Drone Applications for Wildfires and Other Emergency Situations

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Introductions

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Overall Introduction

- Communication between the first responder, dispatcher, and the person flying the drone
- Types of fire retardants safe for humans and the environment
- Public air space
- UAV sensors used for fire surveillance
- A special focus on remote locations with more rural communities
- Innovative tactics to fight wildfires during the dark hours of the second shift.

National Wildland Fire Preparedness Levels

- Very minimal fire activity
- No Incident Management Team (IMT) mobilization. IMTs are specialized teams of experienced, interagency wildland fire personnel who manage large, complex wildland fire incidents
- Very few personnel committed to wildfires

- High to extreme fire danger in several geographic areas
- 5 to 18 large wildland fire incidents are occurring across the country
- 2 to 7 IMTs are mobilized to wildland fires
- 400 to 5,000 wildland fire suppression personnel are committed to wildfires throughout the country

- Two or more geographic areas require significant wildland fire suppression resources from other areas
- 15 to 32 large wildland fires are occurring across the country
- 7 to 13 IMTs are mobilized to wildland fires
- 3,900 to 8,800 wildland fire suppression personnel are committed to wildfires throughout the country
- The National Interagency Coordination Center (NICC), based at the National Interagency Fire Center (NIFC) in Boise, Idaho, is moving an increased amount of wildland fire suppression resources around the nation

- Three or more geographic areas have large, complex wildfires that require IMTs
- 25 to 52 large wildland fire incidents are occurring across the country
- 15 to 25 IMTs are mobilized to wildland fires
- 8,000 to 17,000 or more wildland fire suppression personnel are committed to incidents throughout the country
- Geographic areas are competing for wildland fire suppression resources and about 60 percent of the country's IMTs and firefighting crews are committed to wildland fires

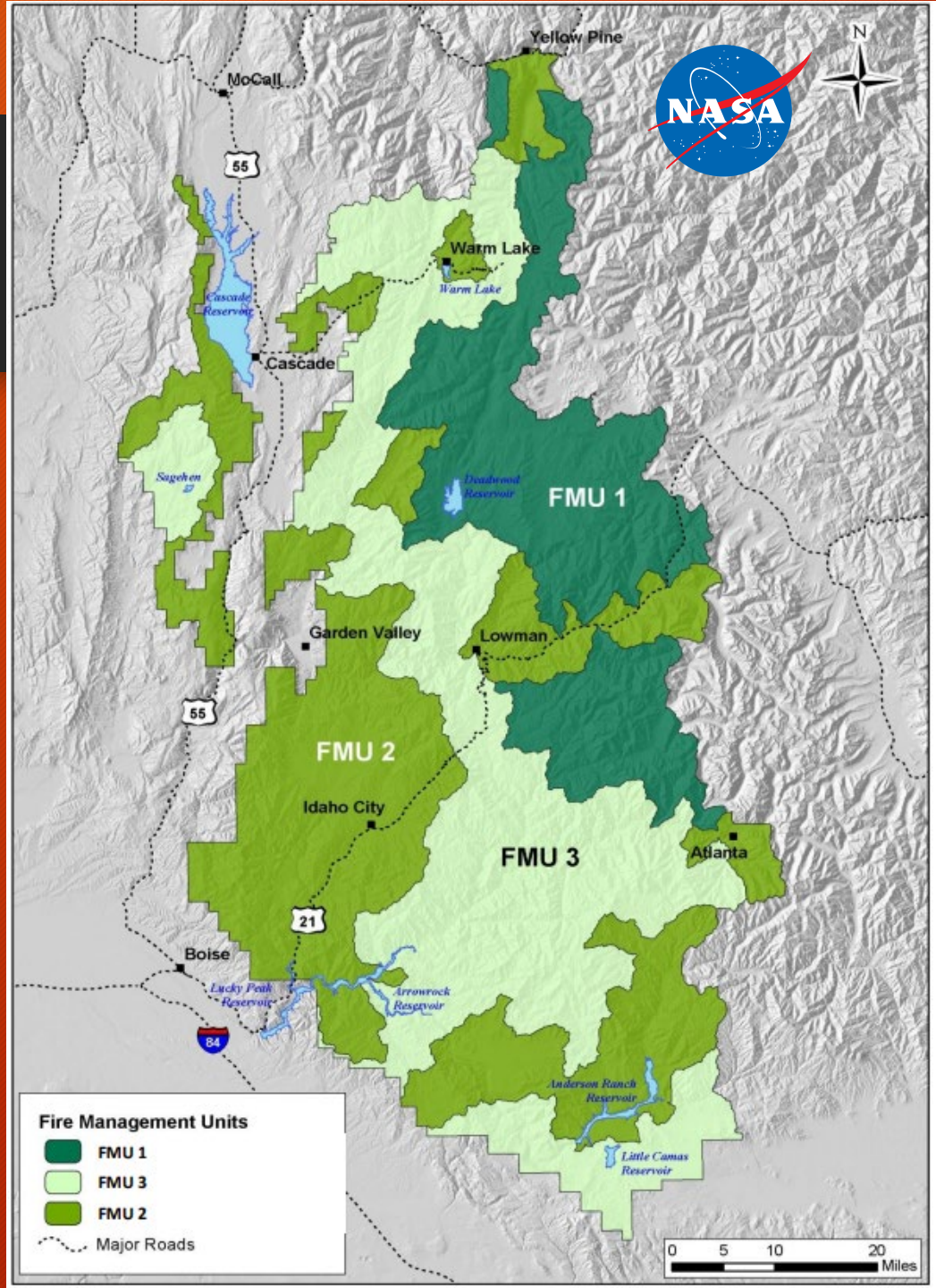
- This is the highest level of wildland fire activity. Several geographic areas are experiencing large, complex wildland fire incidents that have the potential to exhaust national wildland firefighting resources
- 38 to 85 large wildland fires are occurring across the country
- 31 to 38 IMTs are mobilized to wildland fires
- 14,000 to more than 20,000 wildland fire suppression personnel are committed to incidents
- At least 80 percent of the country's IMTs and wildland firefighting crews are deployed to wildland fire incidents
- The Secretary of the Interior and the Secretary of Agriculture release internal correspondence requesting wildland fire assistance and support from all available employees

NATIONAL INTERAGENCY FIRE CENTER
Boise, Idaho

NASA

We Have a Plan

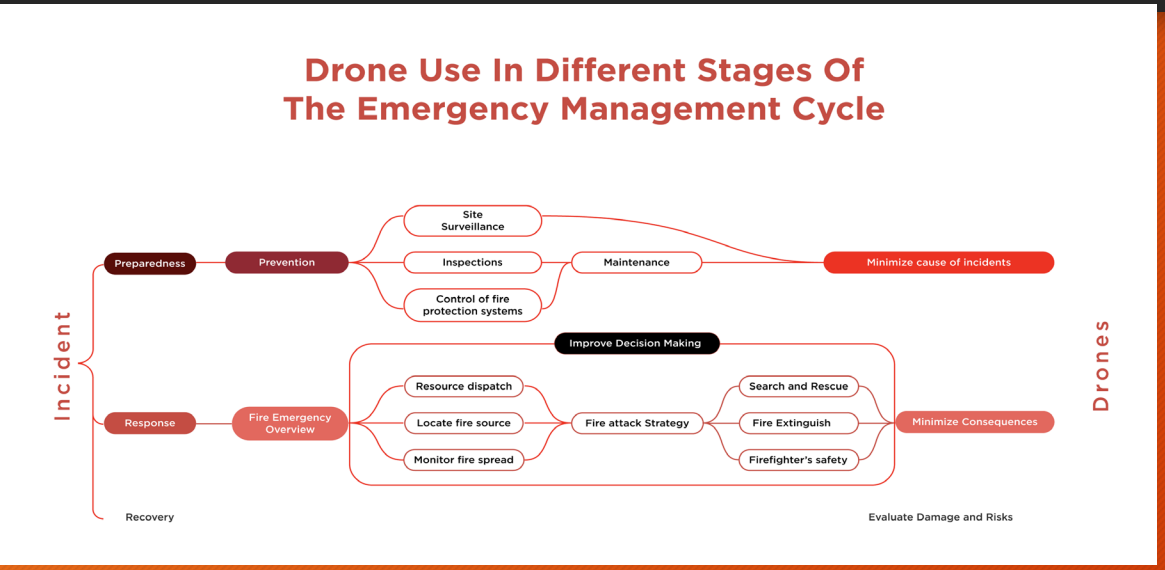
- Most, if not all, National Forest in America have a fire management plan.
- National Forests Fire Management plans include:
  - Nearest fire department
    - Number of fire trucks
    - Number of firefighters
  - Radio frequencies used in walkie talkies
  - Number of acres between land, shrubbery, and trees
  - Amount of rain fall in a given period of time
  - Nearest bodies of water
  - Other additional useful information.
- Image includes map of Boise National Forest in Idaho with a fire management strategy by dividing the forest into zones.



Communication is Key

- Time is extremely valuable: one minute lost means one life lost.
- Helicopters are the most efficient wat for first responders to get from point A to point B, but it is expensive.
- Communication between the Drone Responder, computer aided dispatcher and first responder is critical.
- Drones can be used in most natural disasters such as Hurricane, Search and Rescue, Earthquake, Flood, or Fire.

Connected Through Drones



- Some of the equipment that a small remote drone can carry are, but not limited to, thermal cameras, camera, GPS, spotlight, speaker
- Large drones or aircrafts have the lift capabilities to carry a water hose

- Dispatcher can see the capturing footage coming from the Drone
- Thermal imaging can locate the hot spots of a fire
- Thermal imaging can go through thick patches of smoke

Current Vision Remote Sensing Techniques

- **Satellite imaging:** popular approach due to its low cost. However, does not detect fire at early stages and it is limited by weather conditions.
- **Remote sensing:** use of cameras and sensors in UAVs. The reliability decreases under different weather conditions and battery of the UAV.
- **Wireless sensor network (WSN) detection:** senses data like temperature, smoke, moisture content etc.

Improving Vision

Possible ways of improving Vision remote sensing techniques on drones:

- Combination of remote and wireless sensor network (WSN) detection (Bushnaq, Osama M. et al)
- Use of low cost IoT sensors in combination with uncrewed aerial vehicles complement satellite imaging
- Placement of disperse sensors throughout the forest
- Gathered data such as moisture content, windspeed, temperature, etc.

This helps maximize fire detection and provides enough data for forest monitoring.

Establishing a Safe Airspace

- In 2020, there were 21 documented reports of drone incursions (Corbin,2021)
- Aerial firefighting was shutdown at least 9 times from 2014-2019
- British Columbia Wildfire Service staff were forced to temporarily halt air operations on July 10, 2021, due to people operating unmanned aerial vehicles (UAVs or drones) near a fire.(Schafe)

Credit: U.S. DEPARTMENT OF AGRICULTURE

Establishing a Safe Airspace

Possible solutions to establish a safe airspace during wildfires:

- Geospatial information system provides users with a 3D map of surroundings, including trees, people, buildings and more.
- Up-to-date guidance on areas where flight may be limited due to safety concerns or regulations
- Geofencing to prevent or alert drones approaching a certain point or area.

Establishing a Safe Airspace

Possible solutions to establish a safe airspace during wildfires:

- Anti-Drone Systems (Seongjoon et al.)
- Drone Spoofing:
  - Generate fake GPS signals to make the drone miscalculate its actual position.
- B4UFLY mobile app (warnings, authorizations etc)
- Convince drone manufactures to add the following features to their drone software:
  - Warnings of TFR
  - Drone re-routing if it is in proximity of a TFR or in a do not fly zone
  - Drone safe return to owner when connectivity is lost.

Eco-Friendly Gel to Stop Forest Fires Produced by Scientists at Stanford University

Carrier gel is made of non-toxic cellulose-based material and can be combined with current fire retardants in use and then sprayed onto fire-prone areas

Advantages

- Gel texture allows for it to withstand severe weather conditions (a single application can provide protection for an entire fire season!)
- Although the gel dries quickly, a retardant film is kept over vegetation that maintain its retardant function
- When the gel flakes, it biodegrades into the environment without causing harm
- Scientists have stated that 20,000 gallons would be needed to prevent fires

Experimental Results

- -Stanford researchers worked with California Department of Forestry and Fire Protection (CalFire) and tested the gel on chamise and grass
- -Treatment provided fire protection even with half an inch of rainfall
- -has potential to reduce fires from high-risk roadside areas

Alternative Fire Retardants

Different Eco-Friendly Retardant Types:

1. **Phosphorus-based fire**
- Most used because they are versatile
- Decomposition of chemical rxns yield carbon rather than CO or CO2

2. **Nitrogen-based**
- Does not form dioxin and halogen-acid by-product + during combustion, low evolution of smoke
- More stable than common retardants with high bond energy with nitrogen atoms

Alternative Fire Retardants Continued

3. **Intumescent systems**
- Retardant with most potential
- High efficiency, low smoke, and low toxicity
- Made up of: an acid source, a carbonizing source, and a foaming or blowing source(nitrogen-containing compound)
- At high temp, the acid source decomposes + forms inorganic strong acid, that allows dehydration of the carbonizing agent to form the carbonaceous layer. The blowing agent decomposes and releases inflammable gases, that can expand the carbonaceous layer allows it to form a swollen multicellular layer.

4. **Mineral Flame**
- Inorganic non-toxic fillers
- Inorganic filler flame-retardant efficiency is low, therefore high loading filler is required
- Common minerals used: metal hydroxides, borates, and hydroxycarbonates
- Zinc borate, which improves polymer material function during combustion acts as smoke and afterglow suppressant.

Alternative Fire Retardants Continued

5. **Silicone-based**

- Thermal stability, high heat release, and does not release of toxic gases such as CO during thermal decomposition
- Silica/silicon dioxide have different types (example: silica gel) and the effectiveness depends on different factors, including pore size, particle size, surface silanol concentration, surface area, density, and viscosity.

6. **Nanoparticles**

- Surface area of nanofillers increase so polymer nanocomposites show macro/micro/nanointerfaces
- Carbon nanofillers can improve functionalities that include electrical, thermal, and flammable properties of composites
- High flame-retardant efficiencies
- Adding a small amount (~ <5 %) of nanofiller can reduce the peak heat release rates (PHRRs) of polymers and decrease the speed of which flames spread within them
- Should be combined with conventional flame retardants for a balance of flammability and mechanical properties.

Fire Retardants from Biomass

Cellulose, hemicellulose, starch, hydrogels, carbon-based nanoparticles are examples of fire retardants from biomass

Fire TechX is a long-term non-toxic fire retardant

- Effective while wet or dry
- Lasts for 7days, then becomes fertilizer
- Prevent all Class A fires, which include forest fires and at-risk structures. Fire TechX encourages regeneration of ecosystems, becoming a natural fertilizer as it degrades.

Deployment of Fire TechX

- Delivered in powder form and mixed with water on-site, which keeps transport costs down and maximizes response vehicle usage

FireTechX: revolutionary, natural-based fire suppression gel that's also a long-term flame retardant. | Environx Solutions

TetraKO XL-P Gel

TetraKO XL-P firefighting gel gives fast fire knockdown and protection for all vegetative fuels. When applied to grasses and other sensitive fuels, it sticks to surfaces and creates a nontoxic fire protection barrier

Used with great results on fast moving grass fires in Minnesota and Wisconsin, and has been tested by the French Forest Service.

Wildland Firefighting - EarthCleanEarthClean

Second Shift Firefighting

Pros

- Lower Temperatures
- Relative humidity rises
- Less active fires (wind)
- Ease of identifying slop-overs and spot fires

Cons

- Falling and tripping hazards, rolling rocks and widow-makers make unsafe conditions
- Cannot see changes in clouds or smoke columns
- Difficult to locate fire accurately on terrain
- Flying with night vision goggles is difficult.
- Many aircraft must be grounded at night due to lack of visibility

Thermal Belts

- A mountainside zone in which frost and freezing temperatures are less abundant.
- Thermal belts provide a healthy environment for wildfires and are difficult to reach on foot.
- These areas harbor fires during the night very well, keeping them burning till the following day.

Using Drones to Combat Wildfires at Night

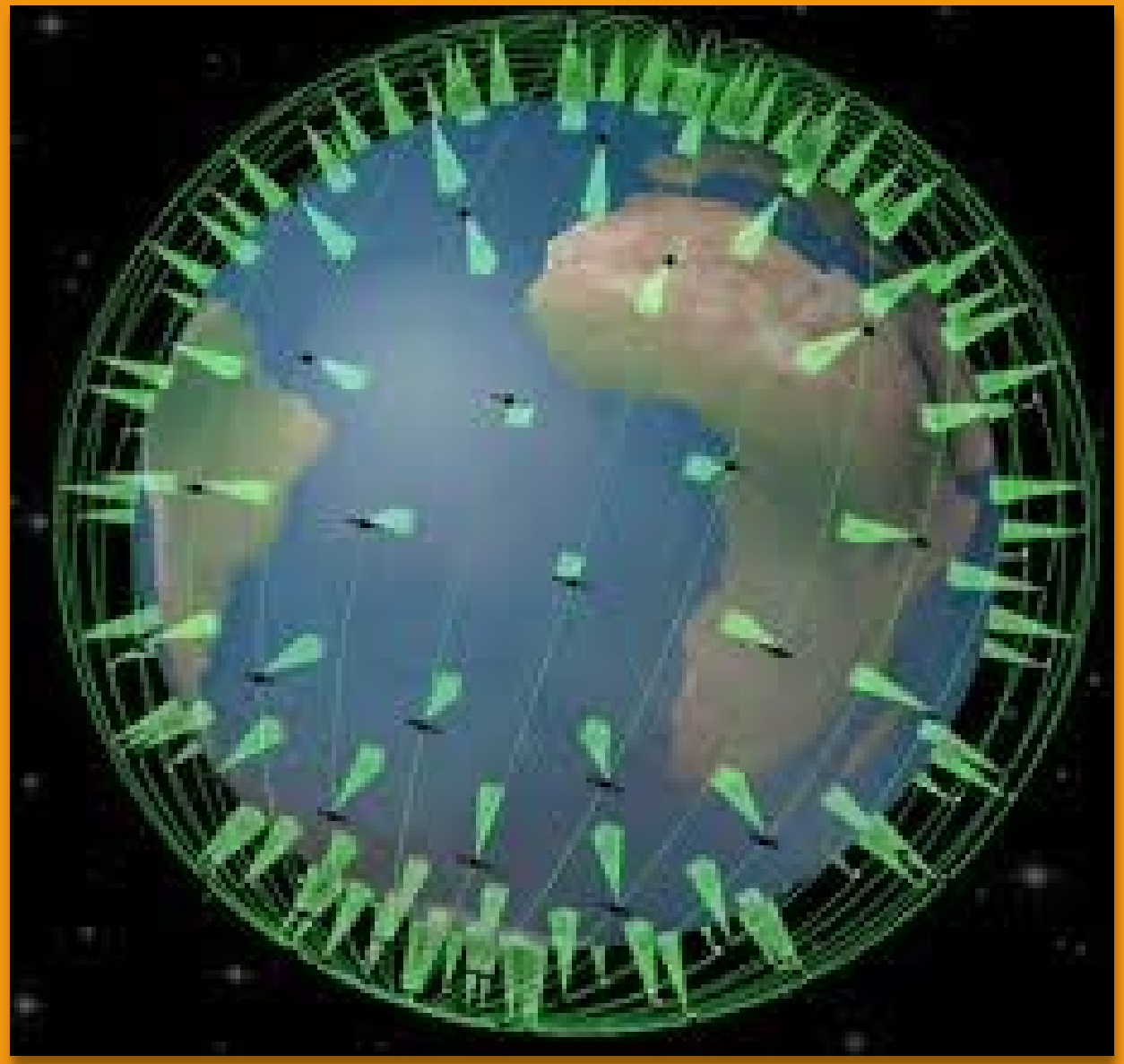
- HALE drones
  - Used for surveillance
  - Northrop Grumman MQ-8C Helicopter drone
- Large Drones
  - GA-Predator C Avenger
    - Max payload: 6500 lbs (778 gallons of water)
    - Endurance: 20 hours
  - Design of own equipment
    - Development of drones specifically for firefighting
    - Existing platforms used as basis

Satellite Systems to detect wildfires

- Often the first to detect wildfires in remote regions
- Can detect actively burning fires, track transport of smoke, provide information for fire management, map ecosystem changes(burn severity mapping), and boundary determination
- Generally, rely on a constellation system of satellites with a wide swath
  - Around poles, observe planet several times a day i.e. Sentinel-1
  - Geostationary orbits – imagery of fires, smoke, clouds every 5-15 minutes i.e. GOES

FireSat

- Proposed sensor constellation of 200 satellites
- Low resolution image of a fire once per minute, along with latitude and longitude (continuous communication with ground)
- Detect fires that are at least 35-50 feet wide, average of 15 min from where they begin.



Sentinel-1/Sentinel-2

- Imagining radar mission providing continous all-weather imagery at C band
- Satellite constellation
- Images global landmasses, coastal zones and shipping routes in European waters in high resolution
- 250 km swath

Single Satellite in a Constellation System

FireSat

- A cryogenic cooler
- 2 instrument modulus
- Field of regard has three overlapping swaths
- 3 telescopes
  - Center points nadir
  - Outboard telescopes point off nadir (~32 degrees)

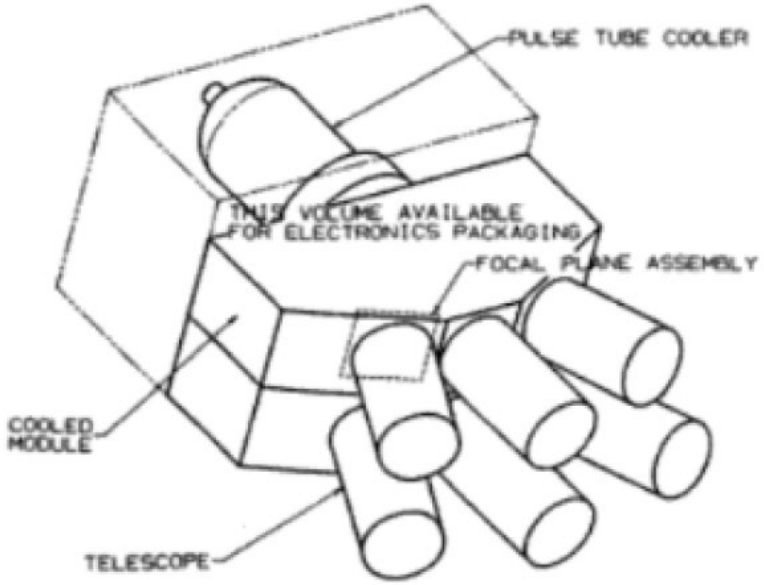


Figure 12.10 FireSat instrument configuration

Single Satellite in Sentinel-1

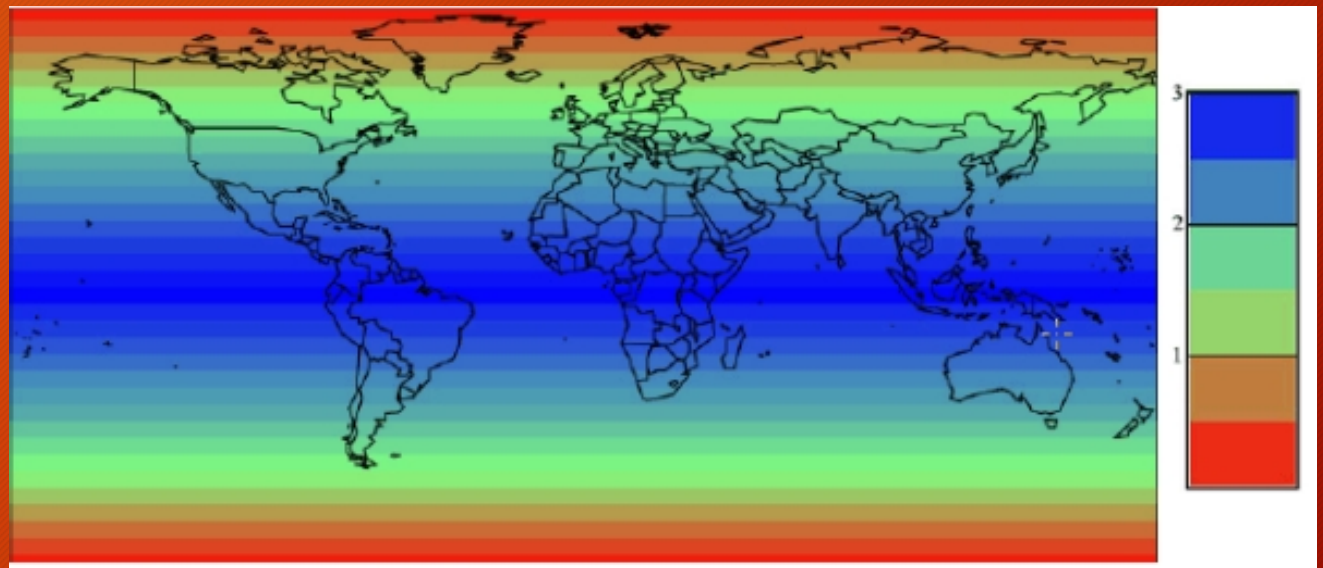
- Near polar sun synchronous orbit
- 12 day repeat cycle

Instrumentation:

- Low spatial resolution visible infrared imaging radiometer suite (VIIRS) and the moderate resolution imaging spectroradiometer (MODIS) are often used for preliminary mapping.
- Landsat and Sentinel-2 (multi-spectral imaging) are deployed for post-fire boundary determination and burn severity mapping.
- Active sensing technology, doesn't rely on solar radiation.

Astrodynamic Considerations

- Composite field of regard is taken with concatenating images.
- FireSat has an orbit altitude of 830 km with tropical regions left unobserved for a 24-hour period.
- Sentinel-1 is able to cover tropic regions, but has a re-visit rate greater at high latitudes.



✓ Two satellites in a 12 day orbit
✓ Repeat frequency: 6 days (important for coherence)
✓ Revisit frequency: (asc/desc & overlap): 3 days at the equator, <1 day at high latitudes (Europe ~ 2 days)

Effects of Astrodynamics on Detection

Response time will be delayed for places that don't have effective fire management, or dispersed/remote communities (such as fire-prone rangelands in the Northern territory of Australia)

Potential Solutions:

- Deployment or constant monitoring of UAVs in such remote locations (both rural and uninhabited parts of the world, to lessen environmental impact)
- Geostationary satellites
- Combination of FireSat-like system with satellites modeled as single Sentinel-1 satellites, with aid from geostationary satellites and UAVs.

Conclusion

- Drone can scope out the scene before first responders arrive for an efficient way of gathering information
- Working in conjunction with US drone manufactures can help develop a safer airspace for drones fighting wildfires.
- A combination of Wireless Sensor Networks and UAVs can help for a quick detection of a wildfire.
- Eco-friendly fire retardants although are being researched, still require in depth experimentation in order to deploy in scale-up situations
- The use of large UAV’s is necessary for a safter second shift battle against wildfires.

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Questions?

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