

Images courtesy Iridium, Rochester Institute of Technology

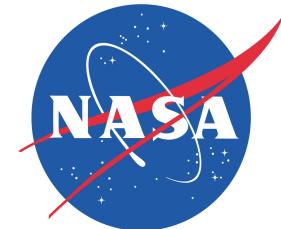
FIRE DETECTION CONSTELLATION CONCEPT: IRIDIUM BACKCOUNTRY WILDFIRE DETECTION NETWORK

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We at JPL are not experts on wildland fires...

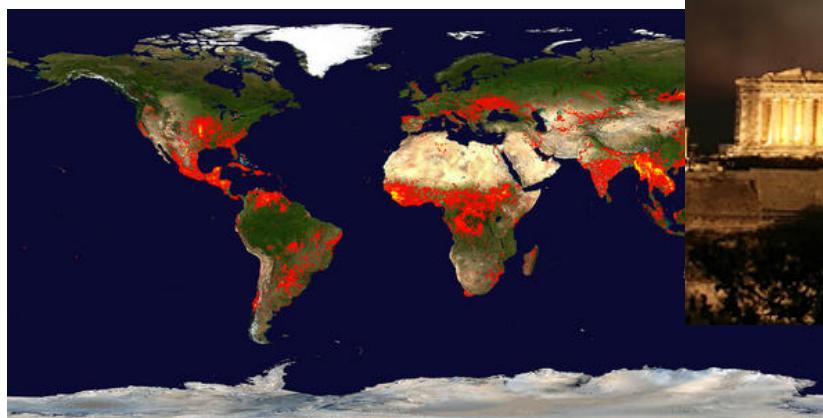
Looking for feedback, adjustments, comments on a concept for detection of new fires:

1. That have reached a threshold size $\sim 15 \times 15$ m
2. Within the last $<\sim 30$ 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]

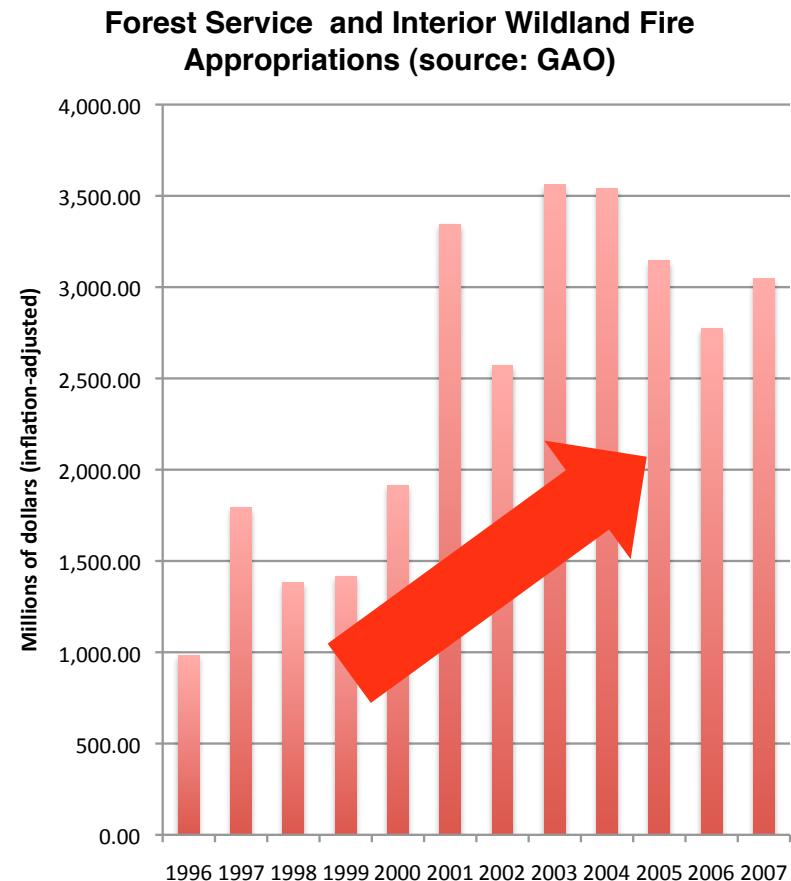


Source: NY Daily News Aug. 23, 2009. AP, (Bicanski/Getty).

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

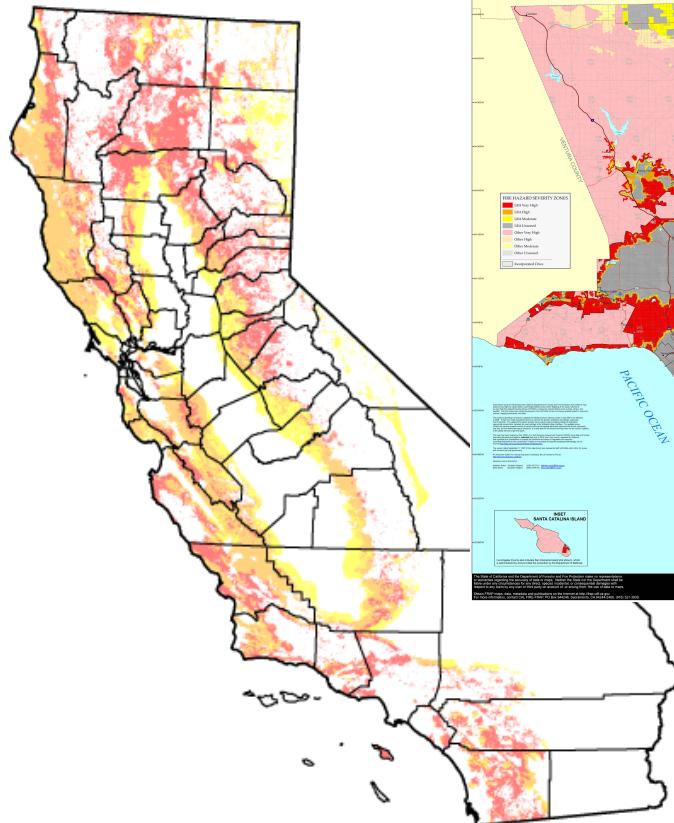
WILDFIRE COSTS IN THE US ARE SIGNIFICANT AND GROWING

- 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]

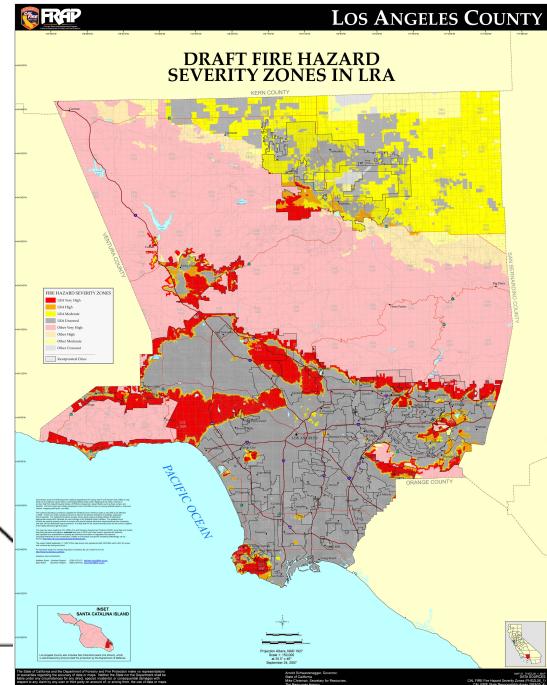


CALIFORNIA IS ESPECIALLY VULNERABLE

- 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



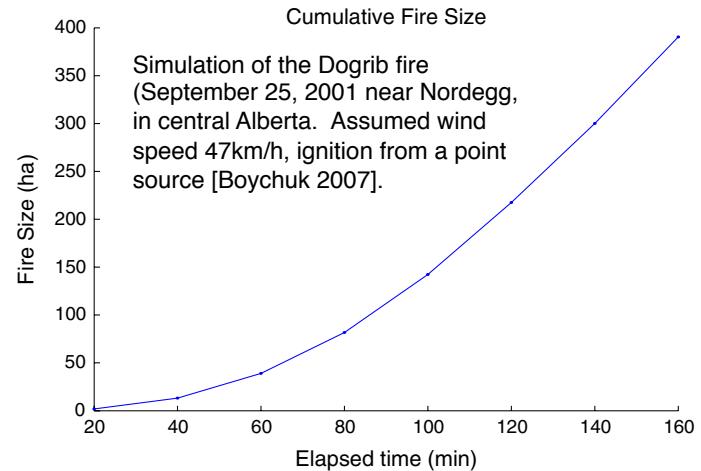
Fire Hazard Zones. Source: CAL FIRE



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]



REQUIREMENTS FOR SATELLITE EARLY WARNING SYSTEMS

- 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]

Satellite detection network “requirements”	
(Lyman et al., G7 CEOS Disaster Mgmt. Support Group, 2002)	
Repeat time	15 min
Ultimate detection time	5 min
Spatial resolution	250m
False positive rate	5%
Data transmission	real time

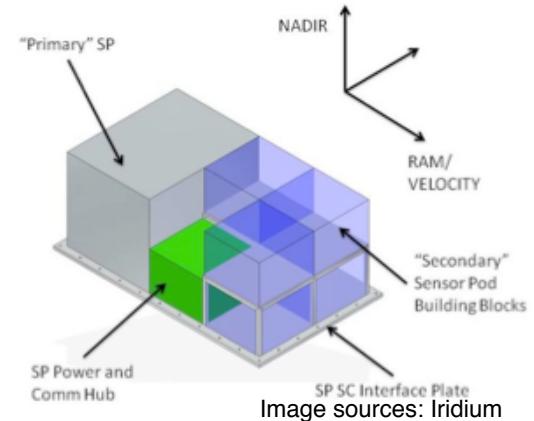
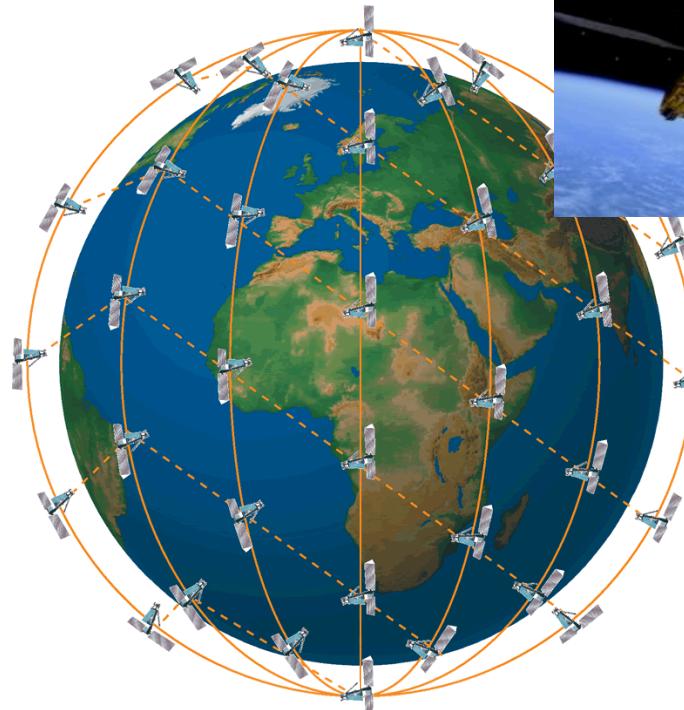
Table VI - All Systems, Board Requirements

System	Early Detection	24-Hour	All-Weather	Automated
Ground-Based Visual Cameras	✓	✓	✓	✓
Ground-Based Infrared Cameras	✓	✓	✓	✓
Other Ground-Based Sensor Systems	✓	✓		✓
Manned Aircraft				✓
Unmanned Aircraft				✓
Weather Satellites				✓
DOD/DSP Satellites	✓	✓	✓	✓

Evaluation of existing detection options, from the LA County CEO Report

AN ALTERNATIVE SOLUTION: SATELLITE CONSTELLATIONS

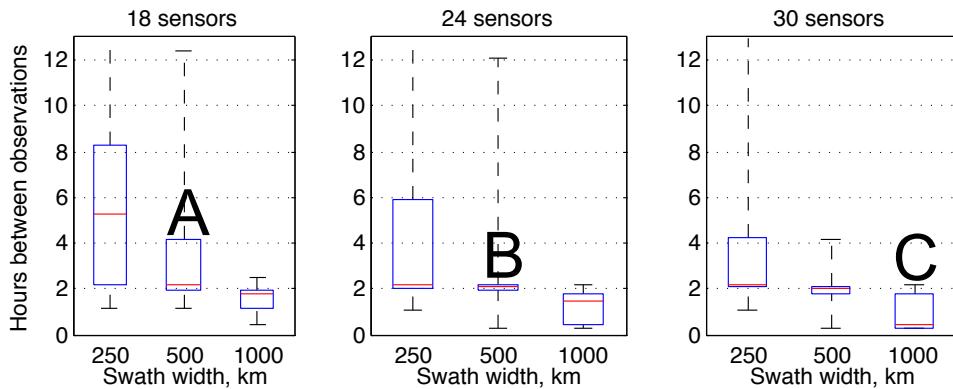
- The Iridium Next network (2015) will host client payloads on up to 66 satellites



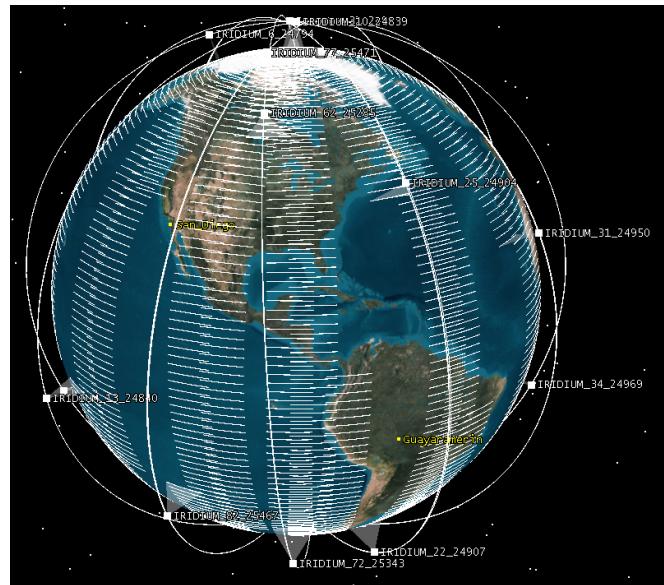
	Primary payload option	“Sensor Pod” payload option
Mass	50kg	5kg
Volume	30x40x70cm	20x20x14cm
Power	50W avg. / 200W peak	5W avg. / 10W peak per block
Data	<1Mbps	10kbps avg. / 100kbps peak

IRIDIUM SYSTEM COMPARISON

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



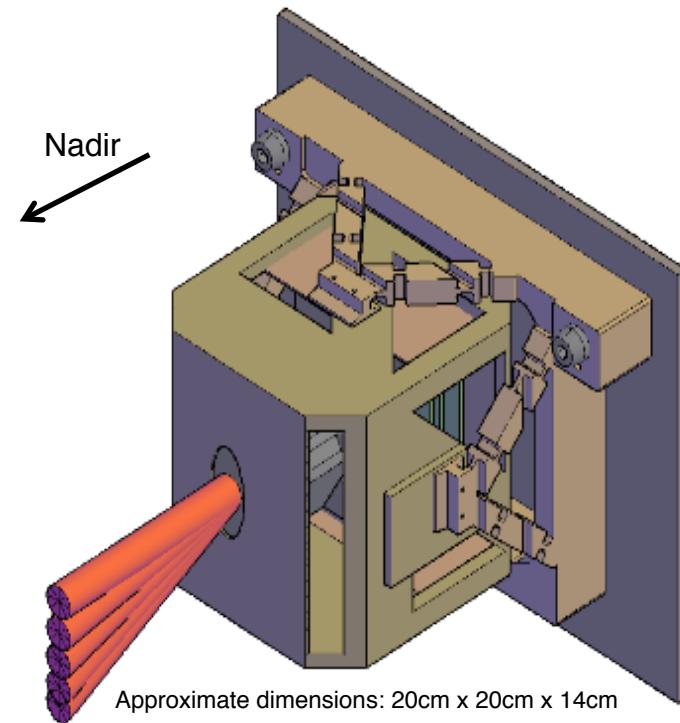
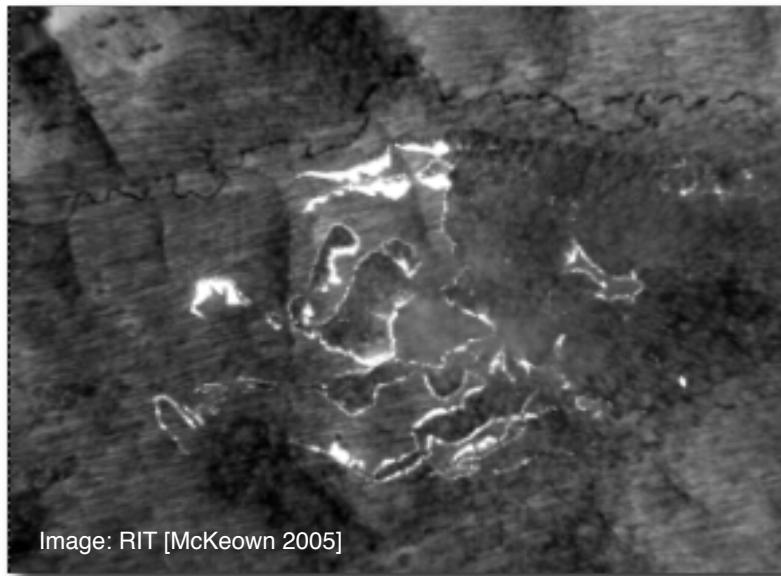
24 sensors, 1000km swath (1 hour coverage)



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

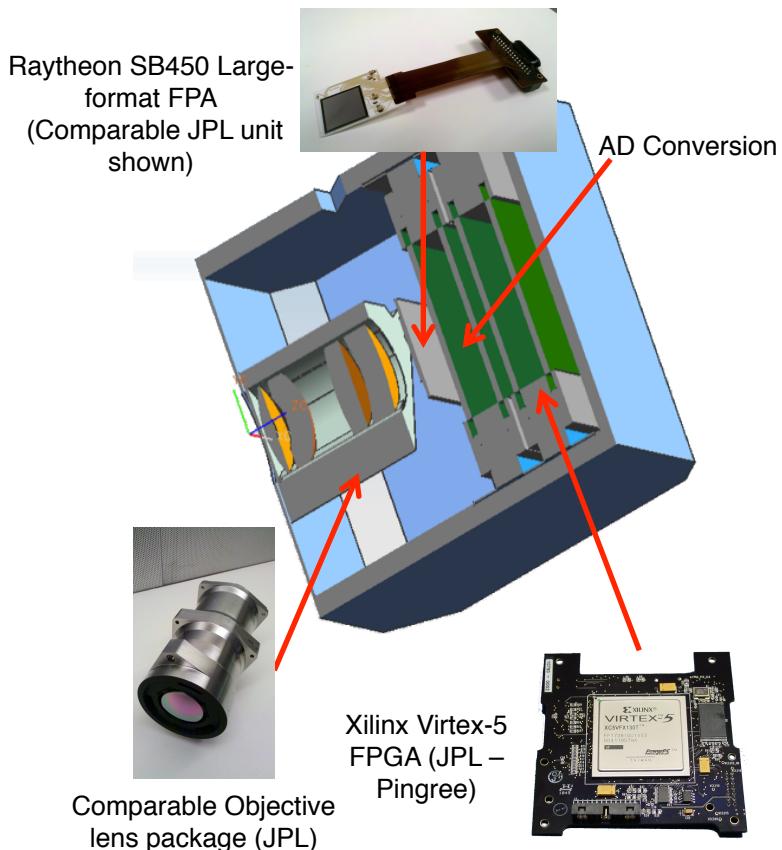
A 4 μ m CAMERA POINT DESIGN

- 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



A 4 μ m CAMERA POINT DESIGN

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



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

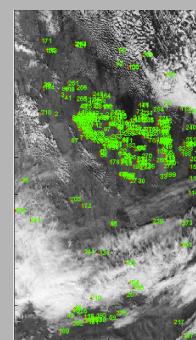
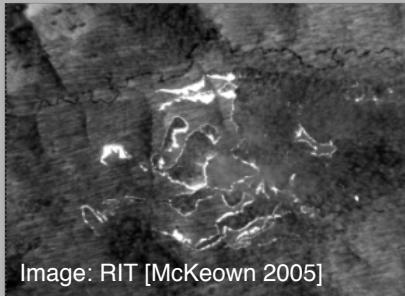
1. Fire detection
in 4um band

2. FPGA processing
finds landmark points
[JPL/Wang 2008, JPL/
Werne 2010]

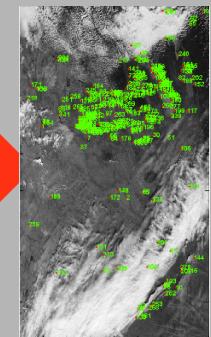
3. Compressed
downlink includes
fire pixel and
landmark locations

4. Landmarks are
matched against an
image database to
find false & repeat
detections

onboard processing



mission operations



OTHER APPLICATIONS

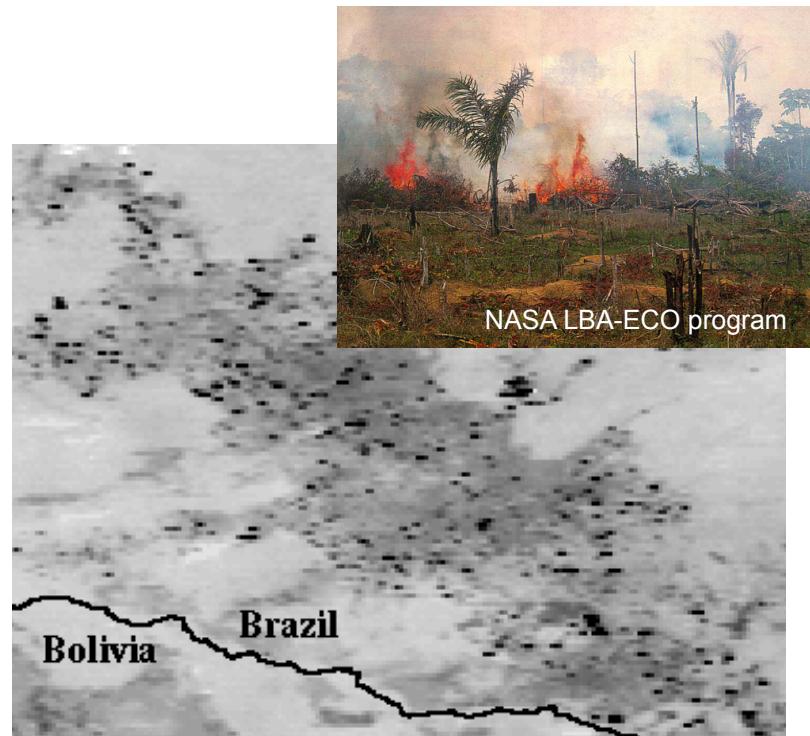
Protection of oil pipelines and other energy assets

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



Enforcement of biomass burning laws and treaties

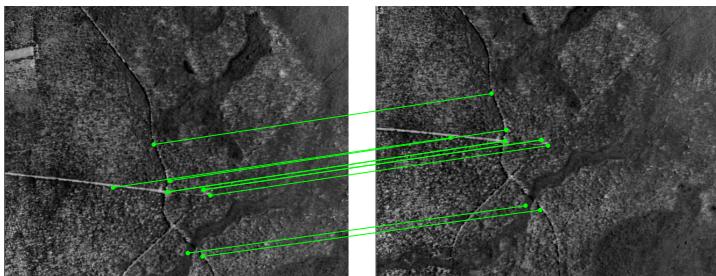
GOES MWIR biomass products show subpixel fires in Western Brazil



MULTIPLE FRAME DETECTION METHOD

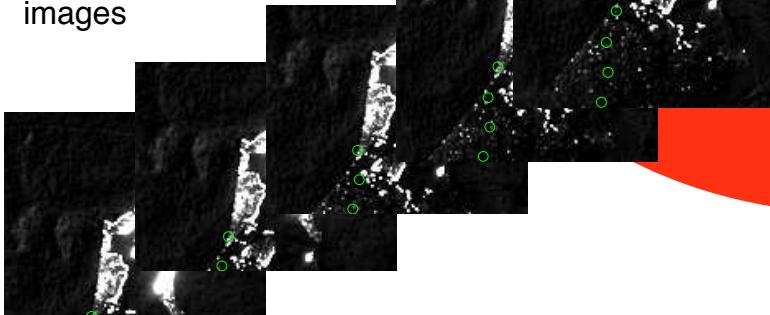
Step 1: Matching

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

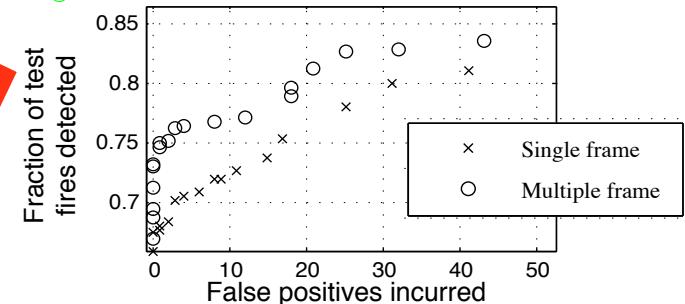
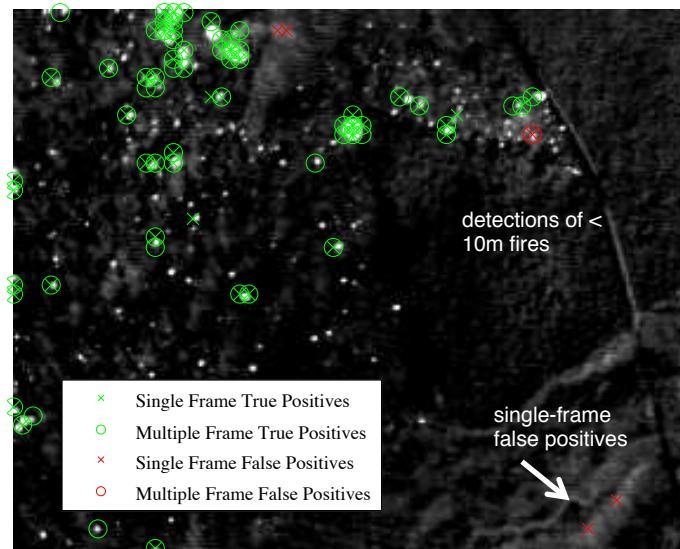
Subpixel detections are tracked across multiple images



Unprocessed Images from the RIT WASP project [McKeown 2005]

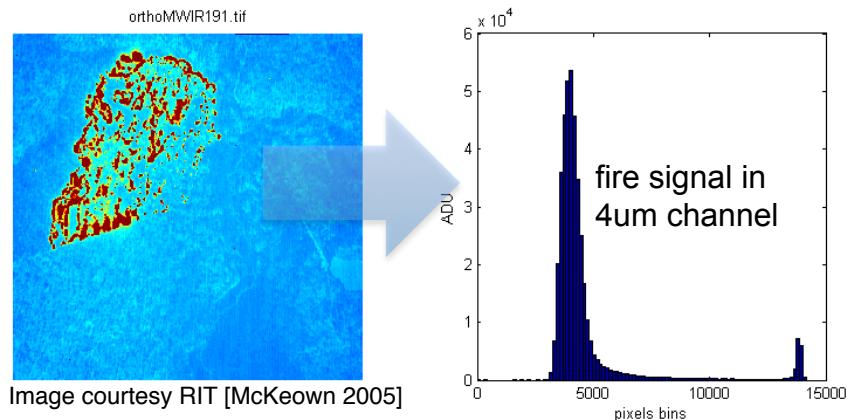
Step 3: Detection

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



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



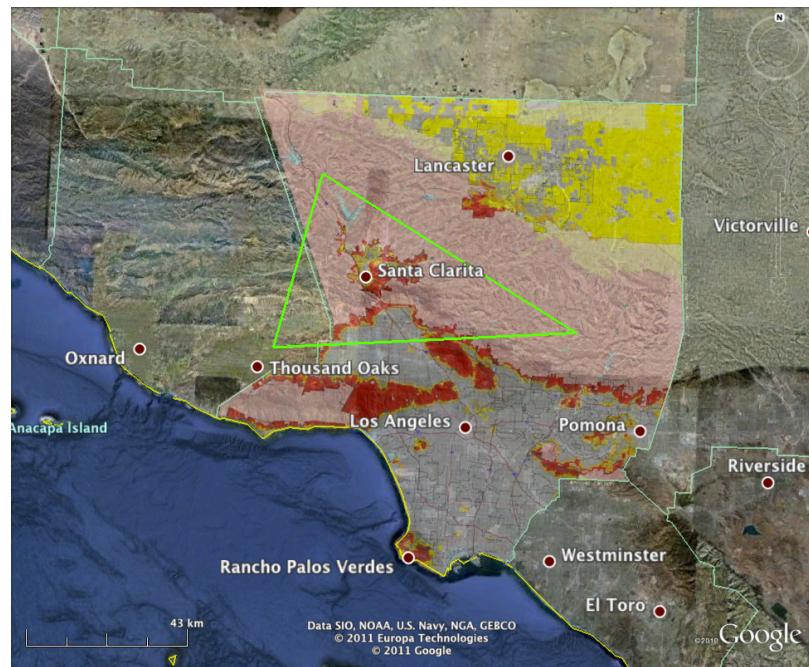
REGIONAL UAV OPTION

- 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



Global Observer. Source: Aerovironment

Aerovironment Global Observer	
Operating altitude	~65000 ft (>18km)
Duration	7 days
Propulsion	Liquid Hydrogen
Observation Swath	12km (53-degree optics)



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