Simulating the Observation of Wildfires with Geostationary Satellite Instruments

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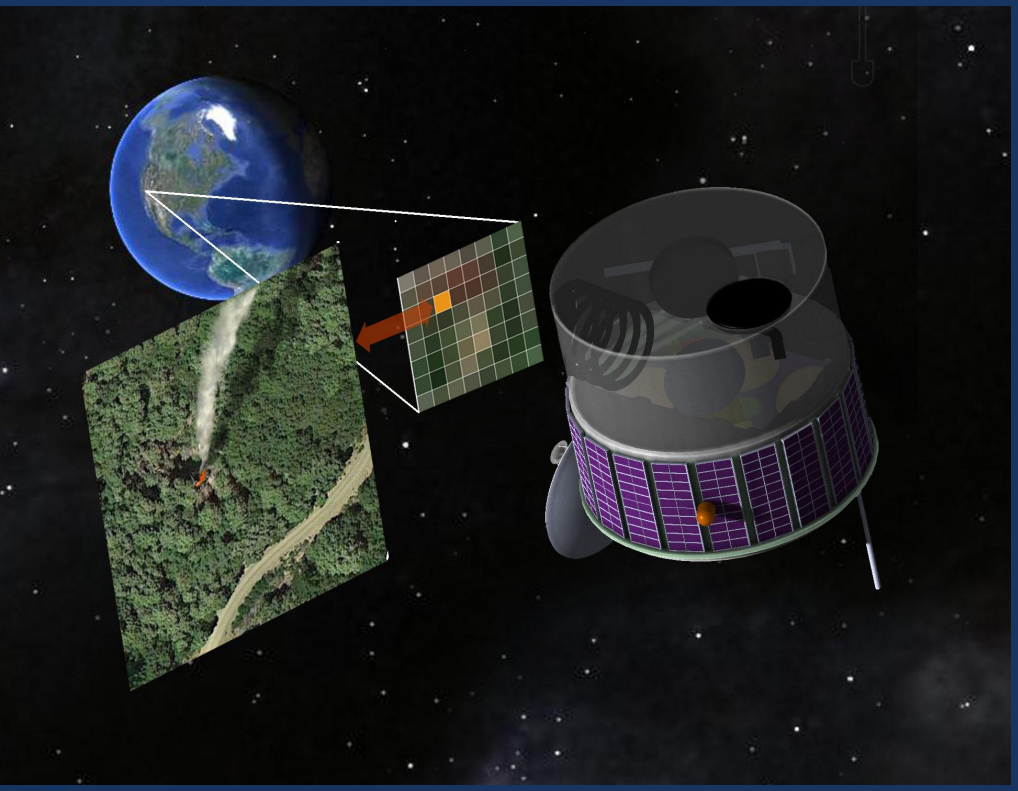
Fire Urgency Estimator from Geostationary Orbit (FUEGO)



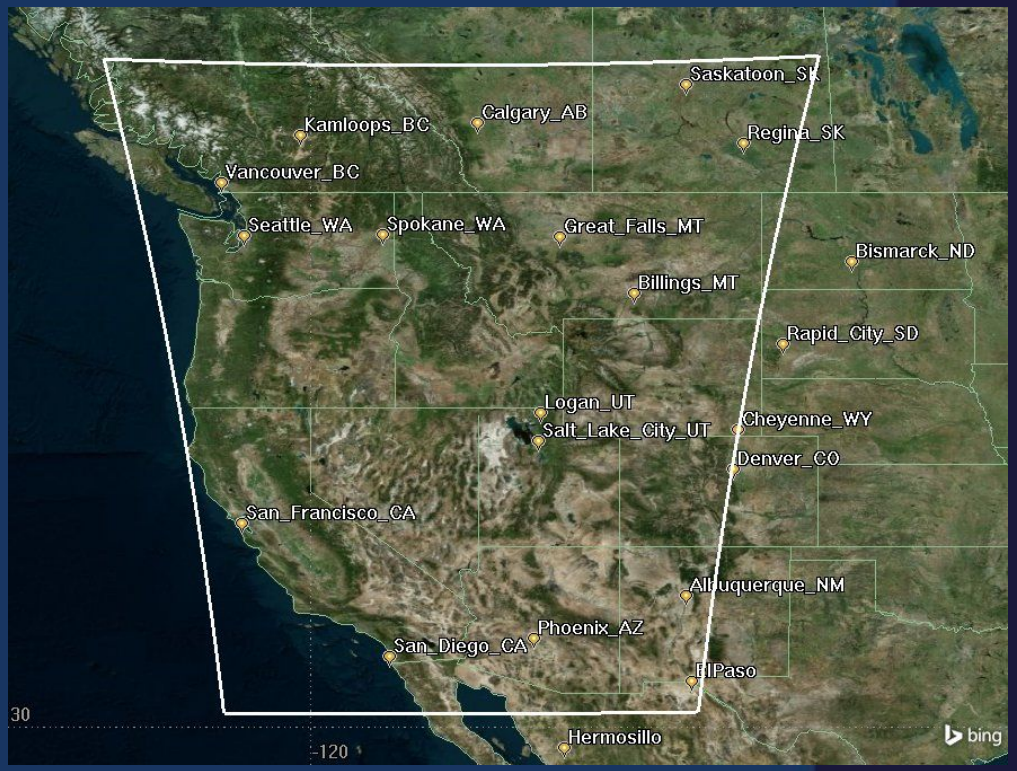
A Geostationary Satellite for Early Detection and Continuous Monitoring of Wildland Fires

- Observe the Western US from space with steering capabilities
- Greatly enhance the response to and early suppression of wildfires.
- Dedicated to wildfire detection / tracking

- Revisit time ~0.5 minute
- Ground sample distance: ~ 300 – 500 m
- VIS, MWIR, LWIR bands

Satellite temporal/spatial resolution

Instrument	Repeat Coverage in US	Nominal Ground Sample Distance [m]	Fire-sensi-tive Band
Landsat 8/9	8 days	30	SWIR
MODIS	1-2 days	1000	MWIR
VIIRS	3-4x day	375	MWIR
		750	MWIR
GOES	5 min	2000	MWIR
FUEGO (planned)	0.5 min	~300 - 500	MWIR



Geostationary 2.5°x2.5° field of view covering the western United States

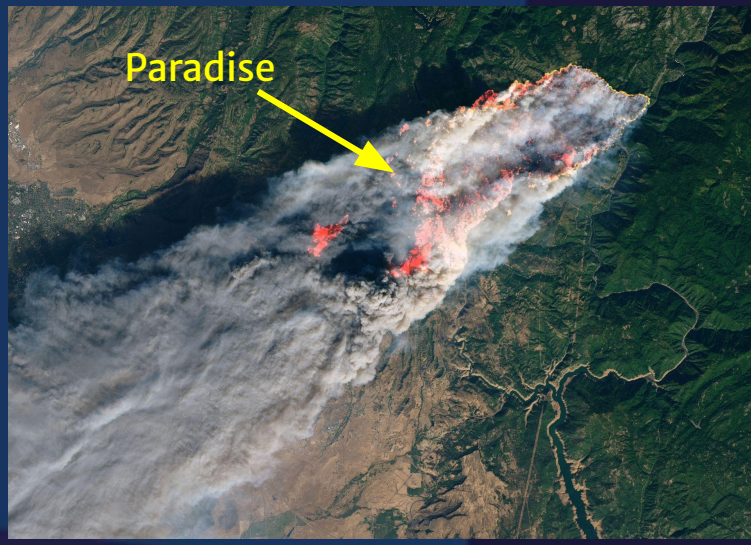
FUEGO ⇨ *higher spatial and temporal resolution* to inform fire agency response on the ground for initial detection and fire spread evolution.

2018 Camp Fire killed 86 people

- First reported at 6:25 am
- Advanced or spotted 7.5 miles within 1.5 hours to Paradise
- "80 football fields per minute"
  https://www.pbs.org/wgbh/frontline/documentary/fire-in-paradise/
- No sufficient warning on residents of Paradise, CA

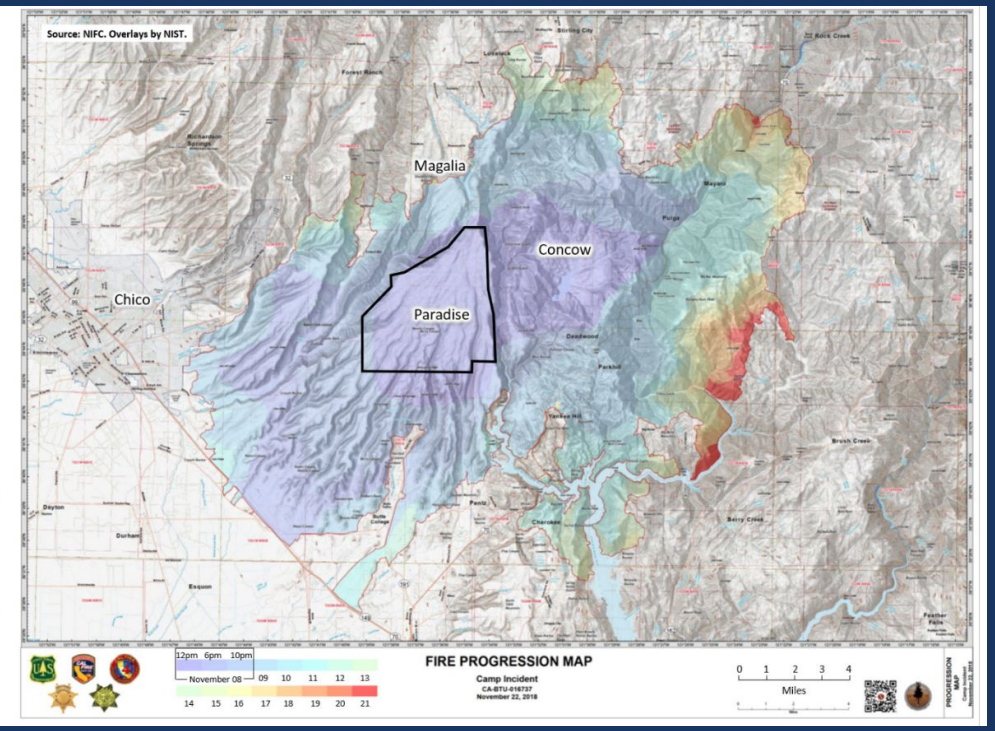
Fire intelligence was challenged

- Fast moving fire with *substantial spotting*
- No flights ⬅️ sustained 35 mph winds
- Inability to see in the midst of fire and smoke
- Inability to report due to immersion in rescue efforts



By NASA, Joshua Stevens - https://earthobservatory.nasa.gov/images/144225/camp-fire-rages-in-california, Public Domain, https://commons.wikimedia.org/w/index.php?curid=74269291

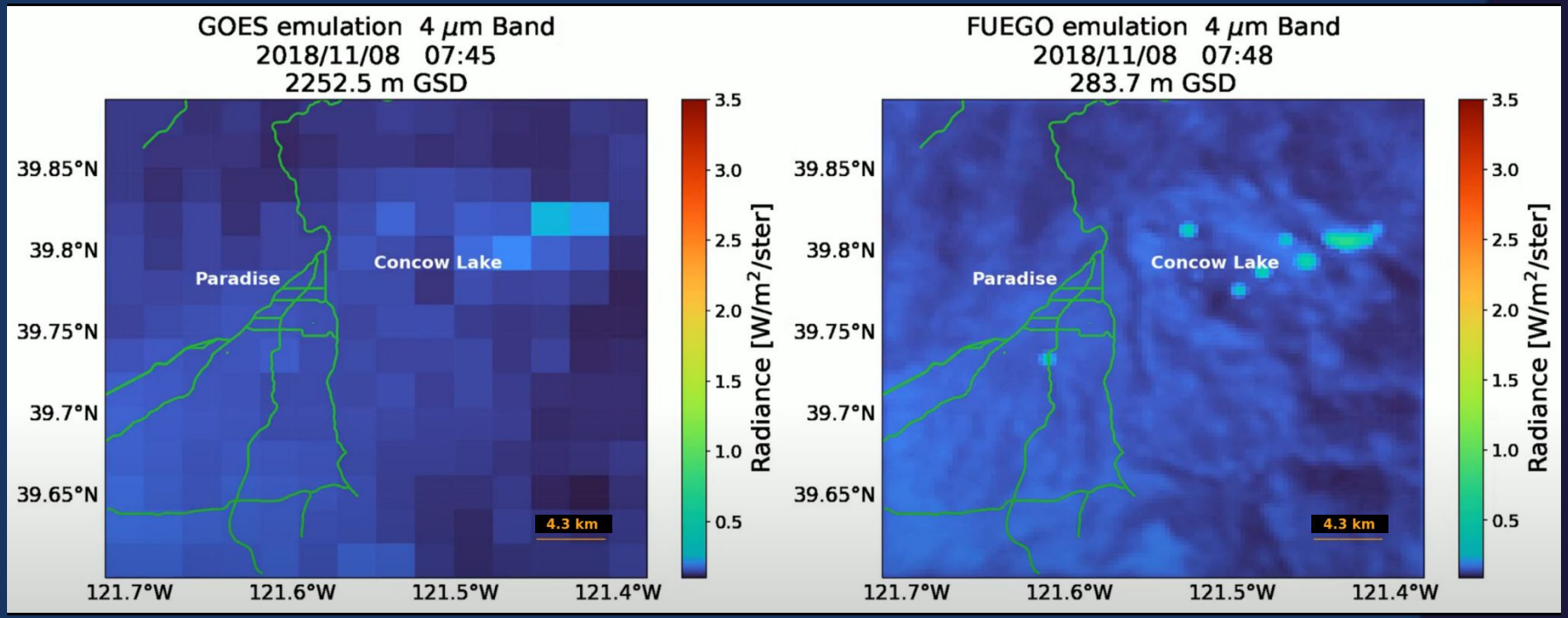
Early Camp Fire 2018 Timeline



Time (PDT)	Notable Observation
06:25	911 call reporting ignition
06:44	Vegetation fire observed under transmission lines. Reports of 35-mile-an-hour sustained wind. Camp Creek Road is nearly inaccessible.
07:10	Report of 300 acre size and heading in the direction towards Concow Lake.
07:25	First structures burning in Concow, 5 km (3 mi) from the origin
07:30	Burning embers sprayed by the wind.
07:21-07:41	Calls to 911 re: evacuation? Without intelligence on fire location, 911 dispatchers told residents to stay put.
07:50	Spot fires had arrived in Paradise
08:30	30 spot fires had occurred

Fire Progression Map and reports from https://doi.org/10.6028/NIST.TN.2135 and https://www.pbs.org/wgbh/frontline/documentary/fire-in-paradise/transcript/

FUEGO could inform community response with higher temporal and spatial resolution



Fire Spot Model Based on NIST reports

Spot locations from Maranghides, A., Link, E., Hawks, S., Wilson, M., Brewer, W., Brown, C., Vihnaneck, B. and Walton, W.D., 2021. A Case Study of the Camp Fire—Fire Progression Timeline, https://doi.org/10.6028/NIST.TN.2135

Demonstration modeling: surface emission

- Emissivity ε and Ts map from ECOSTRESS (~70 m GSD)
  - Paradise, CA region
  - 2022/10/13 16:36:49
  - caveat: ε Band 2 – 8.78 μm , no diurnal Ts modeled
- Model fire temperature and burn area (vegetation / spot fire)
- Model temporal evolution of fire/burn temperature

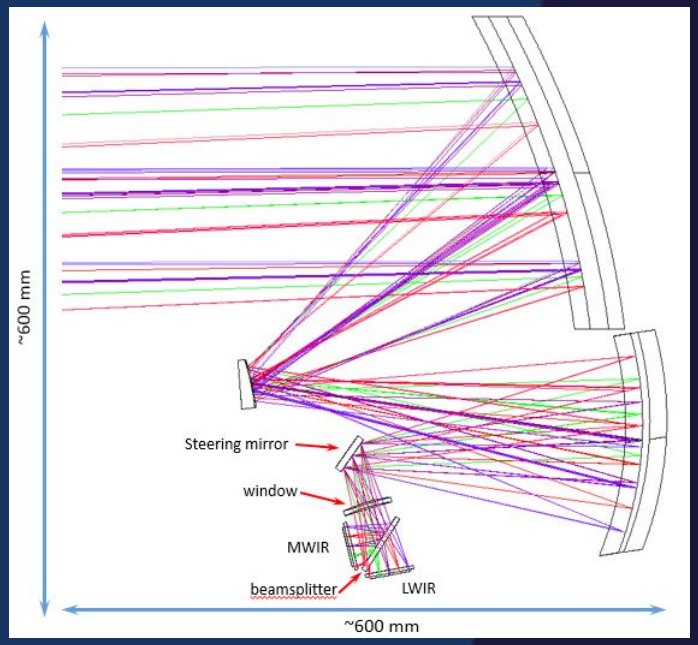
- List of incident reports from NIST.TN.2135.pdf
  https://doi.org/10.6028/NIST.TN.2135
- Unknown fire perimeter, but much were spot fires

Signal modeling at satellites

- Generate in-band flux arriving in pupil at geostationary distance
- Atmospheric effects
  - low PWV profile, clear sky
  - LBLRTM

- Optics transmission
- Convolve with Airy Point Spread Function
- FPA quantum efficiency
- Bin at Focal Plane Array given pixel size
- Integrate
  - 33 ms & 0.4 ms FUEGO
  - 2 ms GOES
- Add shot noise, read out noise , and dark noise
- Radiance unit conversion with optimal dynamic range for FUEGO

Optics Point Design



Sensor sensitivity informs acquisition schedule

Temporal sensitivity tests

- Simulate low/high gain integration times
  - Desire SNR ≥ 25
- HgCdTe (Mercury Cadium Telluride) Focal Plane Array
- Acquisition scheme
  - High dynamic range
  - Avoid saturation
- Data dissemination
  - 30 second data cadence
  - 120 second data latency

Spatial sensitivity tests

- *Centroid error < 50 m*
  - Within 300 m or 500 m pixel
  - Noise & background structure included
  - Fire spots Fire Radiative Power (FRP) ≥ 9.0 MW

Closing Comments

- FUEGO high resolution design
  - Geostationary orbit overlooking Western U.S.
  - ~300-500 m Ground Sample Distance
  - 30 second repeat cycle, 120 second latency

- Simple fire simulation demonstrated value
  - Fire intelligence for Camp Fire 2018
    - Evacuations
    - Direct fire response
  - Model improvements ongoing

- Cooperative intelligence system
  - Multi-altitude sensors
    - ground-based (FUEGOMap)
    - GEO
    - LEO

- Inquiries for possible aerospace industry partners this winter