FIRE DETECTION CONSTELLATION CONCEPT:

IRIDIUM BACKCOUNTRY WILDFIRE DETECTION NETWORK

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We at JPL are not experts on wildland fires…

Looking for feedback, adjustments, comments on a concept for detection of new fires:

1. That have reached a threshold size ~15 x 15 m
2. Within the last <~30 minutes, day or night
3. Where there are not commonly “hot spots”
4. Specifying their location within ~500 m to appropriate emergency service providers within ~3 minutes of detection
5. Mainly not under cloud cover (e.g., Santa Anna or Chinook conditions)
6. With a false alarm rate <10%.

If this isn’t useful, what set of performance parameters would be?
WILDFIRES ARE A GLOBAL PROBLEM

• The number and intensity of catastrophic wildfires is growing due to:
  – Droughts increasing with climate trends
  – Invasive non-native plant species
  – Development of Urban / Wildland Interfaces

• Recent fires cost Greece $6.8B [DPA 2007], Australia $4.4B [Bushfires Royal Commission 2010]

Source: MODIS global fire product, MODIS rapid response system, Apr. 1-11, 2011

WILDFIRE COSTS IN THE US ARE SIGNIFICANT AND GROWING

• In 2008 there were 78,949 wildfires
  – 5.3 million acres burned
  – 16 deaths occurred

• Direct federal cost for suppression is $3B/year [GAO 2009]

• However, the total cost of wildfires (in tax revenue, rehabilitation) is generally 2-30x larger [WFLC Rpt, 2010]
CALIFORNIA IS ESPECIALLY VULNERABLE

• Suppression costs exceed $1B/year [LA Times 2008]

• Damages top $1B/year in San Diego county alone [AP 2007]

• Costs grew 150% in the last decade
EARLY WARNING CAN PLAY A VITAL ROLE

- Fires are almost always discovered by 911 calls
- Fires at night or in remote areas can grow undetected
- **Over half** of the most destructive U.S. fires, and **half** of most damaging LA County fires, began in isolated locations or at night without early warning  
  [LA Cty., USFS-DOI]

*“Every wildland fire that is quickly contained translates to saved lives, homes, and assets.”* [LA County CEO, 2010]
Satellites can provide timely detection, and real time fire maps can assist suppression efforts [Kremens 2011]

However, current fire products relying on single satellites provide inadequate coverage [2010 LA Cty. Rpt]

<table>
<thead>
<tr>
<th>Satellite detection network “requirements”</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Lyman et al., G7 CEOS Disaster Mgmt. Support Group, 2002)</td>
</tr>
<tr>
<td>Repeat time</td>
</tr>
<tr>
<td>Ultimate detection time</td>
</tr>
<tr>
<td>Spatial resolution</td>
</tr>
<tr>
<td>False positive rate</td>
</tr>
<tr>
<td>Data transmission</td>
</tr>
</tbody>
</table>

Table VI - All Systems, Board Requirements

<table>
<thead>
<tr>
<th>System</th>
<th>Early Detection</th>
<th>24-Hour</th>
<th>All-Weather</th>
<th>Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground-Based Visual Cameras</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ground-Based Infrared Cameras</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Other Ground-Based Sensor Systems</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Manned Aircraft</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Unmanned Aircraft</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Weather Satellites</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>DOD/DSP Satellites</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Evaluation of existing detection options, from the LA County CEO Report
**AN ALTERNATIVE SOLUTION: SATELLITE CONSTELLATIONS**

- The Iridium Next network (2015) will host client payloads on up to 66 satellites

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**Primary payload option** | **“Sensor Pod” payload option**
---|---
Mass | 50kg | 5kg
Volume | 30x40x70cm | 20x20x14cm
Power | 50W avg. / 200W peak | 5W avg. / 10W peak per block
Data | <1Mbps | 10kbps avg. / 100kbps peak
IRIDIUM SYSTEM COMPARISON

- Simulated revisit times for different system options (Blue boxes below show middle 50%)

<table>
<thead>
<tr>
<th>System</th>
<th>Sensors</th>
<th>Swath width</th>
<th>Overpass interval</th>
<th>Spatial Resolution</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iridium A</td>
<td>18</td>
<td>500km</td>
<td>2.1 hours (median)</td>
<td>250m</td>
<td>Lowest cost</td>
</tr>
<tr>
<td>Iridium B</td>
<td>24</td>
<td>500km</td>
<td>2.1 hours</td>
<td>250m</td>
<td>Very regular overpasses</td>
</tr>
<tr>
<td>Iridium C</td>
<td>30</td>
<td>1000km</td>
<td>27 minutes</td>
<td>500m</td>
<td>Sub-30 minute overpass interval</td>
</tr>
<tr>
<td>GOES ABBA</td>
<td>1</td>
<td>&gt;5000km</td>
<td>15-30 minutes</td>
<td>4000m</td>
<td></td>
</tr>
<tr>
<td>MODIS MOD14</td>
<td>1</td>
<td>2330km</td>
<td>12-24 hours</td>
<td>1000m</td>
<td></td>
</tr>
<tr>
<td>ASTER ETF+</td>
<td>1</td>
<td>60km</td>
<td>24+ hours</td>
<td>30m</td>
<td></td>
</tr>
</tbody>
</table>

24 sensors, 1000km swath (1 hour coverage)
A 4μm CAMERA POINT DESIGN

- Extrapolation from airborne MWIR images suggests that subpixel fires can be detected – as small as 15x15 m²
- Detection is straightforward and can be accomplished with a small-scale instrument

Image: RIT [McKeown 2005]

Approximate dimensions: 20cm x 20cm x 14cm
A 4μm CAMERA POINT DESIGN

- Incorporates a high-resolution Focal Plane Array and onboard FPGA processing

Raytheon SB450 Large-format FPA
(Comparable JPL unit shown)

Comparable Objective lens package (JPL)

Xilinx Virtex-5 FPGA (JPL – Pingree)

AD Conversion
DATA PROCESSING AND DOWNLINK

- Onboard processing reduces downlink requirements
- Transmit detection *locations* (<60KB) instead of images
- Permits ~1 image/minute, low downlink bandwidth
- No precise pointing required

1. Fire detection in 4um band
2. FPGA processing finds landmark points [JPL/Wang 2008, JPL/Werne 2010]
3. Compressed downlink includes fire pixel and landmark locations
4. Landmarks are matched against an image database to find false & repeat detections

Image: RIT [McKeown 2005]

mission operations

donlink: ~60KB per image
OTHER APPLICATIONS

Protection of oil pipelines and other energy assets

MODIS MWIR images show the Mexico Pemex pipeline fire (28 deaths, 12/19/10)

Enforcement of biomass burning laws and treaties

GOES MWIR biomass products show subpixel fires in Western Brazil
MULTIPLE FRAME DETECTION METHOD

Step 1: Matching
Automated algorithms recognize landmark features to determine geometric correspondence between adjacent frames. This pair shows matches from the top 8 high-contrast landmarks in an overflight pair.

Step 2: Tracking
Subpixel detections are tracked across multiple images.

Step 3: Detection
Information from multiple scenes is combined in a final detection decision. This improves false-positive rates relative to single-frame detections [JPL / Thompson 2011].

Unprocessed Images from the RIT WASP project [McKeown 2005]
FOCAL PLANE ARRAY

• First Raytheon SB450 units are under production, with availability in less than 6 months

• Extrapolation from airborne MWIR images suggests that a fire subtending a small fraction of the pixel can be detected

Image courtesy RIT [McKeown 2005]
REGIONAL UAV OPTION

• Persistent high-altitude AUVs might offer the best of all worlds:
  • **Spatial coverage** over entire jurisdictional areas
  • **Continuous monitoring** with high temporal resolution
  • Useful as a bridge application and a **validation testbed** for advanced image processing and spaceborne sensors

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**Aerovironment Global Observer**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating altitude</td>
<td>~65000 ft (&gt;18km)</td>
</tr>
<tr>
<td>Duration</td>
<td>7 days</td>
</tr>
<tr>
<td>Propulsion</td>
<td>Liquid Hydrogen</td>
</tr>
<tr>
<td>Observation Swath</td>
<td>12km (53-degree optics)</td>
</tr>
</tbody>
</table>

Global Observer. Source: Aerovironment
1. LA Times series, “As wildfires get wilder, the costs of fighting them are untamed.” By Bettina Boxall and Julie Cart, Los Angeles Times Staff Writers. First of five parts July 27, 2008.


3. Report by the Western Forestry Leadership Coalition, a State and Federal government partnership. The members of the coalition include: the 23 State and Pacific Island Foresters of the West and the 7 western Regional Foresters, 3 western Research Station Directors, and Forest Products Lab Director of the USDA Forest Service. “The True Cost of Wildfire in the Western U.S.” April 2010. online at http://www.wflcweb.org


5. Deutsche Presse-Agentur, “Damage from Greek fires estimated at 6.8 billion dollars (Extra),” citing Greek Finance Ministry, April 2007.


9. CALFIRE Fire prevention services, online at http://www.fire.ca.gov/fire_prevention/


