LTE and DRONES

"Taking bandwidth where you need it"

Harvey M Gates

March 15, 2017

Presentation For The:

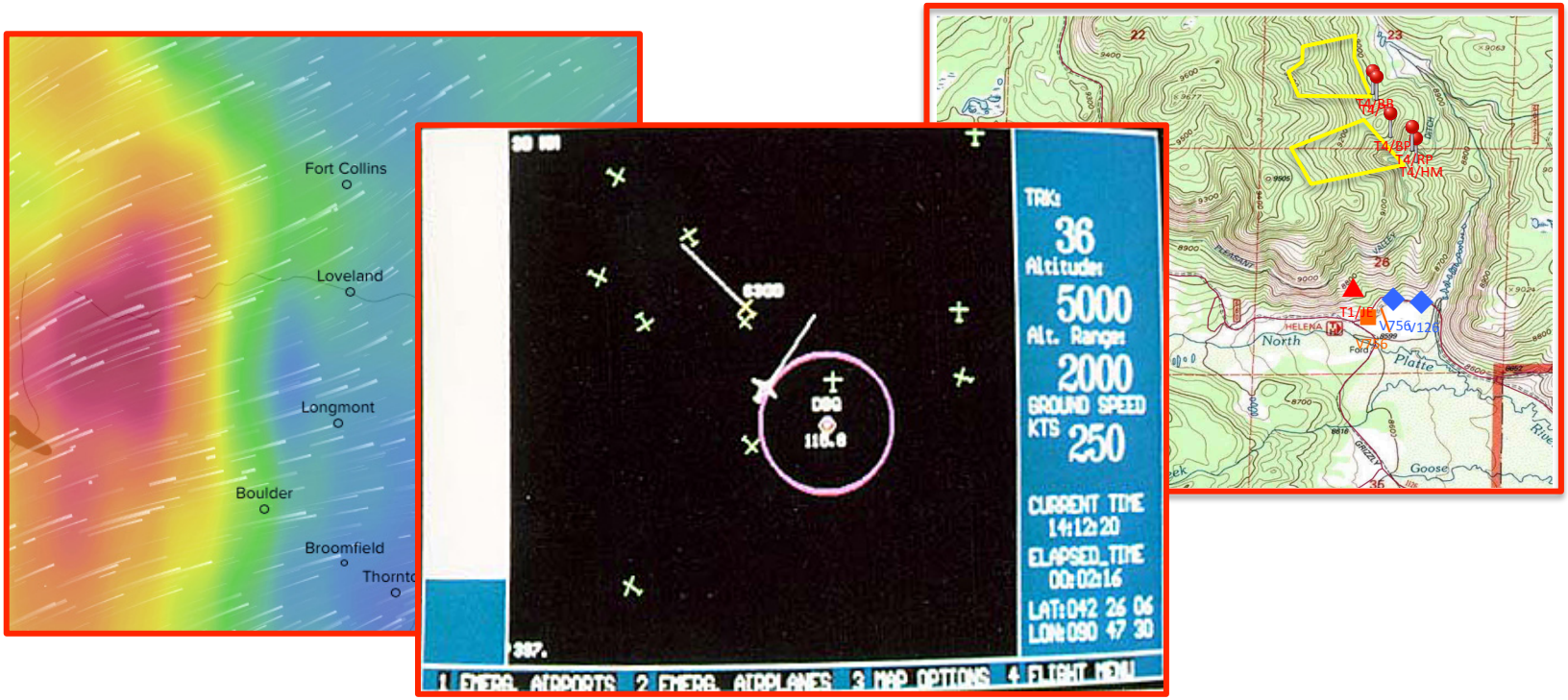
Colorado Division of Fire Prevention & Control
Center of Excellence for Advanced Technology Aerial Firefighting (CoE)

sUAS in Public Safety Summit
Mt Princeton Hot Springs Resort
Nathrop, CO

Interdisciplinary Telecom Program
UNIVERSITY OF COLORADO **BOULDER**

THAT WHICH BONDS US

- We aspire to improve electronic means of communicating
- We aspire to improve situational awareness for **GROUND, AIR, WX**



- We are committed to supporting our warriors and firefighters
- We are committed to saving lives, limbs, and property

WE ARE

- **The University of Colorado at Boulder**
- **The College of Engineering and Applied Science**
  - **Research and Engineering Center for Unmanned Vehicles (RECUV)**
  - **The Interdisciplinary Telecom Program (ITP)**
    - **2014/2015/2016/2017 Graduate Capstone Research Projects**
- **Our 2014/2015/2016 Industrial/Government Partners:**
  - ✓ **National Institute of Standards & Technology (NIST), Boulder, CO**
  - ✓ **Leptron Unmanned Aircraft Systems, Denver, CO**
  - ✓ **Copper Mountain Ski Resort, CO**

RESEARCH OBJECTIVES

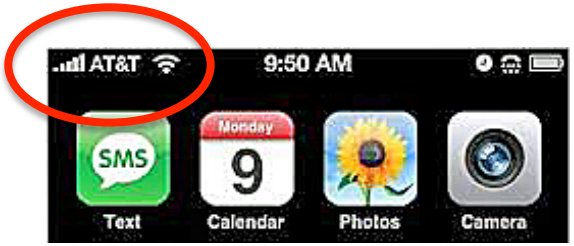
1. To find a buried avalanche victim's 4th Generation (4G) Long Term Evolution (LTE) smartphone in a time-critical situation using a small Unmanned Aircraft System (sUAS) or drone
2. Then use the sUAS (drone) to provide the search, rescue, and/or recovery team with LTE services and connectivity within these troublesome areas of reception
3. Discover shortfalls and limitations of this Concept of Operations (CONOPs) – basically push the envelope

THE ISSUE

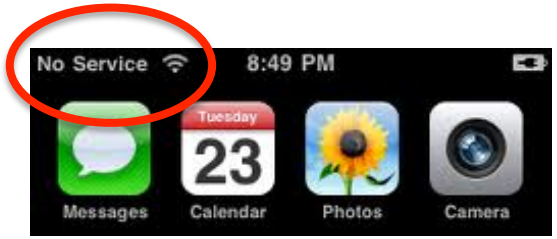
RF CELL SIGNALS

There is a substantial technical differences between finding and geolocating a cell phone buried within an avalanche debris field when there is the presence of a commercial carrier RF signal and where there is no carrier service present

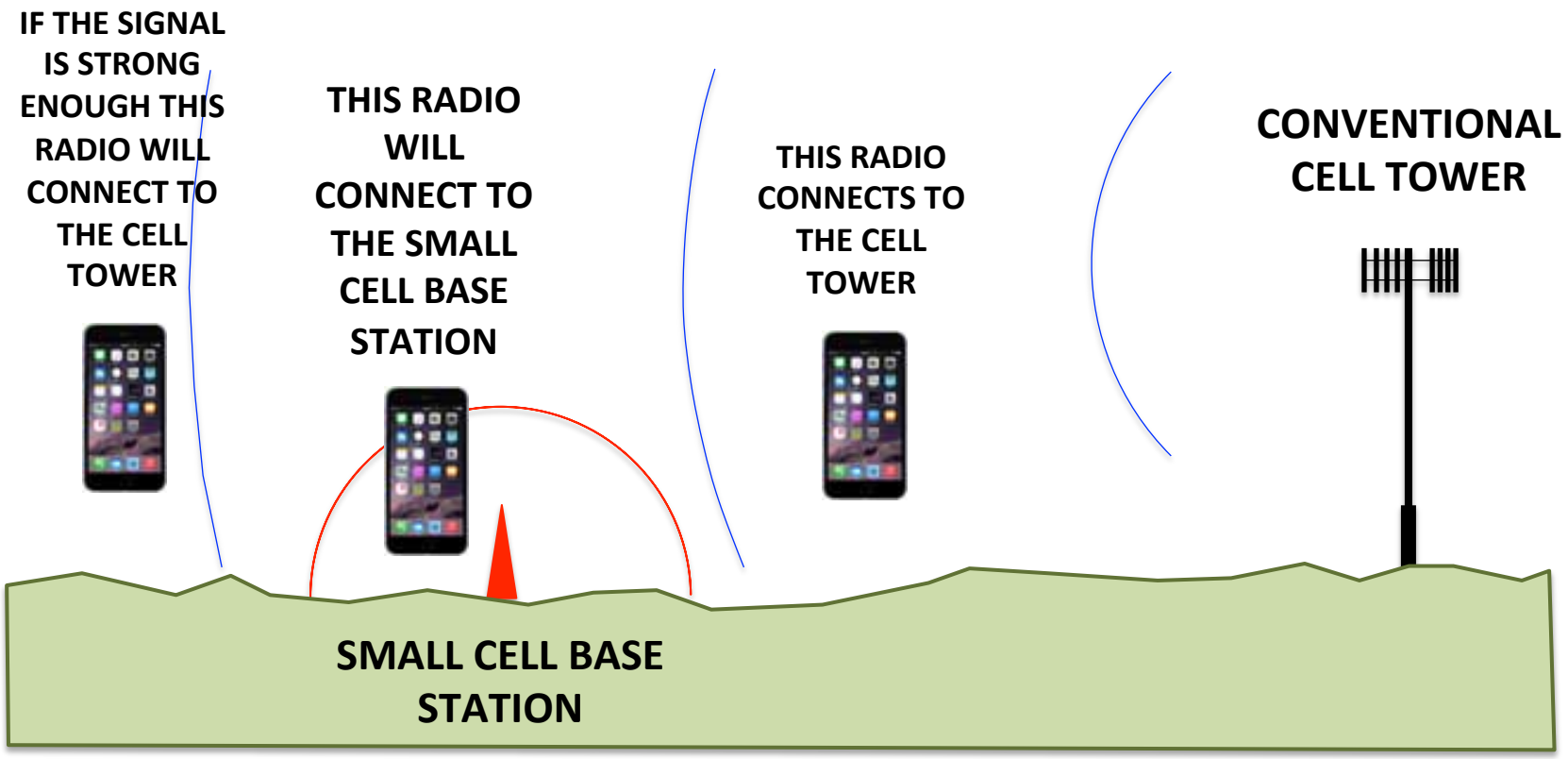
Increment 1
(5 bars)



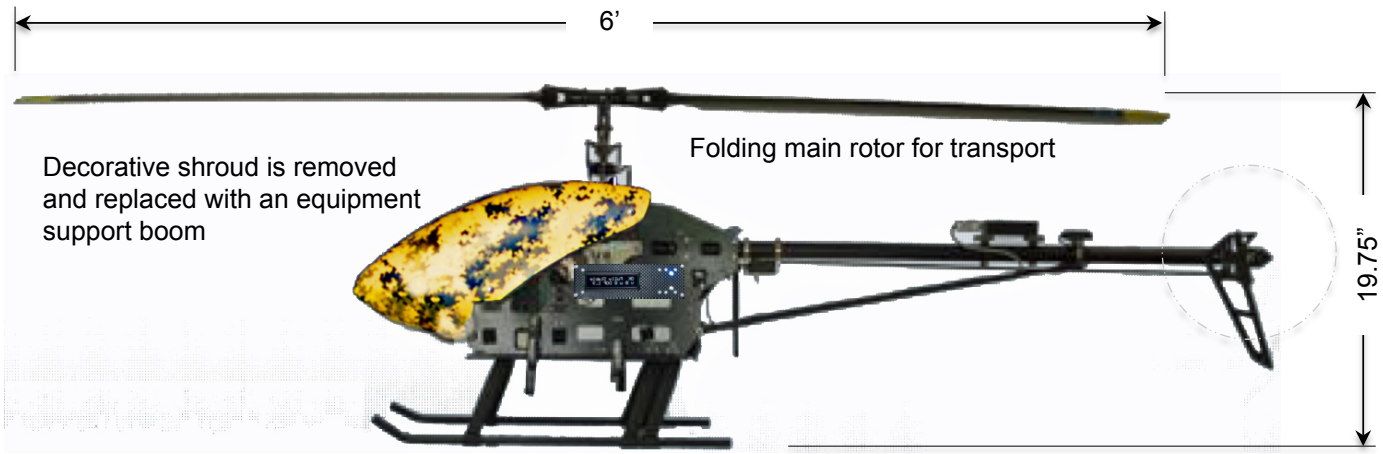
Increment 2
(No Service)



A SMALL LTE CELL SYSTEM



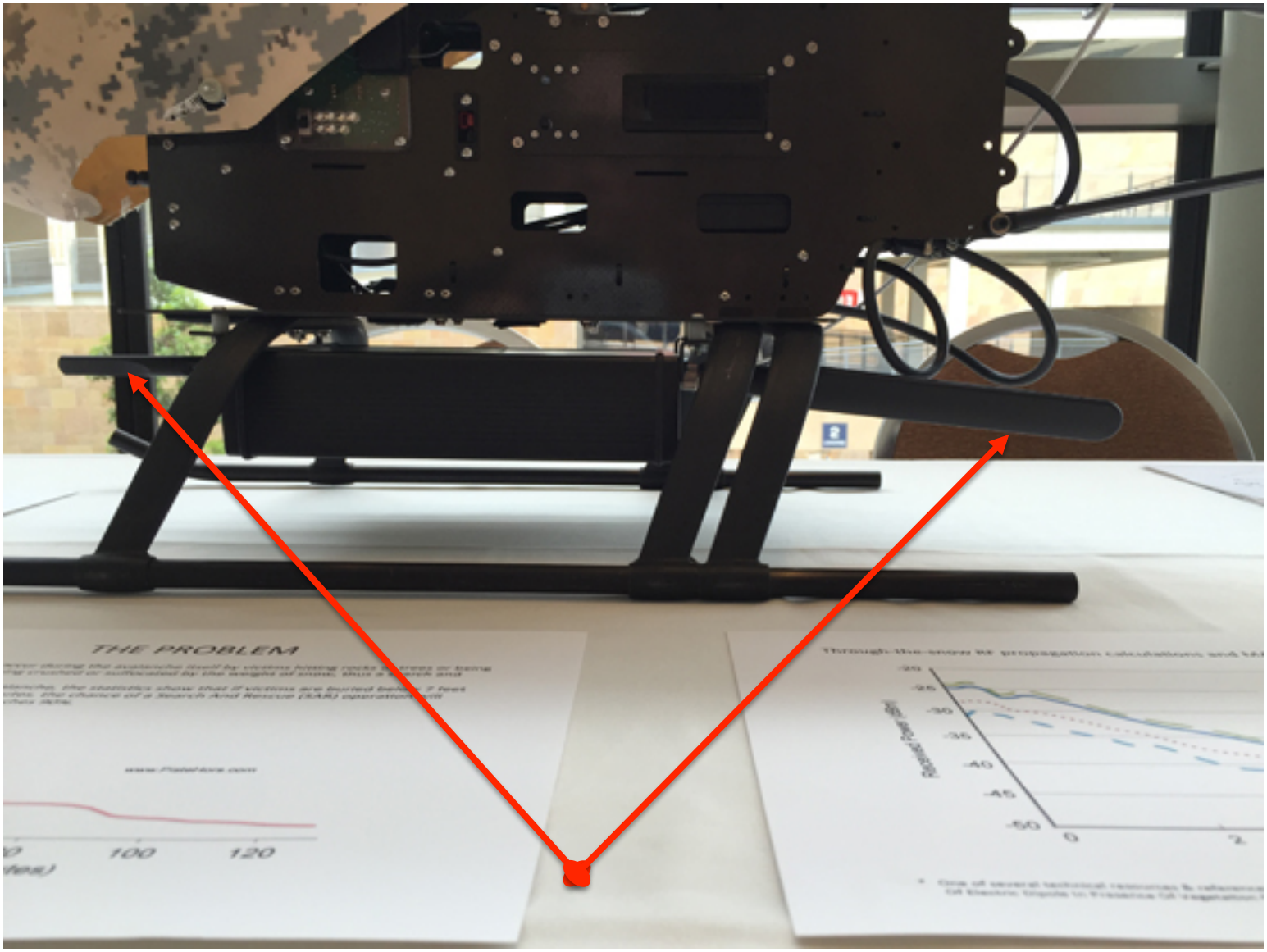
sUAS CAN GET CLOSE – THE LEPTRON AVENGER



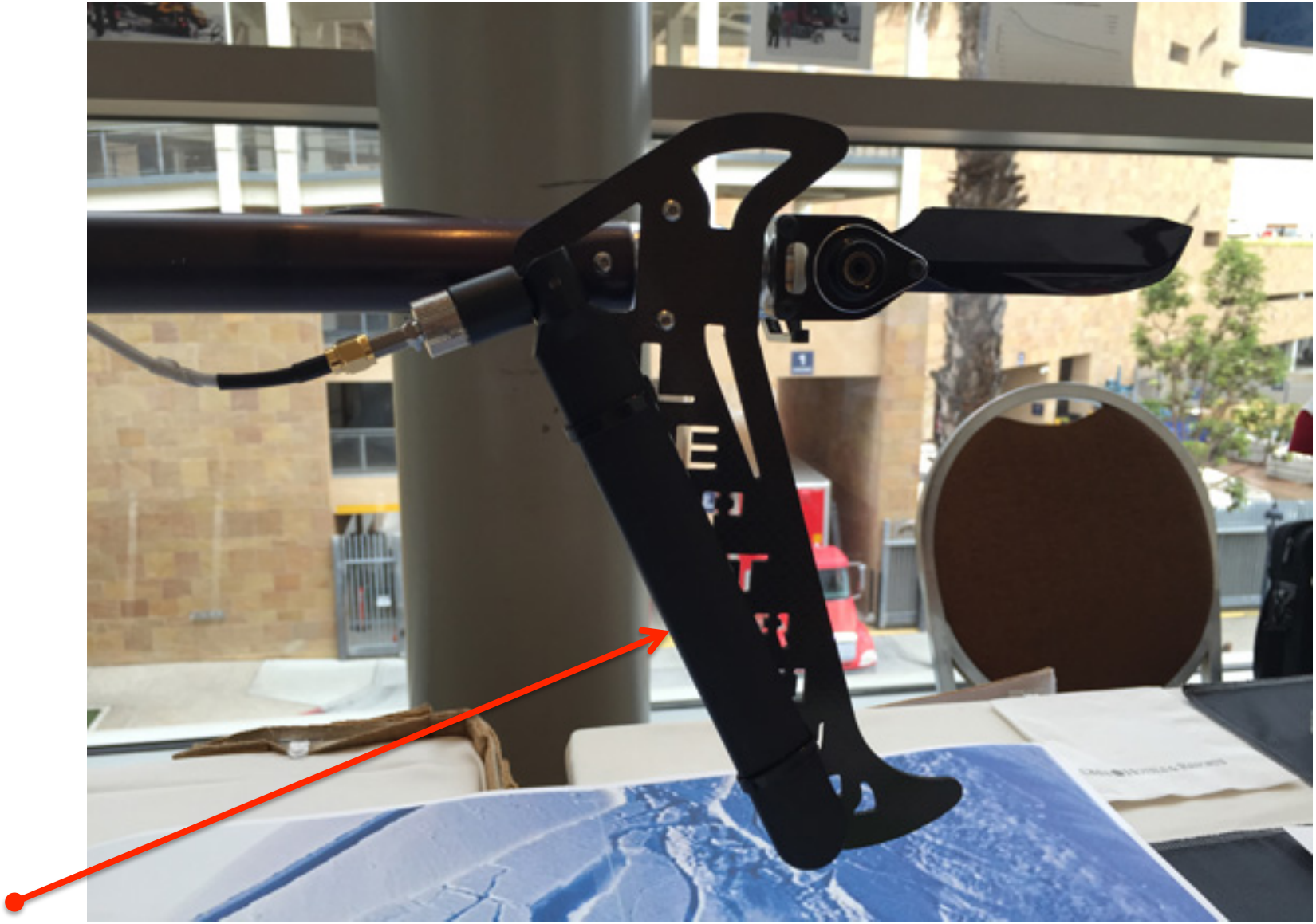
- 10 HP, 7,456 W electric engine
- 10 pound payload
- TRL 9 product maturity
- Communications
  - COTS L, S and C band data links
  - Encrypted/unencrypted digital data links
- Aircraft weight
  - 11 lbs dry
  - 22 lbs wet (with batteries)
- Full featured avionics/autopilot
  - Military grade with GPS waypoints
  - 3D flight terrain with laser altimeter
  - Integrated capability to support sensor driven operations
  - Avionics crash, performance, and safety pilot protection and override
- Dual mode control
  - Ground station mode
  - Wireless handheld remote
- Performance summary
  - 12,000’ ceiling (smaller payloads allow the Avenger to fly higher)
  - Designed for foul weather performance
    - Winds gusting to 40 mph
    - Snow and rain
- Effective range of operation
  - 2 mile radius standard range
  - 10 miles when equipped for a Iridium satellite controlled data link

PROGRAMMING THE SYSTEM & PAYLOAD

SMALL CELL SYSTEM PAYLOAD WITH ANTENNAS



SMALL CELL ANTENNA ON TAIL ROTOR ASSEMBLY

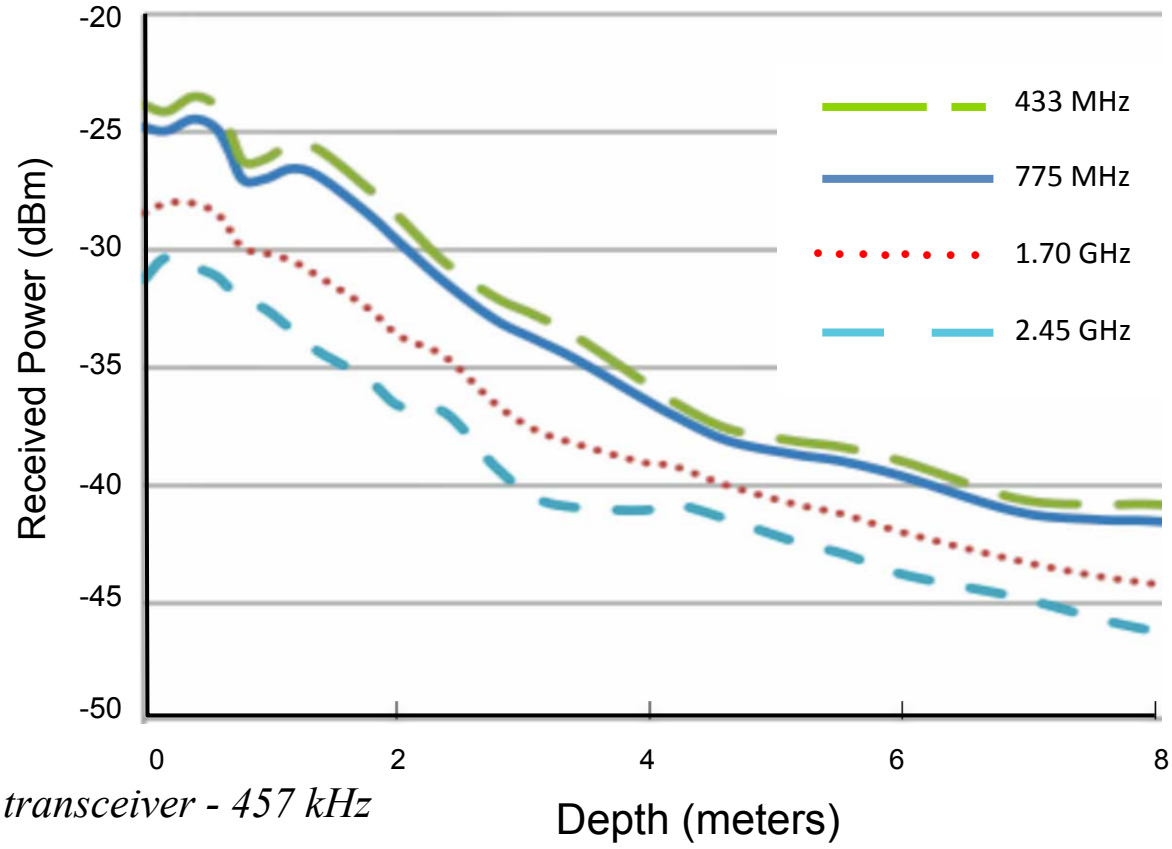


THE RESEARCH PROGRAM

(and a slight skiing hazard)

RF PROPAGATION MODELING

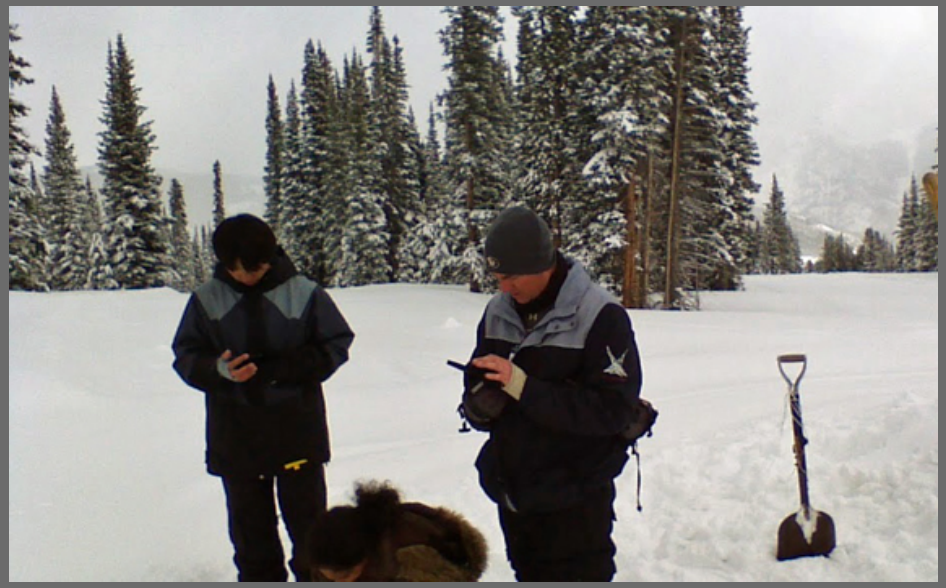
Through-the-snow RF propagation calculations and MATLAB simulations *



Avalanche transceiver - 457 kHz

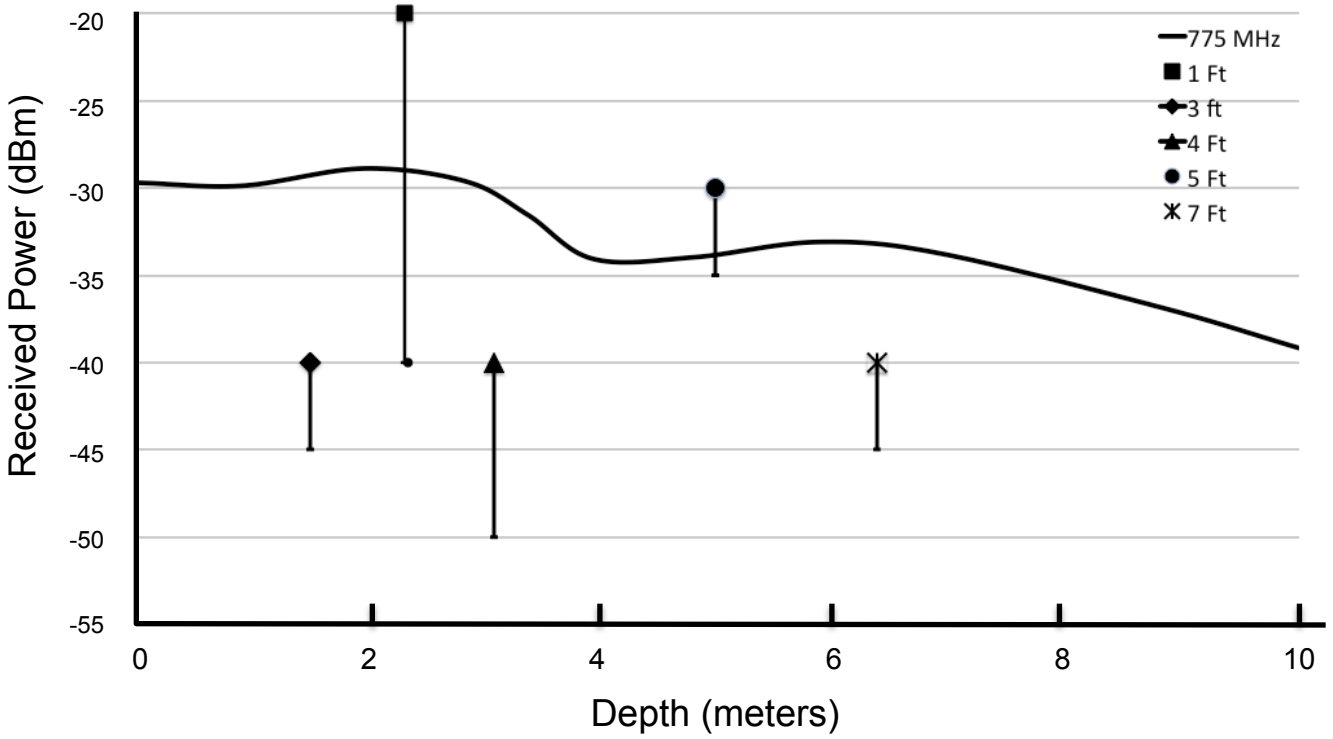
* One of several technical resources & references used for this Capstone research - D. Liao and K. Sarabandi, "Near-earth Wave Propagation Characteristics Of Electric Dipole In Presence Of Vegetation Or Snow Layer," IEEE Transactions on Antennas and Propagation, 53 (11), 3747-3756, (2005)

COPPER FIELD TRIALS

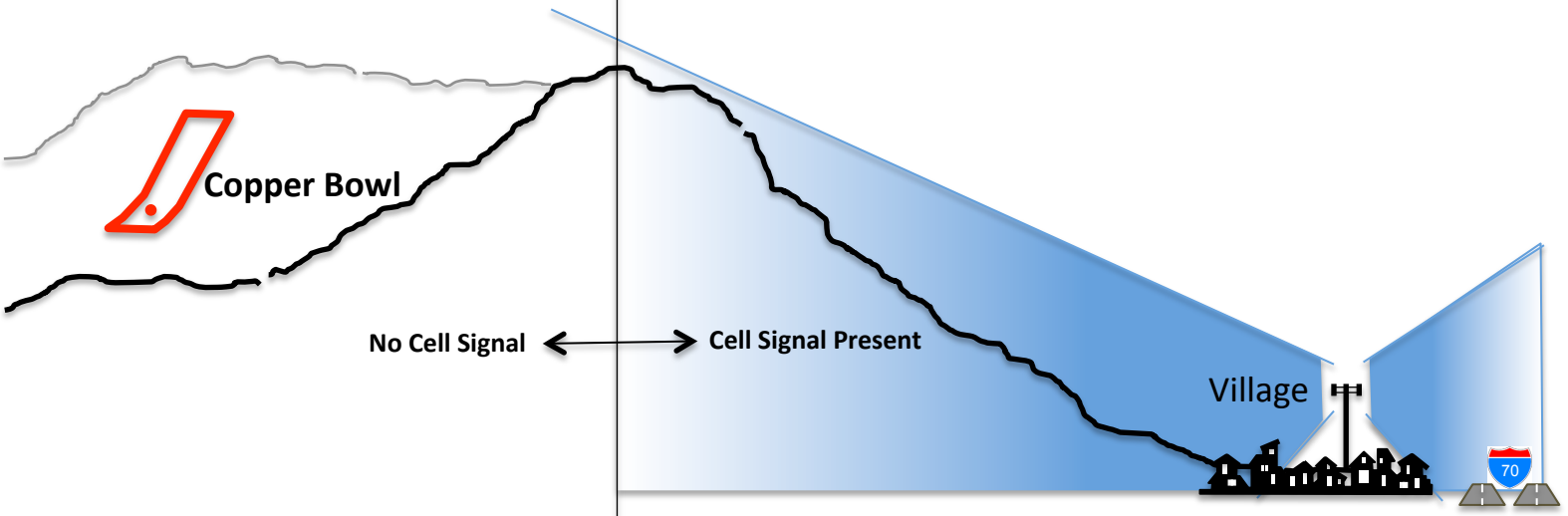


BURIED AVALANCHE CELL PHONE MEASUREMENTS

- Outcome
  - Field trials did validate the theoretical, calculated, and laboratory results
  - Above the avalanche surface cell signal sensing showed that a buried smartphone could be found up to approximately 7 feet deep in the presence of a routine area carrier signal

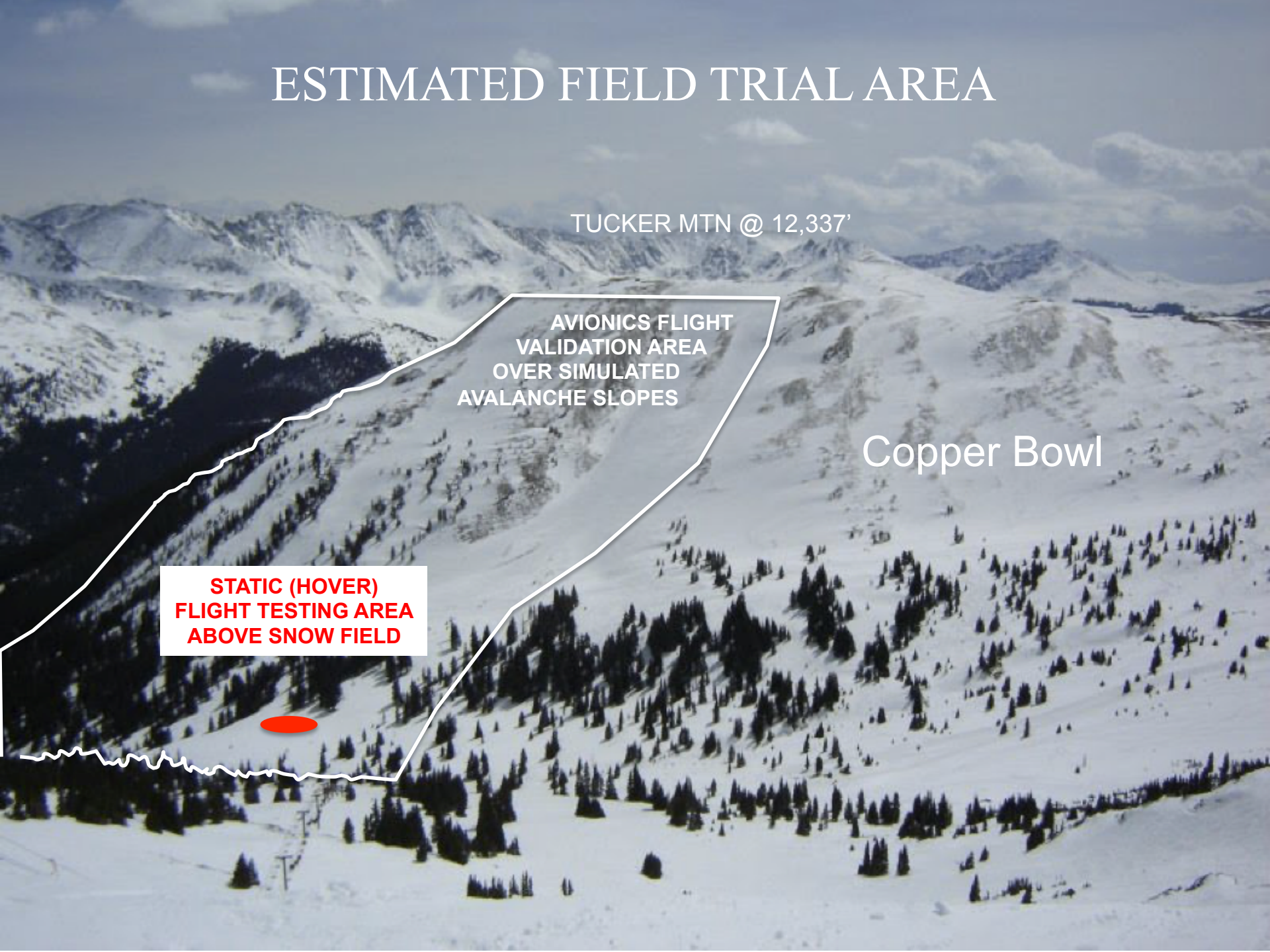


WE LOVE COPPER MOUNTAIN SKI RESORT

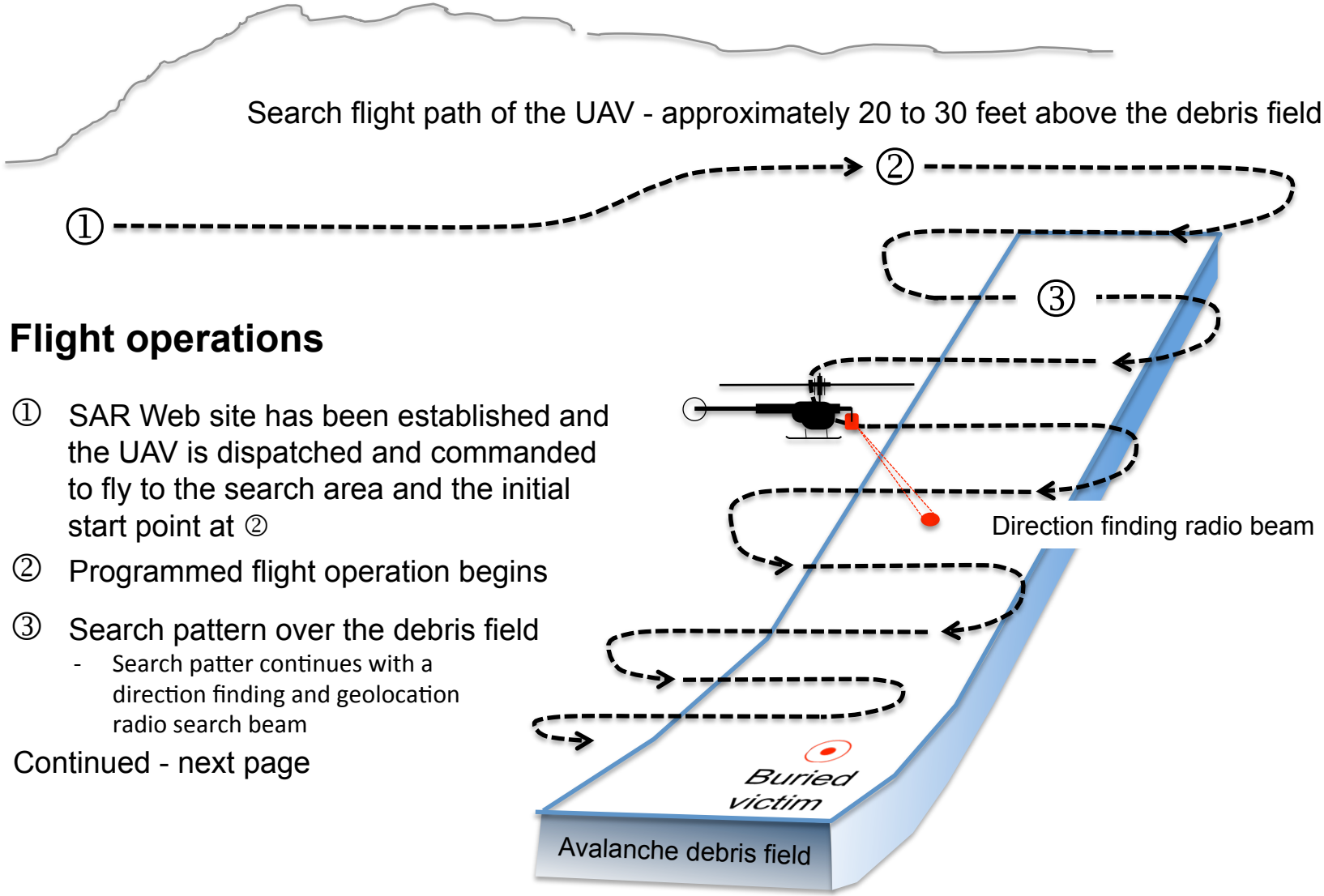


- Near ideal snow conditions and terrain for field trials
  - Replicates a model SAR field site on the side and bottom of Copper Bowl
    - No carrier cell signals present
    - Infrastructure support
    - Safe for the researchers
    - Lifts
    - Potential use of snow vehicles
- Logistically makes field trials convenient and timesaving

ESTIMATED FIELD TRIAL AREA



CONOPS – Phase 1 (Note Autonomous Flight Ops)



Flight operations

① SAR Web site has been established and the UAV is dispatched and commanded to fly to the search area and the initial start point at ②

② Programmed flight operation begins

③ Search pattern over the debris field
- Search patter continues with a direction finding and geolocation radio search beam

Continued - next page

CONOPS – THEN BASICALLY BECOME A CoW-W*

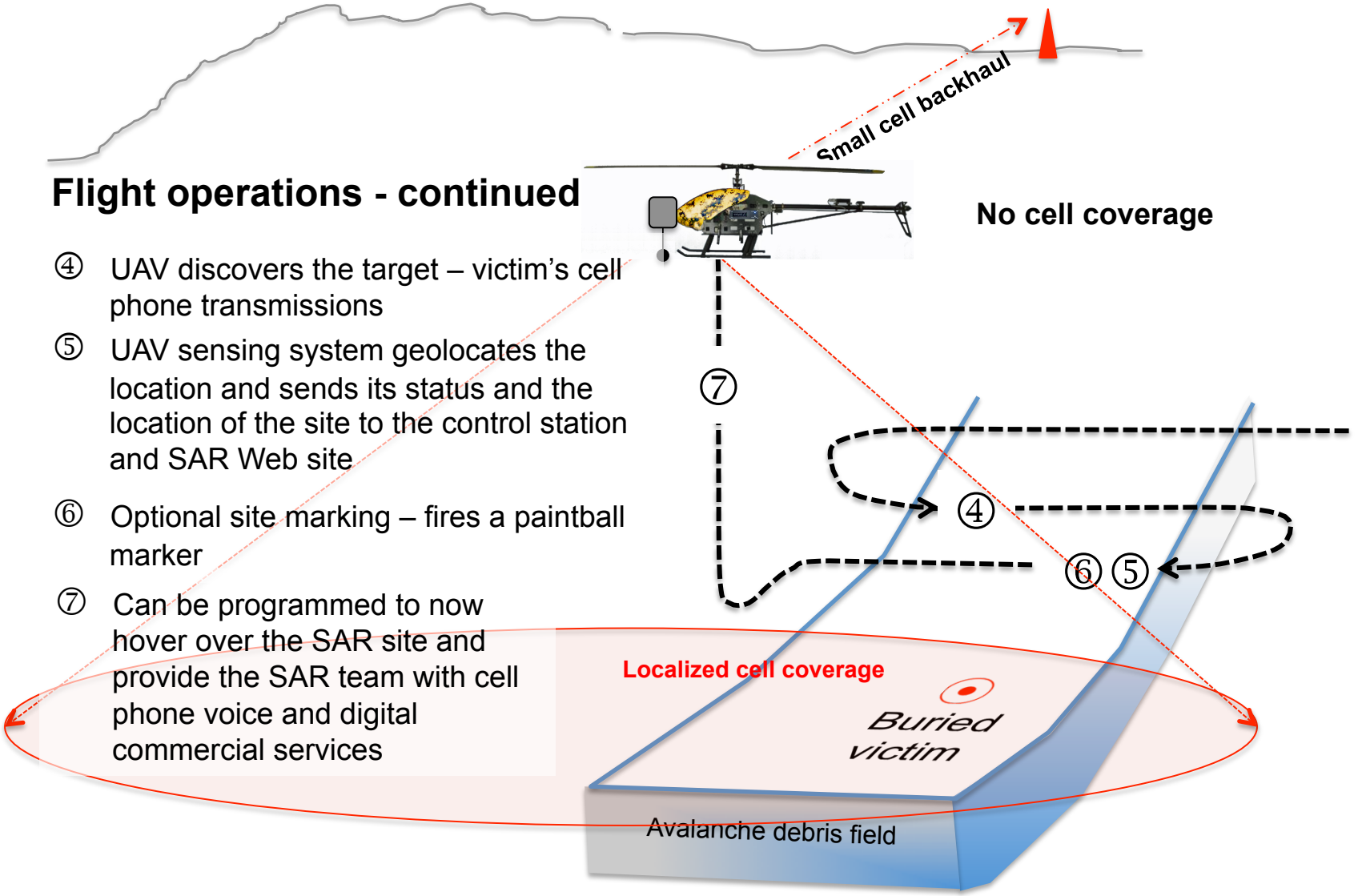
Flight operations - continued

④ UAV discovers the target – victim's cell phone transmissions

⑤ UAV sensing system geolocates the location and sends its status and the location of the site to the control station and SAR Web site

⑥ Optional site marking – fires a paintball marker

⑦ Can be programmed to now hover over the SAR site and provide the SAR team with cell phone voice and digital commercial services



* Cell-on-Wheels with Wings (CoW-W) – really a small cell on a sUAS

SHOW-STOPPER: DECISION MAKING; COULD NOT WRAP ONE'S BRAIN AROUND A FLYING CELL-ON-WHEELS (Flying CoW) – *REALLY A MIRO OR SMALL CELL WITH WINGS*

" A cell tower with WHAT ? ?

With WINGS ! ! ?

John! Are you hearing what I'm hearing ! ? "

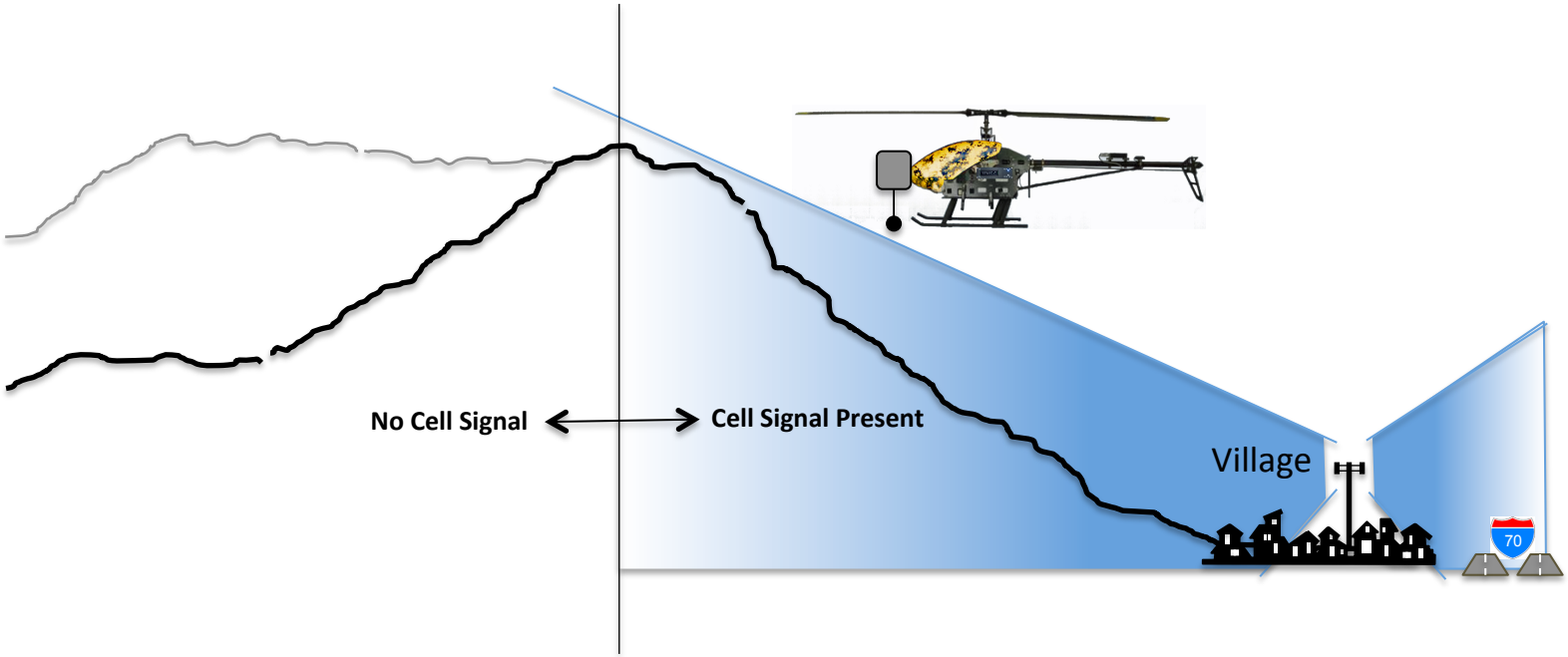
" Yes Boss."

ANOTHER SHOW-STOPPER: DROPPING FROM THE SKI

- *Drone nearly crash lands on skier Marcel Hirscher during World Cup slalom race in Italy*
- *The International Ski Federation bans camera drones from its World Cup races*

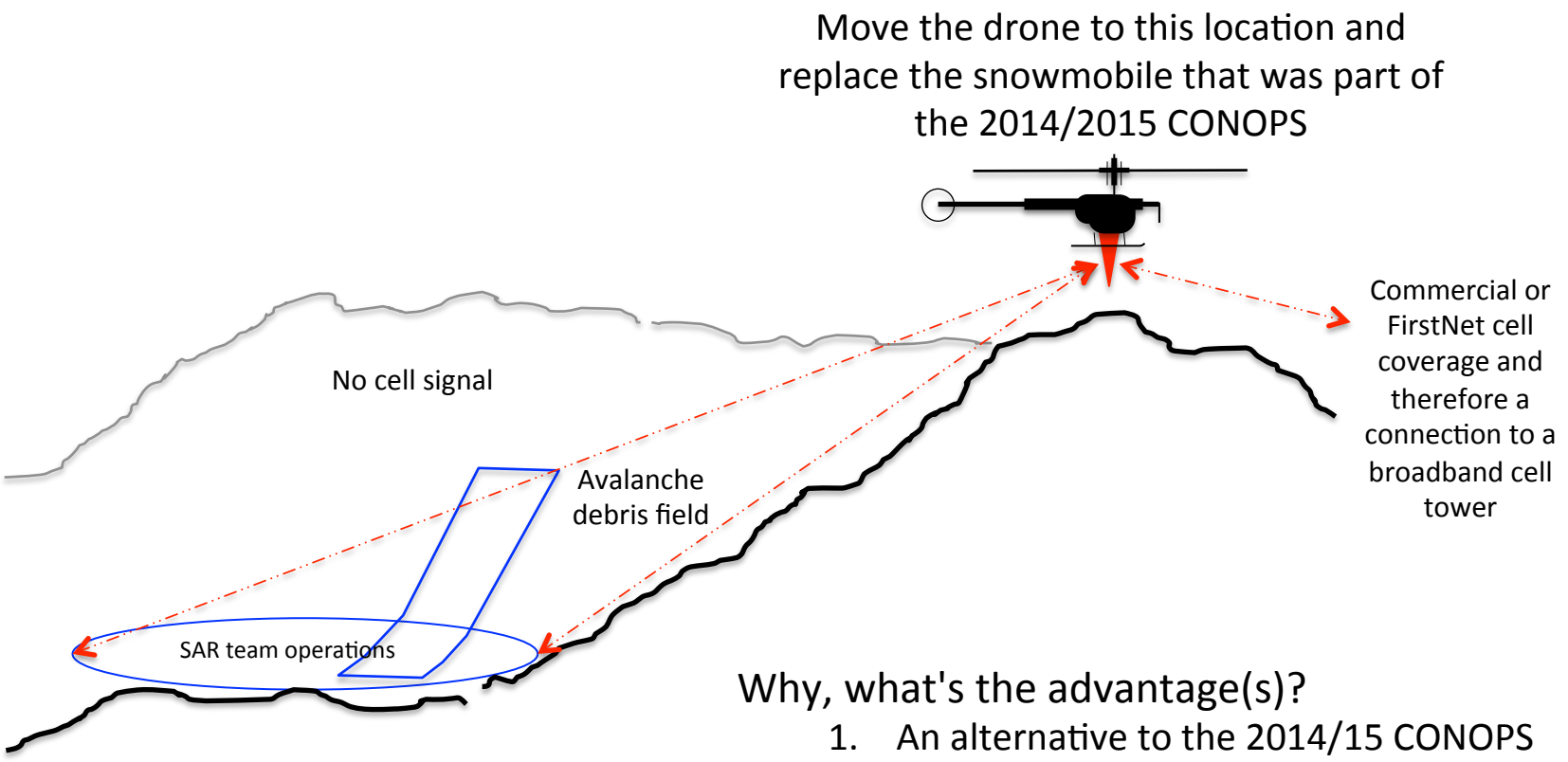

Liability
Corp Returns an Investments (ROIs)
FCC – Special Temp Authority
Public Safety Band 14
FAA - CoA
US Forest Service & other land managers
Ski Resort issues with sUAS
KEEP IT LEGAL
PANDORA'S BOX
USFS
FAA
FCC

OTHER OUTCOMES



- Less hassles if one works in the presence of a commercial cell signal from a fixed cell tower and away from towns and commercial entities
- sUAS does get close enough to detect the buried cell phone signals
- In any event, with or without the presence of a tower signal, one must know the victim's cell provider – AT&T, Verizon, Sprint, etc., **unless** possibly a Software Defined Radio (SDR) system is developed to sweep carrier bands –
  - **Big headache and a lot like 911 issues – where's the ROI?**

CHANGING DIRECTIONS - 2016 CAPSTONE CONOPS



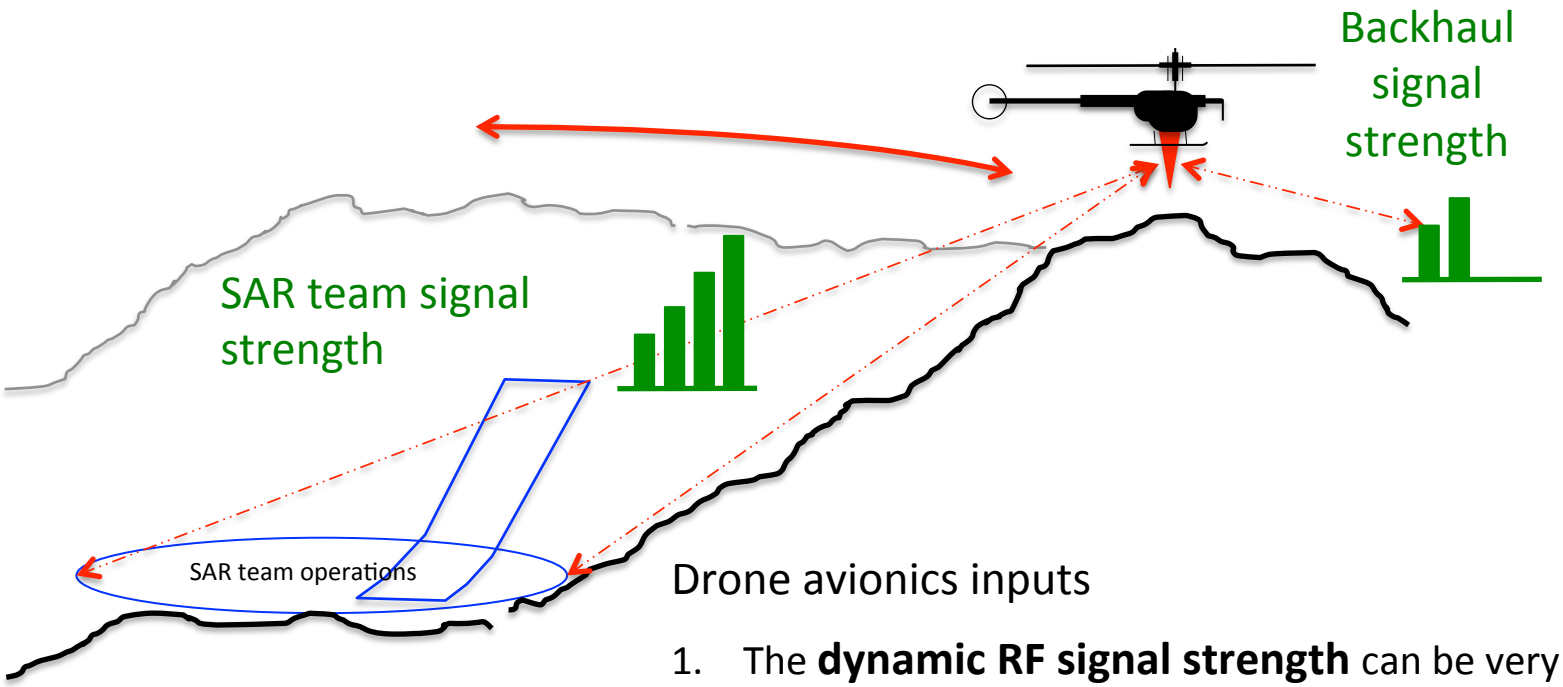
Why, what's the advantage(s)?

1. An alternative to the 2014/15 CONOPS
2. Less equipment to deploy
3. Potentially can greatly increase the time to support the SAR team communications – but how?

WHERE ALONG THE RIDGE?

2016 CAPSTONE CONOPS - Continued

W**here along these ridges** should the drone go to optimize both sides of RF coverage – **same issue if a snowmobile were used**

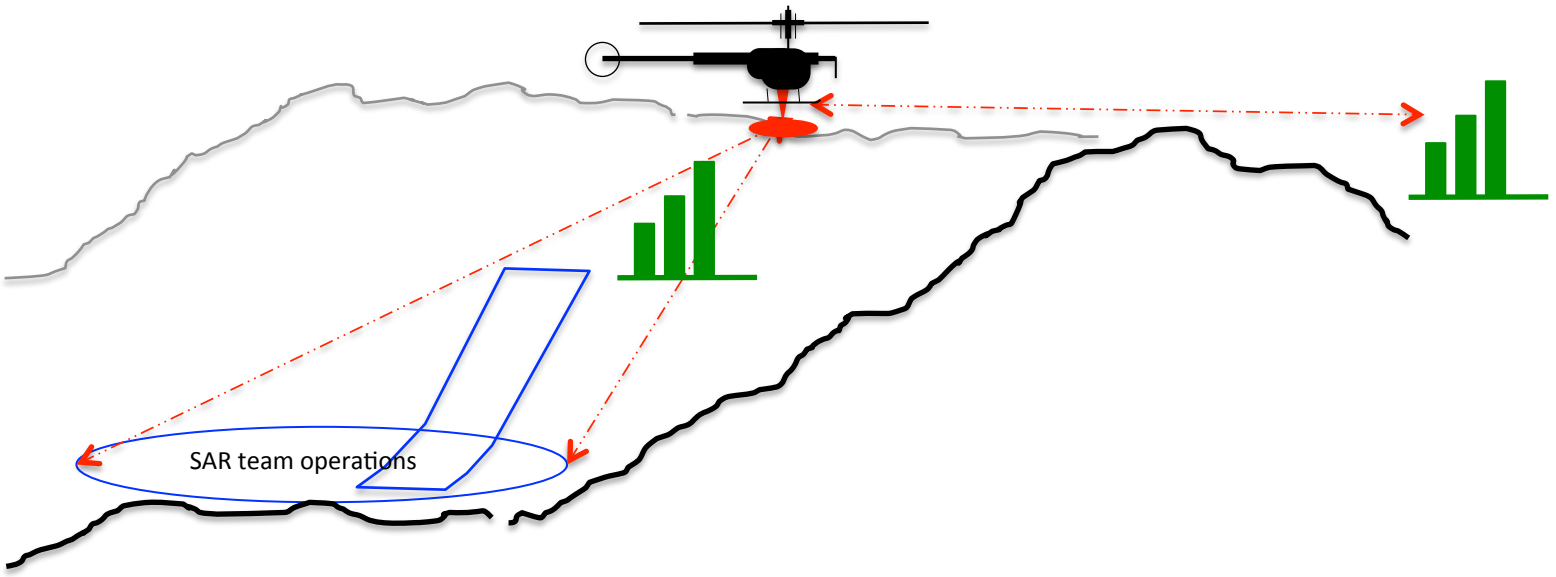


Drone avionics inputs

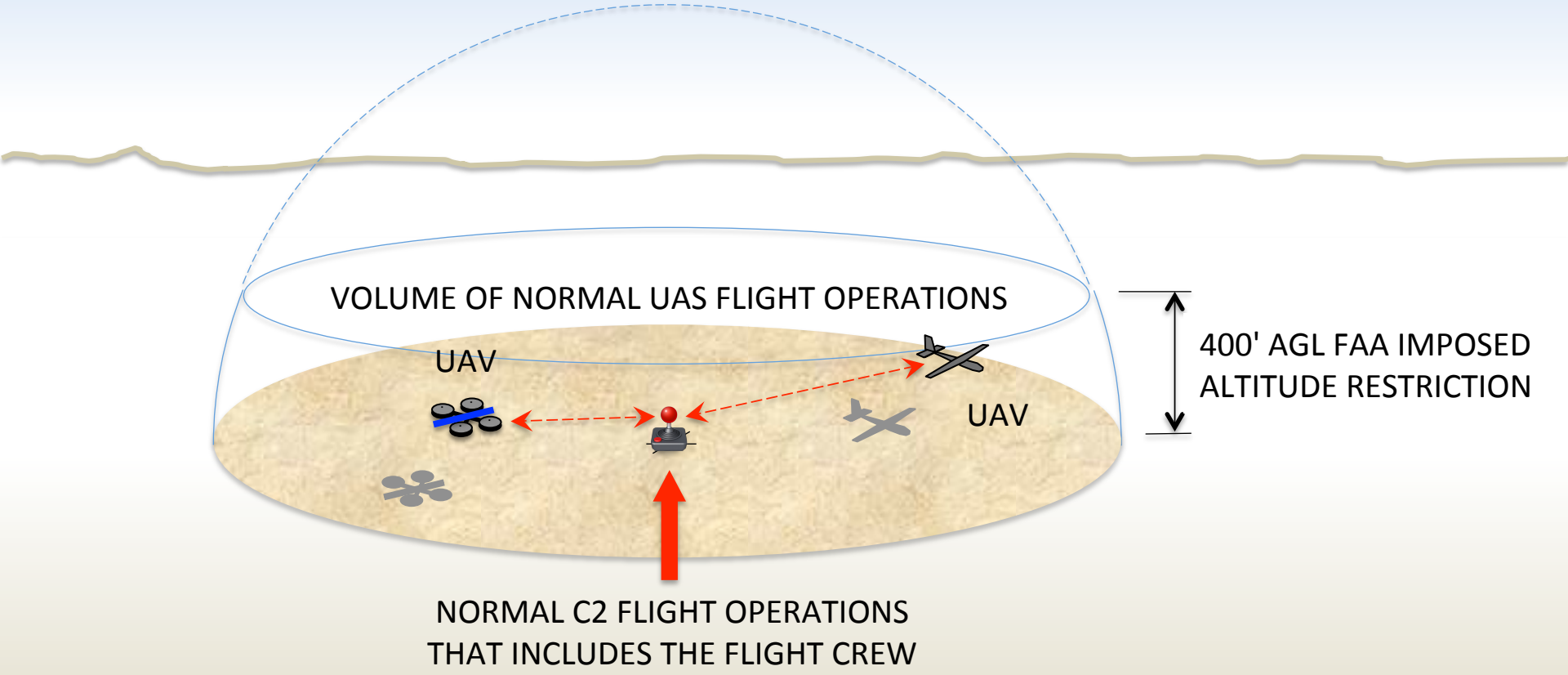
1. The **dynamic RF signal strength** can be very useful as the drone flies along the ridges to find the best location to support **BOTH sides**
2. **Avionic inputs**

2016 CAPSTONE CONOPS - Continued

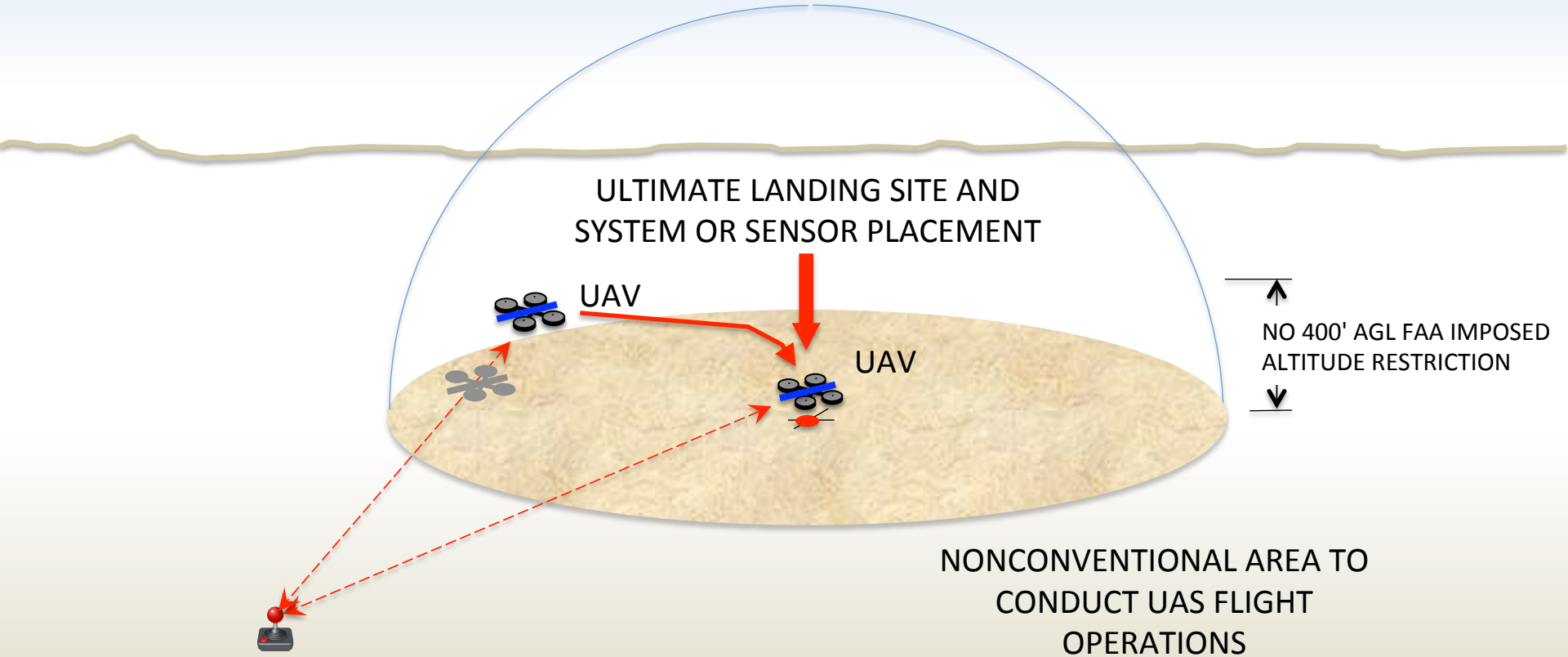
- What if the drone could fly closer and closer to these ridges
- Land and convert all that remaining battery energy toward powering the communication gear – basically **a CoW but now a sUAS deployable small CoW**



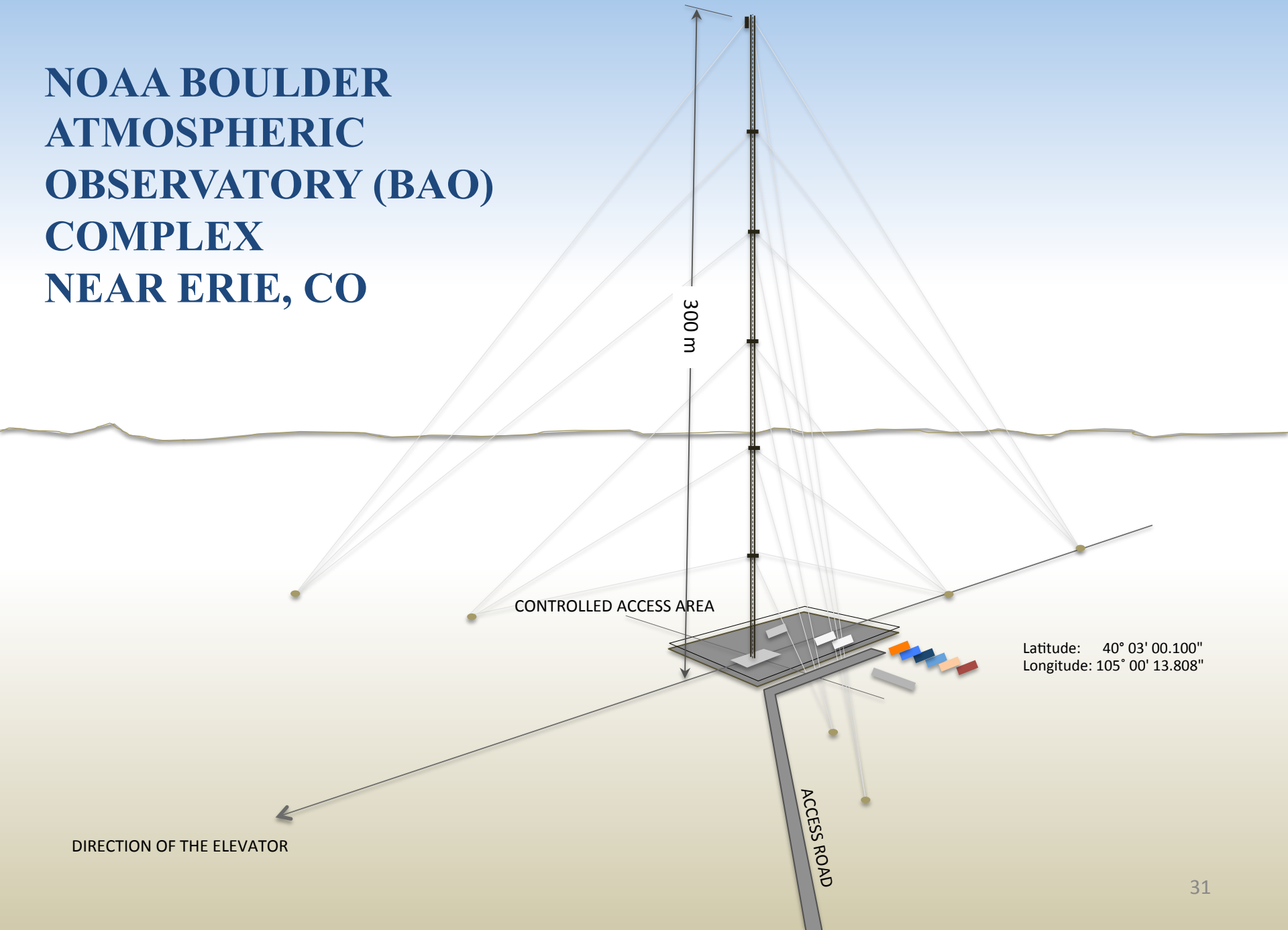
REDIRECTING OUR RESEARCH AND TESTING



NONCONVENTIONAL STANDOFF UAS FLIGHT OPERATIONS

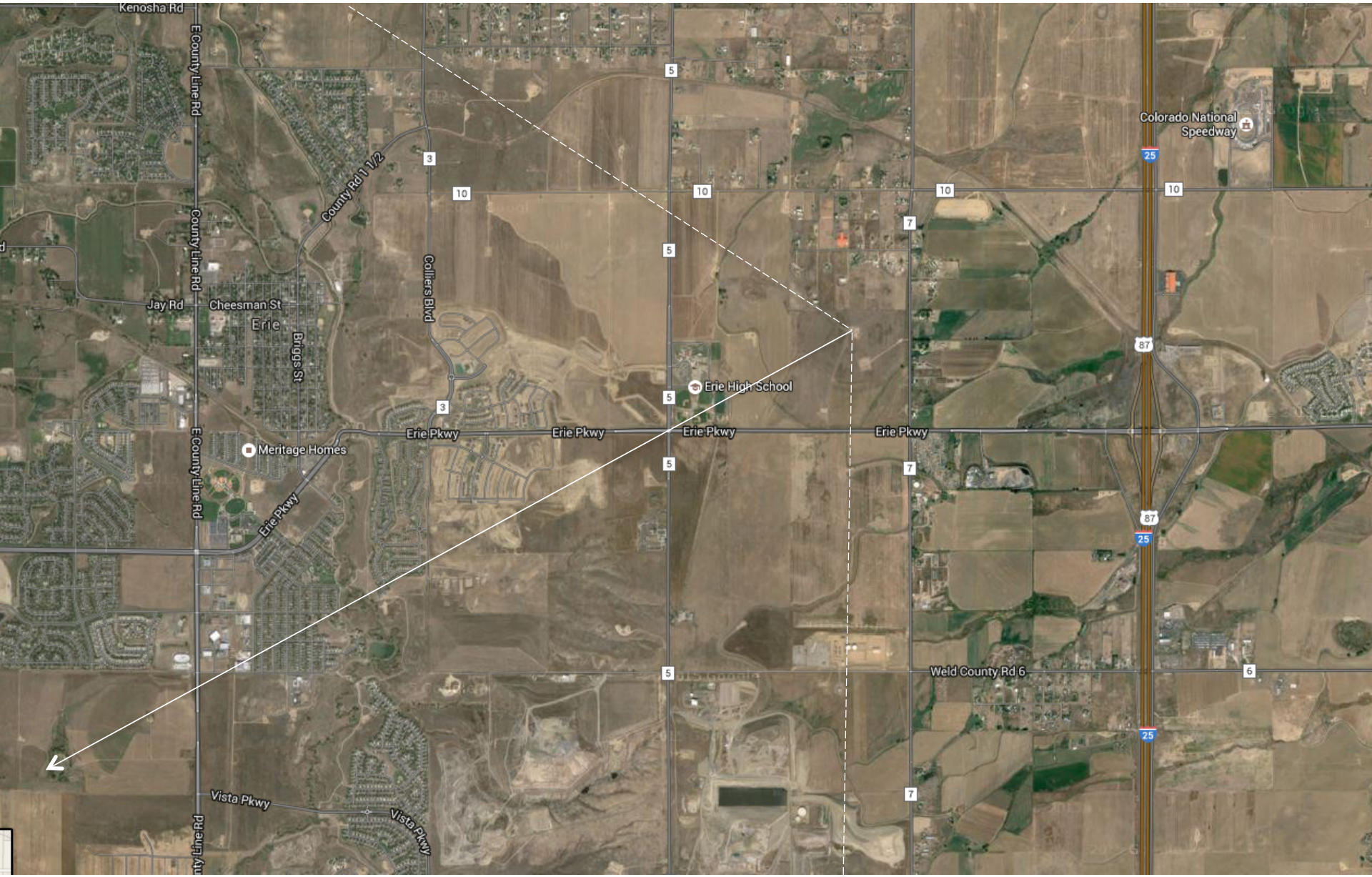


NOAA BOULDER ATMOSPHERIC OBSERVATORY (BAO) COMPLEX NEAR ERIE, CO



BAO TESTING

Elevator view area



Elevator faces this direction

Elevator view area

MORE OUTCOMES

- It is our opinion that:
  - As stated, some form of **rapidly deployable communication localized hot spot** or hot spots will be required where there would be the absence of any RF coverage
    - The **Public Safety LTE Demonstration Network** that was deployed during the 2015 FIS Alpine World Ski Championships in Vail and Beaver Creek, CO
  - It seems logical that some form or forms of **Band 14 LTE CoWs** would be required to support a remote disaster site/area in which there would be an expected high density of first responders
  - A COW-like system should include some form of emergency radio **interoperability between the legacy LMRs and the evolving FirstNet** system – case in point might be a terrestrial form of the USAF BACN
  - **Enabling technologies would include Software Defined Radios (SDRs)**

BOTTOM LINE

- LTE and Unmanned Aircraft Systems will be a valuable match – hand-in-glove so to speak
  - Potential for providing rapidly deployable localized broadband comms and digital support
  - "LTE broadband" is the key enabler
    - Supports valuable handheld applications
    - Enables a plethora of airborne and airborne deployed sensing, imagery, and ISR (Intelligence, surveillance, and Reconnaissance)
- Taking bandwidth where you need it

SUMMARY OF DEPLOYMENT OPTIONS

"Flying COWs just might be how we enhance coverage in notorious troublesome areas of reception." AT&T, February 19, 2017

"EXCLUSIVE: Amazon patents in-flight transformer drones"
Puget Sound Business Journal, January 24, 2017