Recovering Communications after Large Disasters

A Concept Paper

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Executive Summary

- **A strategy for rapid comms recovery after large disasters**
  - Proposes a communications architecture and operational model
- **Leverage & augment present Space Layer for connectivity**
  - Details enhanced and integrated use of existing commercial and DoD assets
  - Proposes national / commercial satellite asset partnerships for public safety
- **Enhance rapidly deployable Airborne Layer: Work with existing terminals**
  - Low cost, fast response plan to substitute for destroyed comms infrastructure
  - Uses existing subscriber radios and mobiles to avoids cost of new terminals
- **Strengthen present Terrestrial tactical communications methods**
  - Leverages current trends in standards, handsets, and terminals for voice/data
  - Highlights terminal battery recharging solutions for extended use
- **Address standards, governmental and commercial issues**
- **Benefits: Enhanced C3, situational awareness, faster recovery**
- **Leadership needed to bring all of the elements together**

A strategy for integrated disaster communications recovery

Some Acronyms

C2	Command and Control
C3	Command, Control and Communications
CONOPS	Concepts of Operation
CONUS	Continental United States
DBS	Direct Broadcast Satellite
DoD	Department of Defense
DHS	Department of Homeland Security (US)
EMA	Emergency Management Agency
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency (US)
LMR	Land Mobile Radio
LTE	Long Term Evolution
MDT	Mobile Data Terminal
MRV	Multi-Radio Vans (US)
NIFC	National Interagency Fire Center (US)
PDA	Personal Digital Assistant
PS	Public Safety
Satcom	Satellite Communications
UAV	Unmanned Aerial Vehicle
VOIP	Voice-Over-Internet Protocol
VSAT	Very Small Aperture Terminal
WiMax	Worldwide Interoperability for Microwave Access

Problem Overview

- **Major effort and money expended to improve Public Safety (PS) communications in the wake of 9/11 (2001)**
  - Concerns for Interoperability/Incompatible communications
- **Major natural disasters, storms and power outage incidents result in disruption of communications over large areas**
  - Concerns for reliability/surviving and maintaining Operability
- **Overall resistance from states to spend money on these scenarios**
  - "It won't happen here", or "Its too big for us to deal with"
- **Large public incidents expose jammed voice communications**
  - Concerns about dependence on landline and cellular systems
  - Concerns for capacity
- **Management problems caused by not knowing ground truth**
  - Failed strategic communications
  - Result in inaccurate and optimistic statements from government
- **Maintenance of law and order is compromised**
  - Failed tactical communications
  - Inability to provide direction or essential rescue and recovery services

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Overview (Cont)

- ***There will always be some incidents too large to be survived intact***
  - Natural: Earthquake, hurricane, Tsunami, etc.
  - Man made: Nuclear, etc.
- **Large incidents often take down communications infrastructure and/or inter-systems links**
  - Access networks destroyed or compromised (Useless radios/terminals)
  - Mobile and portable equipment often left intact with line-of-site comms
  - At best, islands of stranded communications when inter-ties are broken
- **Most solutions concentrate on the Terrestrial (Tactical) Layer**
  - Patching together today's fragmented ground level communications
  - Building more robust structures, towers, generator sites, etc
  - Building redundant forms of terrestrial communications
  - Using diverse sources of power
  - **However, see bullet 1 above (!)**

Large incidents will take down terrestrial systems despite our best efforts

Goal, Approach, Benefits

- **Goal: Recover communications after large scale incidents**
  - Re-establish national/regional disaster management and strategy
  - Re-establish front line communications to enable effective local control
  - Facilitate integrated comms with rescuers from other parts of country
  - Quickly serve a devastated population
- **Approach: Supplement ground communications and make it more resource efficient to facilitate recovery**
  - (1) Bring in network resources that are not affected by the incident
  - (2) Use alternative, capacity-efficient communications to manage recovery and establish command & control
  - (3) Substitute alternative access resources for destroyed comms infrastructure
  - (4) Restore front line communications to *existing* terminals/radios
- **Benefit: Framework could enhances operability and interoperability overall**
  - even for day-to-day operations and routine incidents

Leverage resources that are part of daily operations to restore communications

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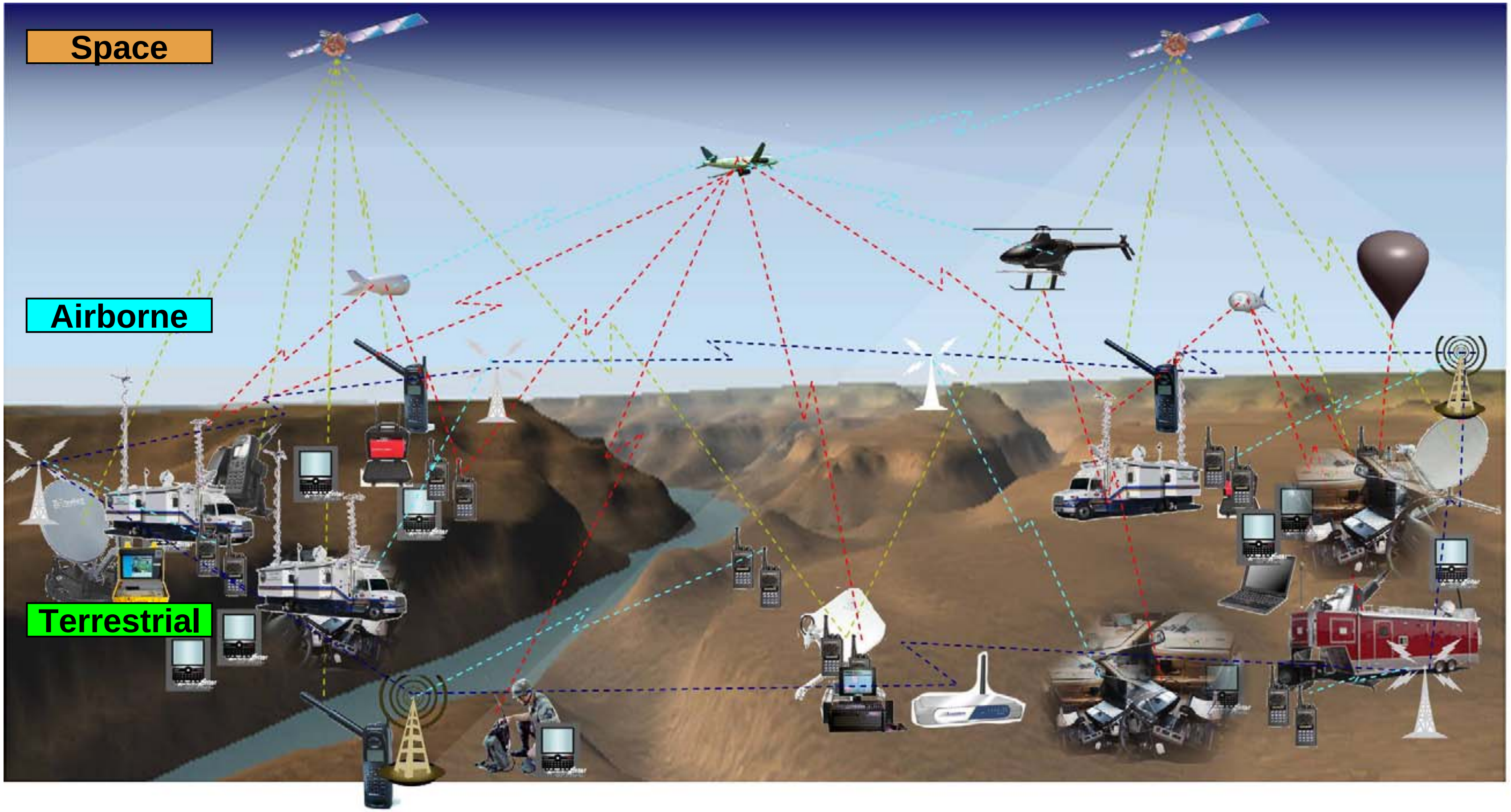
Recovery Communications - Overview



The three layers for communications restoration

Communications Recovery - The Layers & Operational Model

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- **Recognize three layers for Disaster recovery communications**
- **(1) Space Layer: Quickly covers large areas with SATCOM**
  - Goal: Strategic communications/management/situational awareness
  - Compact VSAT terminals with data and some VOIP, first to decision centers, then to the field with local rebroadcast
  - Low capacity portable terminals. Some tactical voice & data comms
- **(2) Add Airborne Layer to increase recovery information flow**
  - Goal: Continue to expand spectrally efficient data communications
  - Allows common access network terminals such as mobile radios to function at limited capacity to enable significant tactical communications
- **(3) Begin traditional Terrestrial Layer communications recovery**
  - Goal: Gradually bring up ground infrastructure supported tactical comms
  - Bring in NIFC resources, cells-on-wheels, FEMA Multi-Radio Vans (MRVs), rig up alternative antenna sites, etc., as done traditionally

Concept: Add two thin upper layers to terrestrial comms for large incident emergency recovery

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Communications Layers – Purpose

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- **<u>Terrestrial Layer</u> – Normally supports communications during emergency response to man-made or natural incidents**
  - Terrestrial layer infrastructure often fails during catastrophic incidents
  - Terrestrial layer must be re-established to allow responders to direct and serve a devastated population; but this takes time
- **<u>Airborne Layer</u> – Nodes deployed at 500 - 50,000 ft (150m – 15 km)**
  - Begins to provide the necessary bandwidth and coverage for responders to send and receive the information necessary to coordinate and integrate their command, control, and tactical response within the devastated area
- **<u>Space Layer</u> – Provides command and control using SATCOM**
  - Initially works between local, regional, state, & federal leadership
  - Provides moderate bandwidth for assistance requests, situational awareness
  - Next provides higher bandwidth for backhaul to field and airborne resources
  - During a catastrophe, services and bandwidth must be increased

Key Approach: Leverage regularly used voice, data, and integrated terminals whenever possible

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Terrestrial Layer Resources

- **Voice Radios and Infrastructure**
  - LMR (Analog, Digital), Digital Cellular, HF, Dispatch centers, Towers
- **Data Radios and Infrastructure**
  - LTE / WiMax (Wide area), Wi-Fi (Incident area), Cellular Data (Wide Area)
- **Backhaul infrastructure**
  - Point-to-point radios, Wireline T1 links, Fiber Backbones, IP based links
- **Infrastructure above could be damaged in a large incident**
- **Voice and data terminals**
  - Portables and mobile radios. Wireless PDA/Phones using cellular data services
  - Future integrated LMR terminals, Laptops and other data terminals with VOIP
- **Space Link Terminals**
  - VSAT terminals (Voice & data), sat-phones (Low capacity Voice)
  - Large communications vehicles have high bandwidth SATCOM capability as well
- **Terminals are undamaged, but may lose service from infrastructure loss**
- **CONOPS to effectively utilize these resources are needed**
  - Issue: Incompatible protocols, applications, databases

Large disasters need a way to quickly re-establish communications using existing terminals

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Space Layer

- **The Space Layer uses satellites at 200 - 22,300 miles (300 - 35,000 km)**
- **Purpose: Rapidly re-establish communications after large incidents**
  - Permits very large areas, including CONUS to be covered for communications
    - Satellite immune to destruction by weather, explosions, etc.
  - Diversity/redundancy from number of large ground stations/satellite portals
  - Small sat-phones, specialized or integrated with other terminals (Cellular/LMR)
  - Small VSAT terminals at EOCs and for deployment at incident sites
  - SATCOM radios with low profile antennas on vehicle roofs
  - Small terminals can be protected from incident or deployed after incident passes
- **Issue: The large coverage area reduces Spatial Capacity**
  - Spatial Capacity is defined in Mbits/sec/MHz/km^2 or Erlangs/MHz/km^2
  - Spatial Capacity is a measure of frequency/channel reuse
  - CONUS antenna beams cannot support all needed communications with limited number of frequency bands and channels
  - Spot beams with higher spatial capacity / frequency reuse are better to cover localized areas. But, these are still “large” (~150+mi, 240+km) covered spaces
  - Large propagation losses and time delays limit voice and indoor/urban use

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Space Layer (Contd.)

- **Voice and Data communications are both provided by SATCOM**
  - Data comms using text (message/email), white-boarding, and websites
  - Limited use of VOIP audio and video where power source is available and functioning on the ground, for strategic communications
- **Uses**
  - Permits communications to the state or regional level or to EOCs for C2
  - First used for command level activity. Encryption available for security
  - Next, provides tactical voice capacity. Can be used as a VOIP backhaul to field deployed repeaters from EOC and data messages/ IM
  - Limited local relaying using Wi-Fi or LMR (voice) repeater is possible
  - Situational Awareness is enhanced
- **General public benefits from SATCOM based radio broadcasts**
  - Convey information to populace if there is power to run DBS TVs/radios
  - Satellite radio is more energy and spectrally efficient than satellite video
  - Large number of consumer satellite radios are in use

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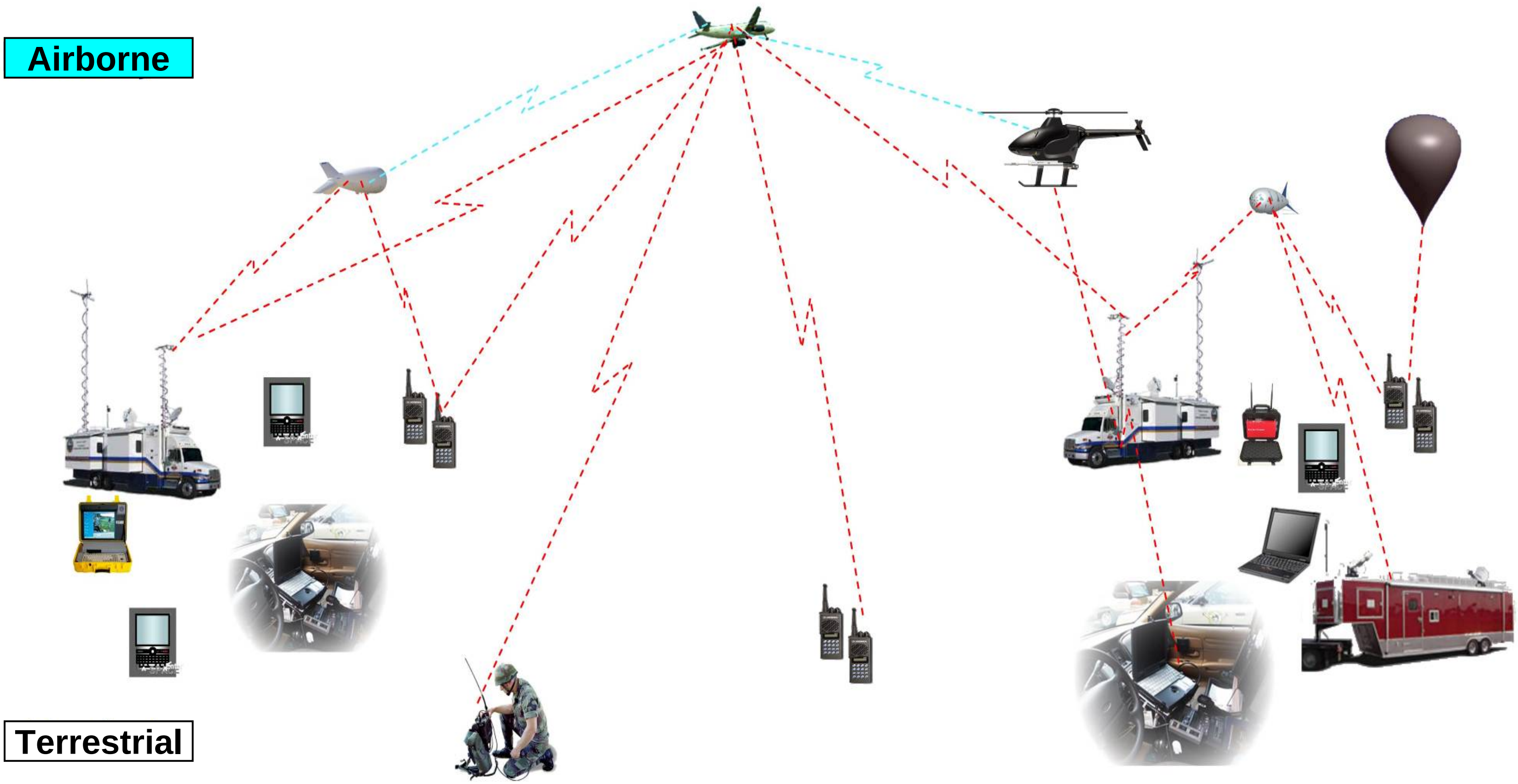
Space layer provides low capacity initial communications for strategic and limited tactical use

Proposed Airborne Layer



Airborne layer used for tactical comms with existing regular Terrestrial terminals and Subscriber Units

Airborne Layer: General

- **Serve as initial Operations Centers for large scale disaster management**
- **Provide key role as relays**
- **As relay platforms are brought lower down from aircraft to aerostats, the spatial capacity (frequency reuse) increases**
- **Airborne layer could allow regular first responder voice radios and data terminals to be used**
- **Self organizing inter-craft mesh networked IP/VOIP relay links serve as ties to provide wider area high capacity service**
- **Satcom links to airborne craft could provide backhaul**
  - If link delays etc can be tolerated by comms systems
- **Much lower path loss compared to terrestrial links enables high quality service with very low power transmitters**
- **Data links often less sensitive and more reliable than voice links**
  - Data links support higher information capacity than voice links
  - Provision a balanced mix of voice and data

Airborne layer substitutes until regular terrestrial layer can be restored over months

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Airborne Layer: Stage 1

- **Airborne Layer deploys resources at 500-50,000 ft (150m – 15 km)**
- **Purpose: Increases Comms capacity. Permits use of traditional terminals**
  - Gradually brought on as calm (weather) returns after the incident
  - Much lower altitude gives much greater spatial capacity than satellites
- **Airborne Command Centers facilitate disaster management**
- **Stage 1: Rigid Fixed wing Comms aircraft (5000-50,000 ft) (1.5 – 15 km)**
  - Fly in a station keeping pattern on auto-pilot
  - Able to handle the high winds associated with weather
  - High power source available from engines
  - Used as airborne comms platforms modeled after military AWACS craft
  - Light weight powered craft with power for comms have been demonstrated
  - Disadvantage (a): Comms packages may need to pierce pressure hull. Hence these need to be specialized aircraft
  - Disadvantage (b): Need to refuel and/or change crew periodically. Requires multiple aircraft to pick up and maintain continuity for comms
  - Disadvantage (c): Unless they fly at low speeds, large Doppler shift could prevent use of some communications terminals

Airborne Layer: Stage 2

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- **Stage 2: Rotating wing craft provide stable platform for comms**
  - Open helicopters reduce problems of installing comms packages
  - Most available craft with adequate extra power can be used if the comms packages are available
  - Stable platforms without large Doppler, function as high comms towers. Permit LMR repeaters, etc. to be installed on board
  - Even a self-contained trunked repeater can be installed
  - LTE / WiMax and some cellular base stations can be carried
  - Positioned over tactical incidents to act as a local relay
  - Antenna will determine extent of coverage, whether wide area or local
  - Depending on height of deployment, self organizing inter-craft mesh radio links could be installed to tie system together
  - High capacity Satcom links to relay out to distant locations
  - Disadvantage: Relatively short mission duration with crew change and for craft maintenance. Number of flight hours limited as well, for safety
    - Learn from firefighters about extended mission use

Airborne Layer: Stage 3

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- **Stage 3: Unmanned craft for long term relay (500-50,000 ft) (150m – 15 km)**
  - UAV/drones and tethered craft act as towers and infrastructure
  - Much higher spatial capacity due to extensive frequency reuse possible
- **Untethered High Altitude Long Endurance Platforms (HALE)**
  - Solar + fuel cell powered very low speed free flying UAVs with 1 kW available power and 500+ lb (225+ kg) payload have been demonstrated
    - ability to fly for a week or more without refueling, with communications pods
- **Free-flying balloons carrying repeaters**
  - Vendor claim: control balloon height into proper wind layer to keep it available for several hours. Launch another balloon when it drifts too far
- **Tethered platforms**
  - As conditions settle, aerostats/ tethered craft act as antennas or carry communications pods for existing subscriber terminals
  - Repeaters, base stations & access nodes for a variety of applications
  - Power and communications fed through tethers

Quickly deployed Airborne layer permits useful tactical comms with existing regular terminals/ Subscriber Units

Powering the Recovery

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- **Loss of grid power is a strong possibility in large incidents**
  - First responders have worked on rugged and alternative energy sources to power ground infrastructure
  - The Airborne layer will permit first responders to use their portables, etc. UNTIL the BATTERIES RUN OUT!
  - Need to look at alternative compact DISTRIBUTED sources of recharging power
- **Explore use of solar, propane, and fuel cell based compact chargers to serve individuals or small squads/ groups**
  - E.g. 1.2 sq. meter solar panel can provide ~180W AC for 6 slot charger
- **Work with industry and first responders to solve powering problem and encourage development of suitable equipment**

Develop solutions for subscriber terminal powering and recharging when grid power is lost

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Actions to Support Development of Airborne Layer

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- **Socialize concept of Airborne Layer and facilitate funding**
- **Work with industry to specify architecture, comms pods, and ground, Satcom, and inter-craft-mesh links**
- **Test Airborne Layer Equipment and Services**
  - Durability, Reliability, Cost, Level of Service, Capacity, Interoperability
- **Develop Usage Protocols and CONOPS**
- **Work with FEMA (US) or other emergency response agency's regions to deploy Airborne Layer equipment**
- **Develop data exchange models to facilitate interoperability**
- **Drive to enhance/ facilitate applications interoperability**
- **Train first responders in use of Airborne Layer equipment**
- **Train first responders on integrated approach**
  - Make use of this equipment part of their routine and training
    - Deploying tethered comms balloons etc.
  - Educate and train users on voice, data, and applications use

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Actions to Support Development of Space Layer

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- **Augment present commercial and DoD SATCOM access**
  - Consider nationally funded commercial emergency access channels
- **Identify funds to develop and launch National Emergency Communications Satellites (NECS) for voice, data**
  - Federal and Private partnership?
  - 3-5 year lead time to launch and commissioning
  - Same justification as national weather, GPS satellites, etc.
  - Cost is miniscule relative to benefits and current expenditures
- **Identify/ develop comms architectures/ standards/ applications**
- **Tie tactical funding to disaster preparedness and encourage common regional or statewide Space Layer standards**
- **Characterize Space Layer ground equipment and links**
  - Capacity, Durability, Bandwidth, Reliability, Cost, Interoperability
- **Train first responders in integrated use**

Contribute to deployment and use of every element of integrated recovery

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Action on Regulatory and Operational Matters

- **Current infrastructure licenses are tied to specific sites on the ground**
- **Explore issues related to airborne use of existing ground frequencies when infrastructure has been disabled**
  - Operational protocols.
  - Interference to undamaged infrastructure outside the disaster zone
  - Regulatory matters
- **Identify and pre-plan frequencies for initial airborne use without additional regulatory changes, if possible**
- **Resolve regulatory protocols/waivers to permit airborne use of existing ground frequencies in cases of emergencies**
  - Where a storm develops slowly, there may be time to pre-plan.
  - In other cases, a protocol needs to exist to start the recovery rapidly
- **Resolve any regulatory issues of airborne relay of aggregated satcom links**

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Long Term Challenges:- Simplifying Deployment

- **Can we help equipment configure automatically?**
  - Free responders from concerns about Spectrum/Frequency, Satellite or airborne system to connect to, frequency and waveform to transmit etc. when using emergency communications equipment
  - They have other things to worry about, like rescuing people
- **Multiband, Multi-system Multi-mode radios, and antennas**
  - For airborne communications,
  - For satellite communications
- **Cognitive Radios, Dynamic Spectrum capability**
  - Sense surroundings and come up on appropriate ground, airborne or satellite infrastructure available
  - Self configuring mesh networking etc at airborne level
  - Range extension at terrestrial level via ad-hoc networking
  - Bridging/cross banding similar-systems

Summary

- **An integrated strategy for rapid comms recovery after large disasters**
  - An architecture and operational model are proposed
- **Strengthens present Terrestrial tactical recovery methods**
  - Leverages current trends in standards, handsets, and terminals for voice and data
  - Highlights terminal battery recharging solutions for extended use
- **Suggests addition of a rapidly deployable Airborne Layer**
  - Low cost, fast response plan to substitute for destroyed infrastructure
  - Uses existing tactical radios and terminals and avoids cost of new terminals
- **Leverages & augments present Space Layer**
  - Details enhanced and integrated use of existing commercial and DoD assets
  - Proposes new National Emergency Communications Satellites (NECS)
- **Address standards, governmental and commercial issues**
- **Benefits: Enhanced C3, improved situational awareness, faster recovery**
- **The time is now, to bring all of the elements together**

Provide leadership for integrated disaster recovery

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