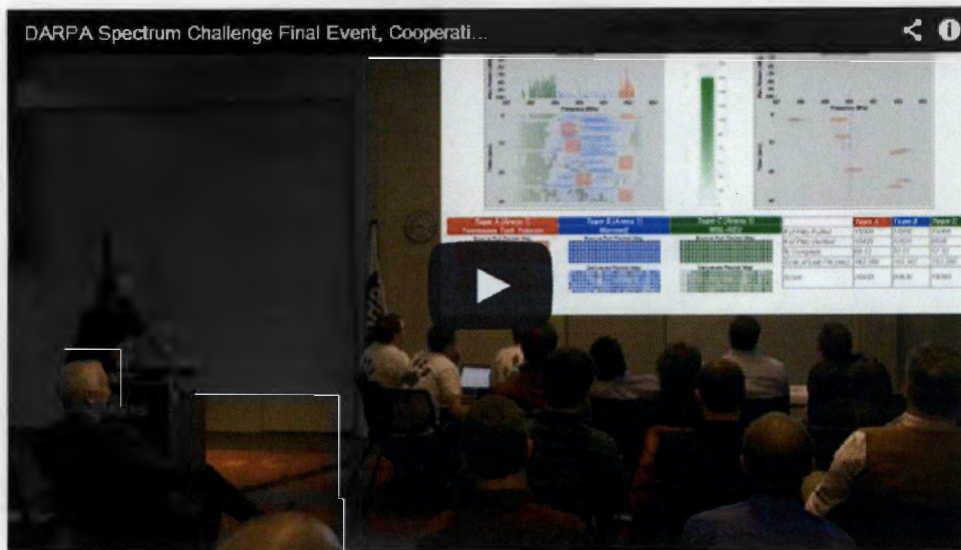
The final event took place at DARPA’s offices in Arlington, Va. Eighteen teams had previously participated in the Spectrum Challenge preliminary event in September 2013. Three teams that participated in the preliminaries were unable to complete their ambitious designs in time for the final event. The competitors at the final event represented the top 15 teams out of the 90 teams that initially registered. Academic institutions from around the country comprised 12 of the 15 teams, while the remaining three teams were individual radio hobbyists and practitioners working on their own time.

Both the preliminary and final events included two separate tournaments, each with its own goals:

- Cooperative tournament: In each match, three teams attempted to effectively share the spectrum while transmitting random data files from their source radio to their destination

radio over the same 5 MHz UHF band. A team's match score was its total packets delivered plus the higher of the two other teams' delivered packets—thus motivating cooperative behavior. Teams could not coordinate in advance on how to share the spectrum; instead, they had to develop and implement algorithms to enable their assigned software-defined radios to dynamically communicate at a high rate while leaving spectrum available for the other two teams to do the same. This event tested conditions encountered during military operations involving multiple units and coalition partners, and also has possible future commercial applications.

Tennessee Tech Telecom, a team from Tennessee Technological University, won the cooperative tournament and a \$50,000 prize. Efficient Spectrum, a team of individuals from Centreville, Va., came in second and earned a \$25,000 prize:



- **Competitive tournament:** In each match, two teams sought to dominate the spectrum, with the winner being the first to transmit all its files of random data (or to successfully transmit the most packets in three minutes) from a source radio to a destination radio. Teams had to develop and implement algorithms to enable their assigned software-defined radio to dynamically communicate at a high rate in the presence of competitors' signals within the same 5 MHz UHF band. This event tested conditions directly applicable to military communications, where radios must deliver high-priority data in congested and often contested electromagnetic environments. Efficient Spectrum—the runner-up in the cooperative tournament—won the competitive tournament and added another \$50,000 to its earnings. A team from Georgia Tech Research Institute (GTRI) took home \$25,000 as the second-place finisher:



As in the preliminaries, DARPA provided all teams with the same radio hardware to ensure that each team would win or lose based on its software algorithms alone. All the matches again occurred on the ORBIT testbed at Rutgers University's WINLAB, which streamed the proceedings live to big screens in DARPA's conference center, where contestants as well as representatives from across the government and industry eagerly watched the event unfold.

"The Spectrum Challenge exceeded expectations for stimulating new technologies and attracting new talent," said Dan Kaufman, director of DARPA's Information Innovation Office, which oversaw the Spectrum Challenge. "As competitors alternately battled over and worked to share the spectrum, it was easy to see how these advanced capabilities could prove invaluable in a wide range of military and civilian applications that seek to maximize the value of this precious and finite resource."

"It was immensely satisfying to see the enthusiasm of the participants and how quickly they grasped the complexities of operating in dynamic spectrum environments," Eisenberg said. "We want to continue to work with industry and academia to build upon the achievements we have seen so far."

More information about the Spectrum Challenge is available at <http://go.usa.gov/KtSx> (<http://go.usa.gov/KtSx>).

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Images



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Teams from Tennessee Technological University (Tennessee Tech Telecom, top) and an independent team of individuals from Centreville, Va., (Efficient Spectrum, bottom) hold ceremonial checks representing the prizes they each won in the cooperative tournament at the DARPA Spectrum Challenge final event. Presenting the awards are Dr. Yiftach Eisenberg (far right), DARPA program manager, and DARPA Director Dr. Arati Prabhakar (far left). The Spectrum Challenge was a DARPA-sponsored competition designed to encourage development of programmable radios that can deliver high priority transmissions in congested and contested spectrum environments.



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Efficient Spectrum, an independent team of individuals from Centreville, Va., (top), and a team from Georgia Tech Research Institute (GTRI, bottom) hold ceremonial checks representing the prizes they each won in the competitive tournament at the DARPA Spectrum Challenge final event. Presenting the awards are Dr. Yiftach Eisenberg (far right), DARPA program manager, and DARPA Director Dr. Arati Prabhakar (far left). The Spectrum Challenge was a DARPA-sponsored competition designed to encourage development of programmable radios that can deliver high-priority transmissions in congested and contested spectrum environments.



To help competitors see how their software radios performed during the course of each match, Rutgers University's WINLAB developed data visualization technology for the DARPA Spectrum Challenge. The technology showed the specific radio frequencies that each team used and each team's progress in transmitting the test file. Based on color-coded spectrum occupancy patterns projected on large screens in the event hall, watchers could see how the radios interacted and infer each team's likely strategies in real time.

Additional Info

- [Spectrum Challenge](#)
- [Spectrum Challenge - Meet the Teams](#)

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News

Spectrum Challenge Preliminary Event Showcases Robust Radio Techniques

September 19, 2013

Teams from Northeastern University and Vanderbilt University win top honors for designing programmable radios that can communicate in adverse spectrum environments

Radios are used for a wide range of tasks, from the most mundane to the most critical of communications, from garage door openers to first responders to military operations. Wireless devices often inadvertently interfere with and disrupt radio communications, and in battlefield environments adversaries may intentionally jam friendly communications. To stimulate the development of radio techniques that can overcome these impediments, DARPA launched its Spectrum Challenge—a competitive demonstration of robust radio technologies that seek to communicate reliably in congested and contested electromagnetic environments without direct coordination or spectrum preplanning.

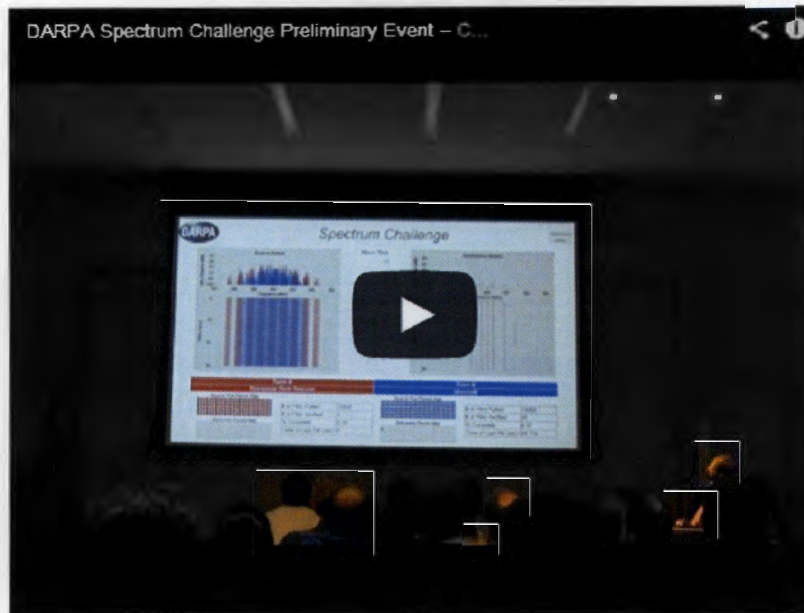
On September 11-12, 2013, 18 teams from around the country converged on DARPA in Arlington, Va., to demonstrate their prototype software-defined radios during the contest's first live competition. The contestants included the 15 highest-scoring teams and three wildcard teams (<http://www.darpa.mil/NewsEvents/Releases/2013/06/18.aspx>) from the 90 teams that initially registered. **After two days, teams from Northeastern University and Vanderbilt University emerged as the most successful competitors, each earning a \$25,000 prize.** In all, the DARPA Spectrum Challenge plans to award \$150,000 in prizes.

In addition to this preliminary event, the Spectrum Challenge also plans to hold a final event in March 2014. Both events are multiple-elimination and have each team play at least three matches. All 18 teams are scheduled to play both events. The Final Challenge competition is slated to follow the same structure as the preliminaries but award twice the prize money—\$50,000 per winning team.

Both the preliminary and final events include two separate tournaments, each with its own goals:

- **Competitive tournament:** In each match, two teams battled to dominate the spectrum, with the winner being the first to transmit files of random data (or to successfully transmit the greatest proportion of the files) from a source radio to a destination radio. Teams had to evade, jam and/or operate in the presence of competitors' signals within a defined 5 MHz UHF band. This event tested conditions directly applicable to military communications, where radios must deliver high-priority data in congested and often contested electromagnetic environments. MarmotE, a team from Vanderbilt University,

took first place, with Tennessee Tech Telecom, a team from Tennessee Tech University, the runner-up:



- Cooperative tournament: In each match, three teams worked together to share the spectrum and transmit their random data files in the shortest time. Teams could not coordinate in advance on how to share the spectrum, so they had to develop and implement algorithms that enabled their software-defined radios to communicate at a high rate while leaving spectrum for the other two teams to do the same. This event tested conditions that might be encountered during coalition operations, and also has possible future commercial applications. WSL-NEU, a team from Northeastern University came in first, with an independent team—using the name “wasabi”—coming in a close second:



DARPA provided all teams with the same hardware and data to ensure that each team would win or lose based on their software algorithms alone. All the matches occurred on the ORBIT

testbed at Rutgers University's WINLAB, which streamed the proceedings live to DARPA where contestants and government personnel watched the event unfold.

To help competitors see how their software compared with other teams' designs, WINLAB developed data visualization technology for DARPA that showed the specific radio frequencies each team used and their progress in transmitting the test file. Based on color-coded spectrum occupancy patterns projected on large screens in the event hall, watchers could see how the radios interacted and infer each team's likely strategies in real time.

Some matches were blowouts, some were close, and others required tie-breakers. In each match, participating teams sat quietly while the other teams murmured, shouted and even cheered based on what they saw—an atmosphere similar to sports fans watching a live event.

“The insights the teams gained today should give them their ‘big idea’ for the finals,” Yiftach Eisenberg, DARPA program manager heading the Spectrum Challenge said. “I expect we’ll see a massive increase in innovation when many teams come back six months from now with completely new designs. Those designs hopefully will build off the baseline algorithms and techniques we saw, and show us for the first time the reasoning and adaptive capabilities DARPA seeks to deliver.”

“I’m impressed with the creativity, enthusiasm, and performance of the teams that we’ve seen here today,” said DARPA Director Arati Prabhakar, who attended the final matches of both tournaments. “Their original contributions hold great promise in this fast-moving field.”

More information about the Spectrum Challenge is available at <http://go.usa.gov/bqQW> (<http://go.usa.gov/bqQW>).

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Teams from Vanderbilt University (MarmotE, top) and Northeastern University (WSL-NEU, bottom) hold ceremonial checks representing the \$25,000 prizes they each won at the DARPA Spectrum Challenge semifinals. Joining the teams are Dr. Yiftach Eisenberg (far left), DARPA program manager for the Spectrum Challenge, and DARPA Director Dr. Arati Prabhakar (far right). The Spectrum Challenge is a DARPA-sponsored competition designed to encourage development of programmable radios that can deliver priority transmissions in congested and contested spectrum environments.

Additional Info



DARPA Spectrum Challenge

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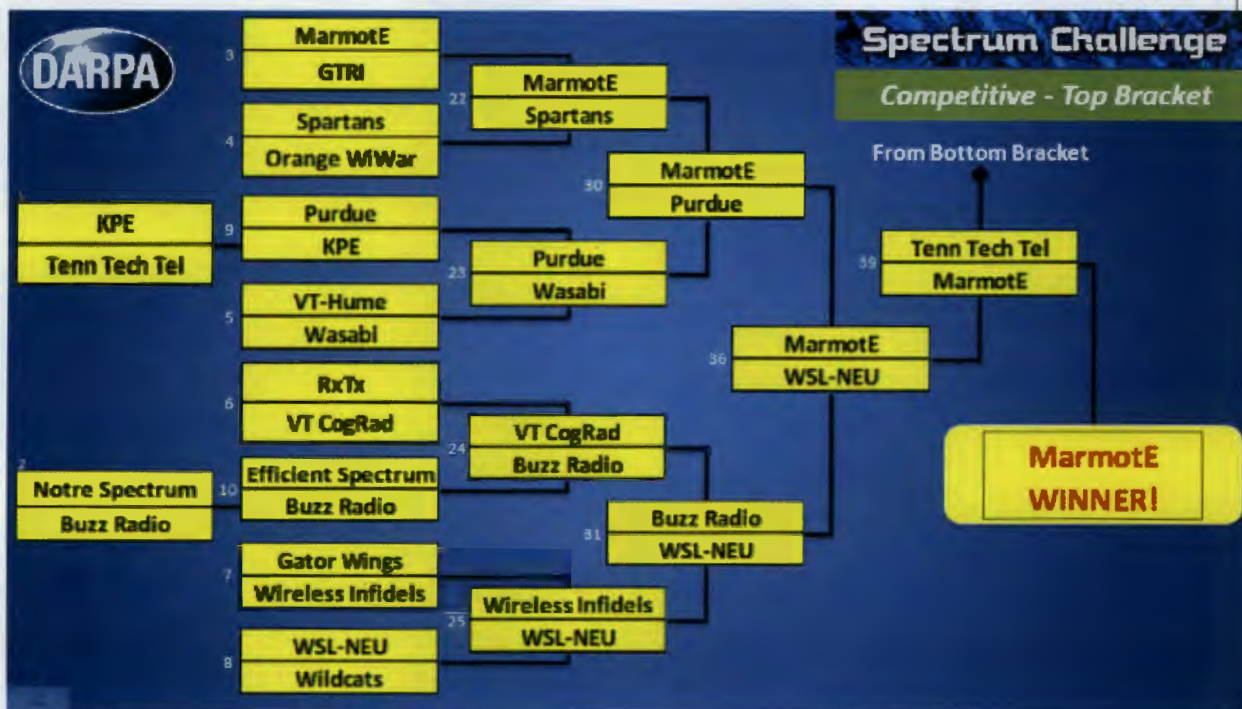
Congratulations to the Preliminary Tournament winners!

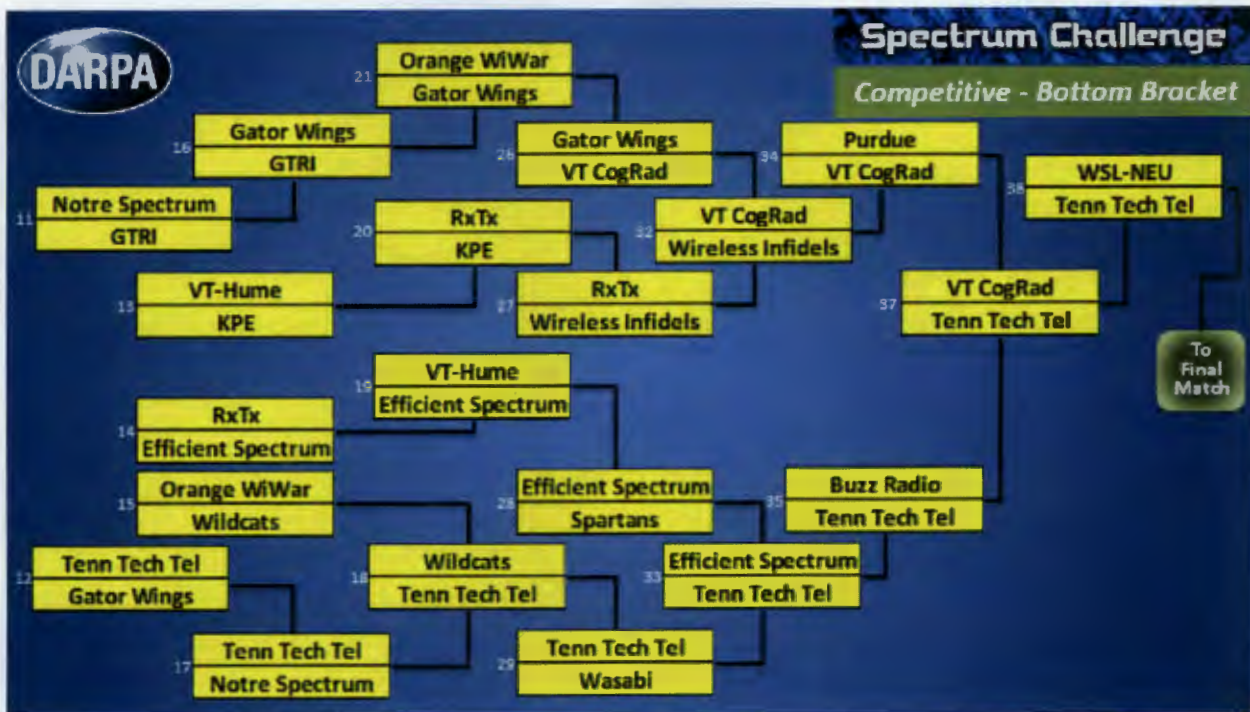
Team MarmotE from Vanderbilt University
Team WSL-NEU from Northeastern University

Team MarmotE has won the Competitive tournament in a close match against Tennessee Tech Telecom.

Team WSL-WEU's final match in the Cooperative tournament went down the final few seconds to clinch its win over team wasabi.

Here are the complete tournament ladders for the Competitive tournament.





Here are the scores for the final round of the Cooperative tournament.

Spectrum Challenge

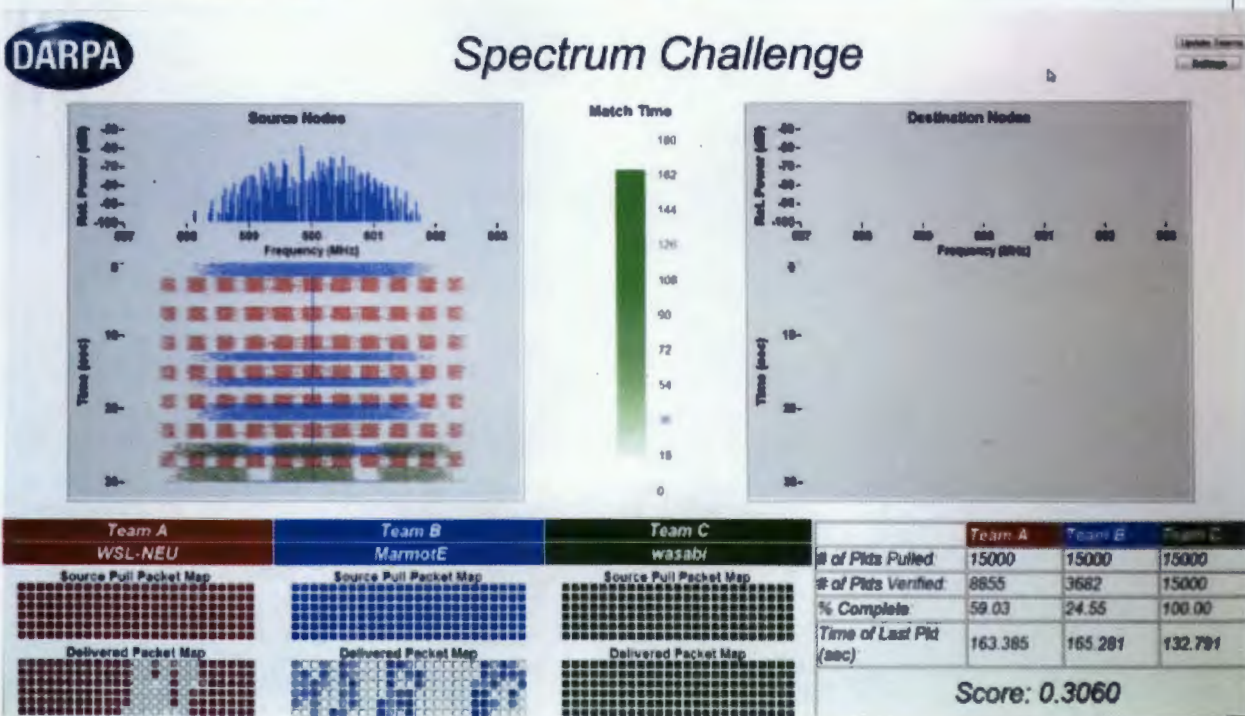
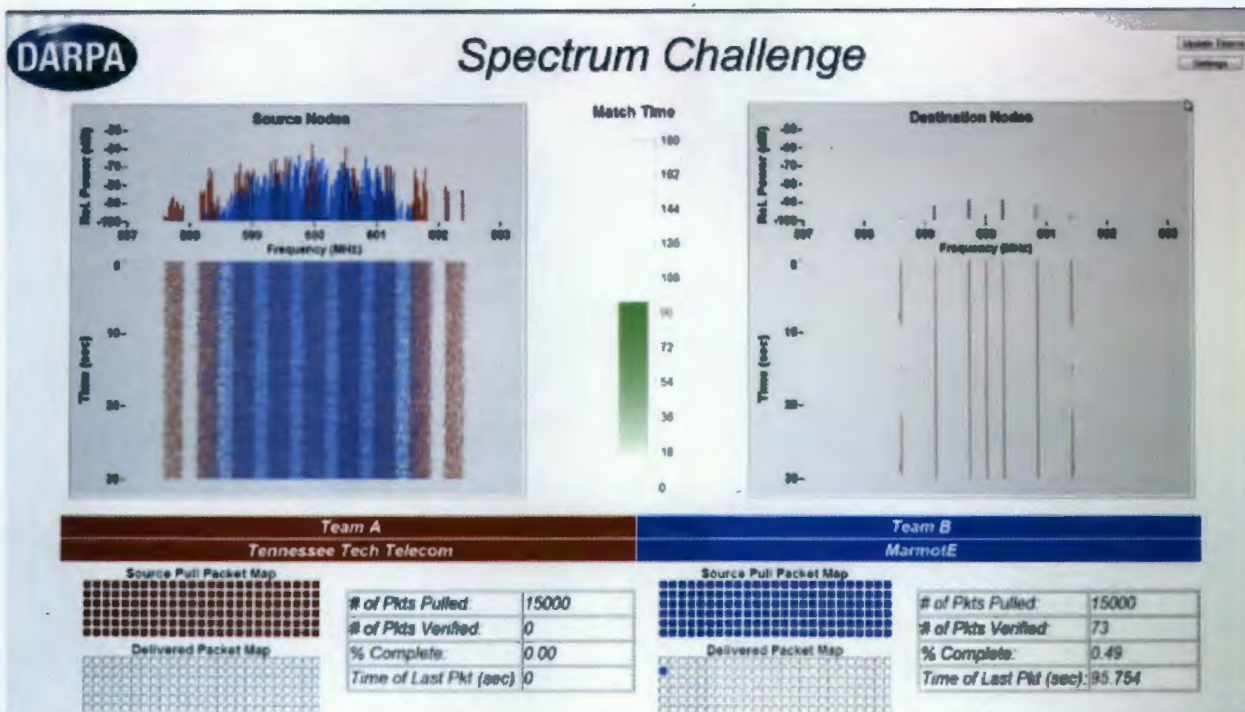
Cooperative Finals

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!

The tournament utilized real-time data visualization software that attendees viewed at the DARPA Conference Center. While the radios were operating on the ORBIT testbed at Rutgers University's WINLAB, attendees viewed spectrograms and the data packet transfer progress as it was happening. The images below are screen shots of the visualization output. The first is a screen shot from the final competitive match between Tennessee Tech Telecom and the second is a screen shot from the final cooperative match involving WSL-NEU, MarmotE and wasabi.



The winners pose with the Dr. Arati Prabhakar, DARPA Director and Dr. Yifty Eisenberg, Program Manager.



Congratulations to all the participants. We look forward to the Final Tournament in March 2014.

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