

DARPA's Bay Area SDR Hackfest Recap

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DARPA/MTO

02/04/2018





DARPA's Hackfest: A three-part event



Hacker Space

- Open space to develop, learn, and play
- Host experts in SDR
- Some problems will be provided for context/ideas

Speaker Series

Experts will discuss emerging technologies in larger societal contexts

Missions

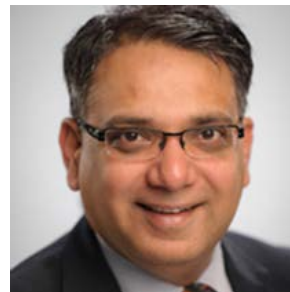
- Team-based
- Teams must apply
 - 8 teams selected
- Hardware provided
 - UAV + SDR
 - Ground station
- Focus on the problem book



CORY DOCTOROW



BEN HILBURN



PARIMAL "PK"
KOPARDEKAR



JOE GRAND



LINDA DOYLE



AMIE STEPANOVICH



HEATHER KIRKSEY



CHRIS ANDERSON



SAMY KAMKAR



PIERRE DE VRIES



Hackfest Schedule

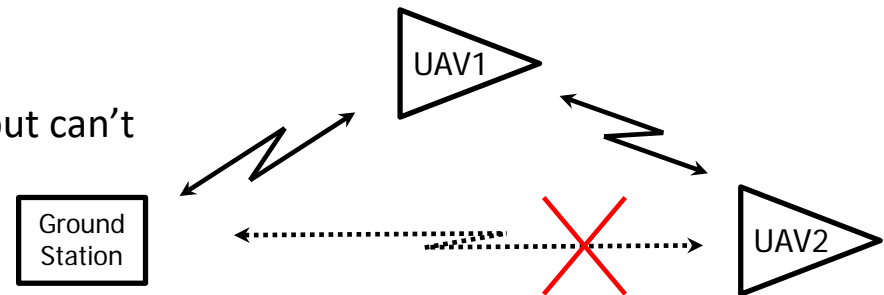
November 13 – 17, 2017



	Monday 13-Nov	Tuesday 14-Nov	Wednesday 15-Nov	Thursday 16-Nov	Friday 17-Nov
8:00	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
9:00	Kickoff: Rondeau	Team Work /Hacker Space	Team Work /Hacker Space	Team Work /Hacker Space	Team Work /Hacker Space
10:00	Team Orientation				
11:00					
					Final Flight Tests
					Hacker Space wrap-up
12:00	Lunch	Lunch	Lunch	Lunch	Lunch
13:00	Keynote <i>Doctorow</i> <i>Stepanovich</i>	BS Session	BS Session	BS Session	Keynote <i>Doyle</i> <i>de Vries</i>
14:00	Team Work /Hacker Space	Team Work /Hacker Space	Team Work /Hacker Space	Team Work /Hacker Space	Mission Judging
15:00					
16:00					
17:00	Lightning Talks	Lightning Talks	Lightning Talks	Lightning Talks	
	Dinner	Dinner	Dinner	Dinner	Dinner
18:00		Keynote <i>Hilburn</i> <i>Kirksey</i>	Keynote <i>PK</i> <i>Anderson</i>	Keynote <i>Grand</i> <i>Kamkar</i>	Closing: Rondeau
19:00					

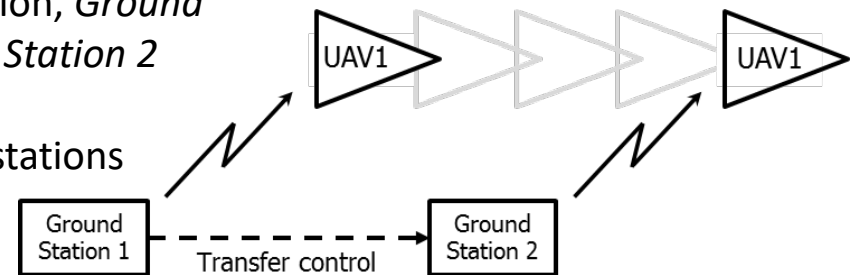
Mission 1: Range Extender

- *Ground Station* needs to communicate to *UAV2* but can't connect directly
- Teams control *UAV1* to provide a relay link



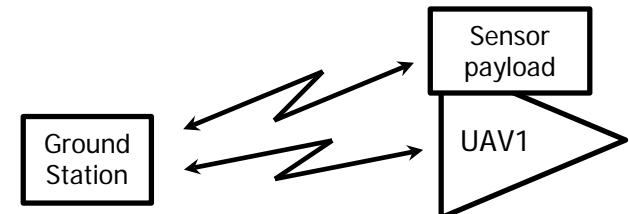
Mission 2: Dynamic Handoff

- *UAV1* is moving away from the controlling ground station, *Ground Station 1 (GS1)*, so need to transfer control to *Ground Station 2 (GS2)*
- Teams transfer control of *UAV1* between two ground stations



Mission 3: Sensor Comms and Integration

- Modify protocols to handle data from other sensors
- Show easy integration of sensor data into link between *Ground Station*

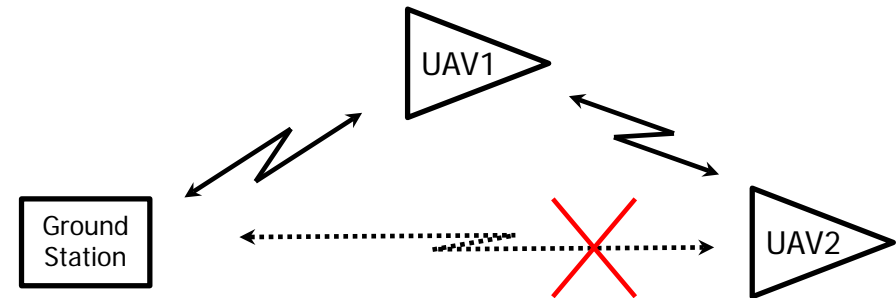


What

- *Ground Station* needs to communicate to *UAV2* but can't connect directly
- Mission: Teams control *UAV1* to provide a relay link

Why

- Comms link can be denied for many reasons
 - ONR interested in problems getting links through ships
- Extends range of drone controls
- Challenges speed to:
 - Set up relay
 - Manage propagation/mobility
 - Latency of data movement
 - Control of logical and physical channels with 1 radio



How

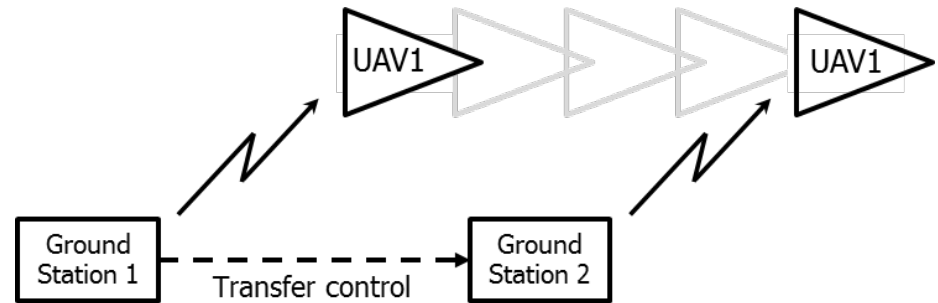
- *UAV2* is a DARPA-controlled system
 - Managed as a stationary SDR
- Block link through poor reception via power control or physical blocks
- Team Goal: Provide packets to *UAV2* through *UAV1* by managing network and routing
- DARPA is working with ONR for technology need

What

- *UAV1* is moving away from the controlling ground station, *Ground Station 1 (GS1)*, so need to transfer control to *Ground Station 2 (GS2)*
- Mission: Teams transfer control of *UAV1* between two ground stations

Why

- Maintaining line-of-sight from pilot to drone can be requirement of civilian and disaster response operations
- Extends range of drone controls
- Mission could be extended to perform the handoff through the UAV



How

- Connection between *GS1* and *GS2* can be assumed to be robust via direct cable connection or Wifi through the local network
- When one ground station has control, the other ground station should no longer be able to send commands to control the drone
- Team Goal: Demonstrate control can be easily and repeatedly transferred



Mission 3: Sensor Comms & Integration

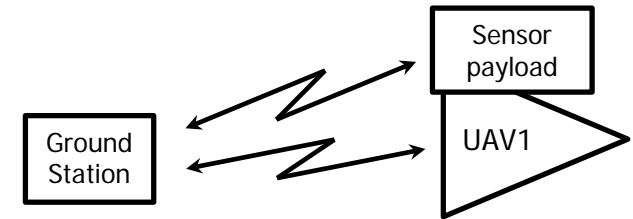


What

- Modify protocols to handle data from other sensors
- Mission: Show easy integration of sensor data into link between *Ground Station*

Why

- Modify how the Ground Station talks to the UAV for:
 - Better efficiency, lower latency, predictive flight commands
 - Manage multiple drones without confusion
- Modify the UAV info to the Ground Station:
 - Better transmission of onboard sensor data
 - Make it easy to add new sensors
 - Study other on-board sensor



How

- Take sensor data from SDR, Raspberry Pi, or other add-ons
- Data from *Ground Station*
- Incorporate into comms link to *UAV1*
- Team Goal: Get data securely between *Ground Station* and *UAV1*
- Modified communications stack to easily support future devices and sensors
 - Dronecode and FAA interested in new drone control protocol



General Mission Challenge: Control Link Interference

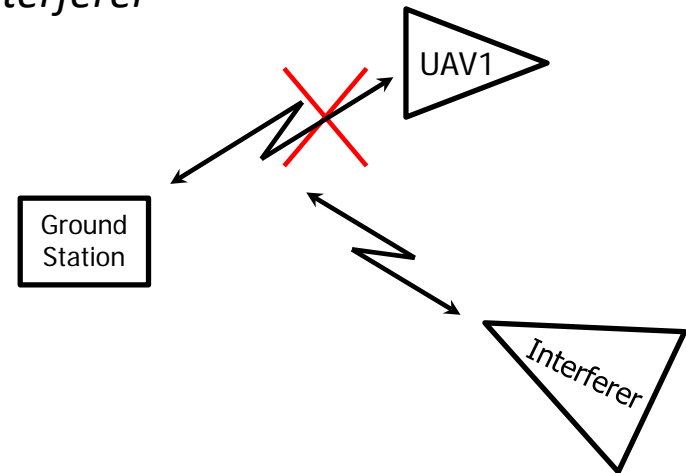


What

- RF control link between the ground station and the UAV is susceptible to interference
- Mission: protect sending packets to *UAV1* against *Interferer*

Why

- DARPA Service Academy Swarm Challenge
 - controlling > 50 drones is interference limited
 - Used off-the-shelf Wifi wireless technology
- Break this limit with better communications systems and/or better use and management of the spectrum
- Challenges of 3-dimensional space
- Need to think more broadly about interference resilience and the impact of approaches to using spectrum under these conditions



How

- *Interferer* is a DARPA-controlled drone using the same spectrum as UAV1
- DARPA will evolve *Interferer* to provide increasing difficulty to teams
- Teams' goal: keep *UAV1* flying
- DARPA will collect the RF spectrum data
 - observe how teams solutions
 - Good input to RFMLs



Eight Mission Teams



Southern Methodist University



Aerospace Corporation



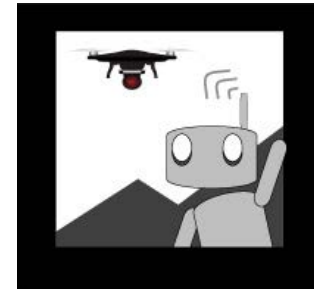
Assured Information Security, Inc.



Parsons



Raytheon BBN Technologies

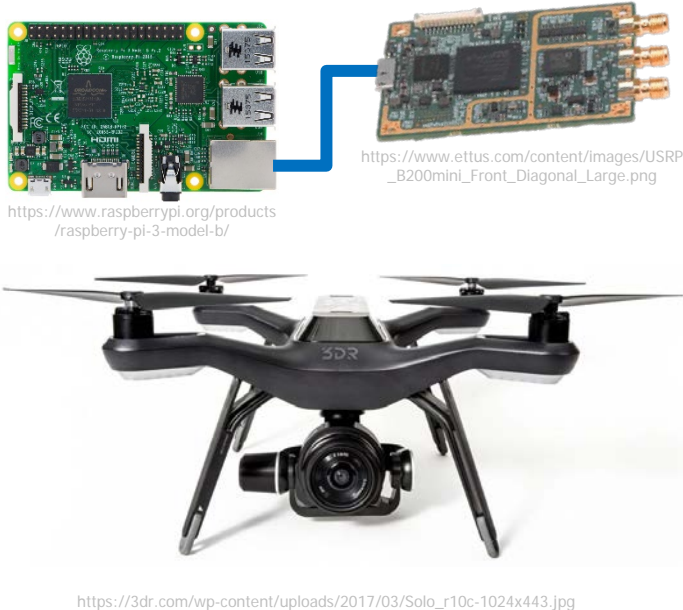


University California, Irvine
University of Southern California

Hacker Dojo

Fat Cat Fab Lab

UAV



Ground Station

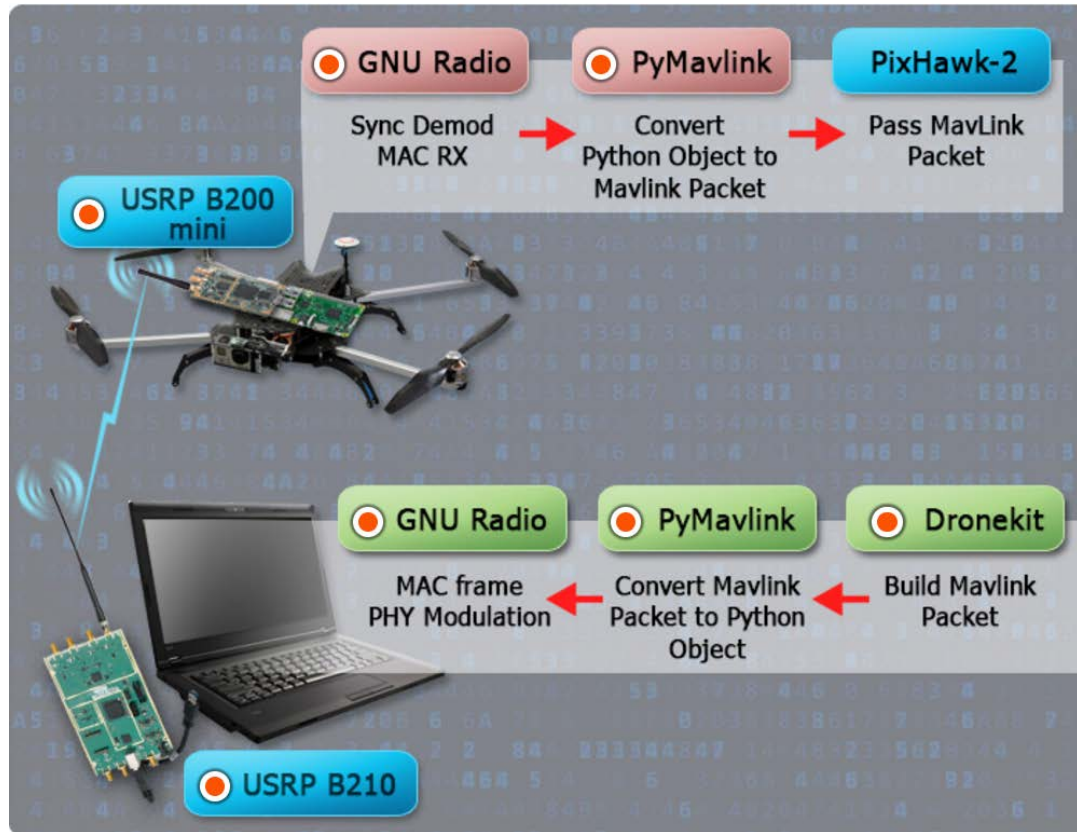


Equipment	Part
UAV SDR	USRP B200mini
UAV Computer	Raspberry Pi 3
UAV	3DR Solo
Antenna	1 Omni
Flight controller	Pixhawk-2
Backup	915 MHz controller

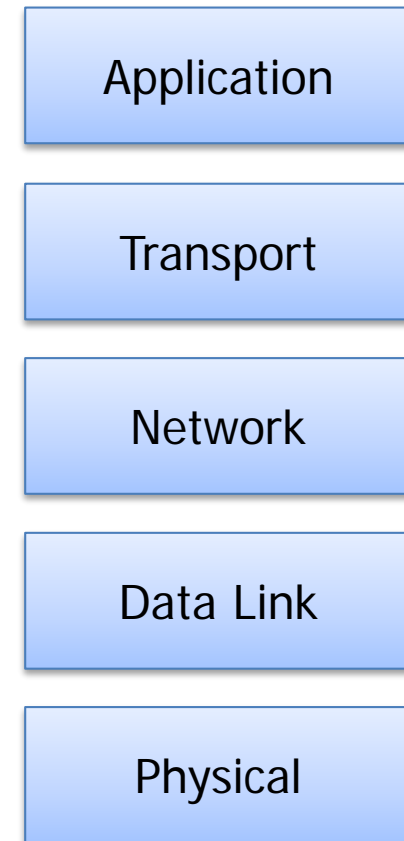
Equipment	Part
GS SDR	USRP B210
GS Computer	<ul style="list-style-type: none"> • Ubuntu based standard laptop • ≥ 256GB SSD hard-drive • ≥ 16GB of RAM • ≥ 4 core i7 Xeon
Antenna	4-omnis



DARPA-Provided Software Radio Application: Allows full control of UAV from the ground station



<https://darpahackfest.com/hardware-uav>

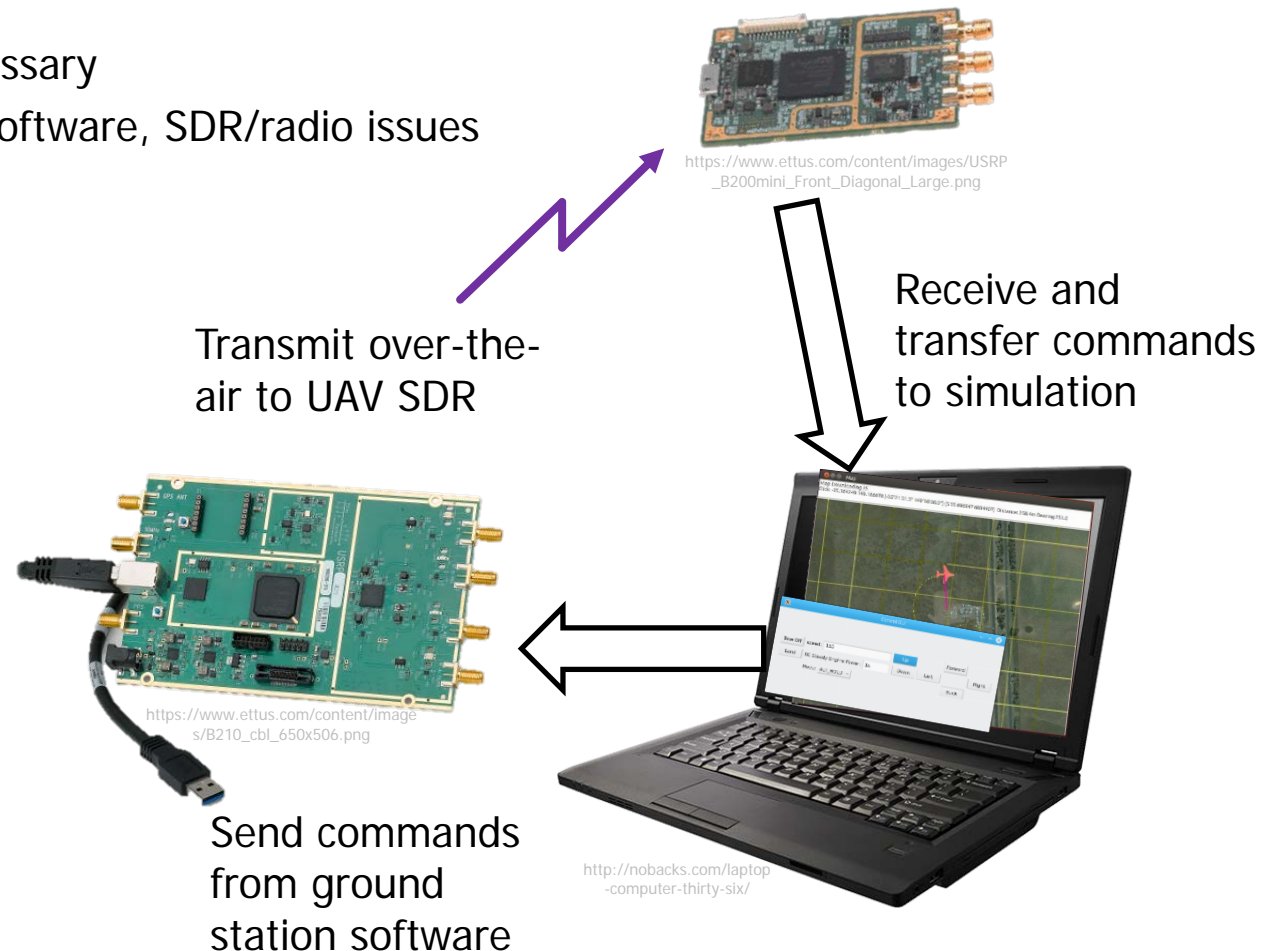


- Simple example implementation
 - gr-uaslink
 - basic flowgraph
- User manual
- OpenEmbedded on RPi3
- Root access
- Free and Open Source Software
- Defense Digital Services to host code (code.mil)

- DDS Hosted: [git://github.com/deptofdefense/gr-uaslink](https://github.com/deptofdefense/gr-uaslink)
 - Stupidest thing that could possibly work
 - Narrowband M-ary phase shift keying (BPSK, QPSK, 8PSK); no FEC; no equalizer; simple framing
 - Tied into host computer to pass MAVLink packets to the flight controller
- Released Sept. 12, 2017 (2 months before Hackfest)
- Expectation was teams would build on top; control drones even before Hackfest kicked off
- Developed by Oak Ridge National Labs



- Ardupilot (FOSS flight controller) has software-in-the-loop
 - <http://ardupilot.org/dev/docs/setting-up-sitl-on-linux.html#setting-up-sitl-on-linux>
- GRCon17 workshop taught the teams how to do Hardware-in-the-loop
 - No need to fly
 - Single computer necessary
 - Explore commands, software, SDR/radio issues





Team Responses to Mission 1



- YeS DR
 - Added authentication method their solution that helped certify who communication packets were intended for
- Team DROGON
 - Used the Linux kernel's BATMAN (Better Approach to Mobile Adhoc Networking)
 - A routing protocol that intelligently distributes information across a network
- Hacker Dojo
 - Tried to tackle all three
 - Tried developing new waveforms to help approach the mission's challenging environments



- Team Platypus Aerospace
 - Interested in addressing scaling problems beyond two or three drones
 - Worked on building a full mesh network solution with authentication and built-in encryption
 - Could be applied to both Mission One and Two
 - Applications for large swarms of drones where authentication of units within a swarm, as well as the messages passed between them, needs to originate from inside the swarm itself or its command and control station.



Team Responses to Mission 3



- Texas Radio Terminator
 - Mixed sensors and feedback from the device in ways that should lead to better decisions about how to communicate and coordinate tactics with future drone technology
- DeepEdge
 - Used computer vision to recognize and track a face with the UAV
 - Demonstrated use of autonomous tracking by making use of the application layer (computer vision) and the physical layer (SDR) for managing the computing and communications resources available.
- Adversarial Science Laboratory
 - Created new physical channels for each sensor
 - Better spectrum resource management
- Fat Cat Flyers
 - Quickly modify a device with sensors and integrate them into the programming environment
 - Published code on Github throughout the week



- DARPA released gr-uaslink (<https://github.com/deptofdefense/gr-uaslink>)
- Fat Cat Flyers published code: <https://github.com/PushTheWorld/FESS>

Team Reported Use of FOSS

- | | |
|--------------------|-------------------------------------|
| • GNU Radio | • OpenCV |
| • UHD | • TkInter |
| • Mavproxy | • Mosquitto |
| • Pymavlink | • Eclipse Paho |
| • DroneKit | • Influxdb |
| • Arucopter | • Grafana |
| • Q Ground Control | • samba |
| • Linux | • Python (and numpy, Jupyter, etc.) |
| • BATMAN | • RPi.GPIO |
| • ZeroMQ | |
| • Git (and Github) | |



- Level-setting event
 - Showed the significant challenge of integrating and working with real-world physics (flying and RF)
 - Not: "This is how a comms system works"
 - Rather: "This is how a system works that needs comms"
- Technical Challenges
 - Multipath
 - Very different in range than at the team operation centers
 - No tools to understand multipath or adapt to it
 - Gain control
 - Teams kept increasing gain, which probably saturated the receiver and made multipath problem worse
 - Antenna management
 - Dangling antennas produce even worse propagation effects (esp. at 3 GHz)
 - Pointing and coupling issues with drone body attached to
 - Lack of directionality (cantenna's hand-held were a fun solution)
 - Radio still a separate part of the solution
 - No live control over things like gain or waveform properties; separate application and GUIs



www.darpa.mil