Smoke Sky: Exploring New Frontiers of Unmanned Aerial Systems for Wildland Fire Science and Applications

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Outline

- Role of Wildfire in the Earth System
- Relevance to JPL
- Current State
- Future State
- Findings
- Recommendations

Role of Fire in the Earth System

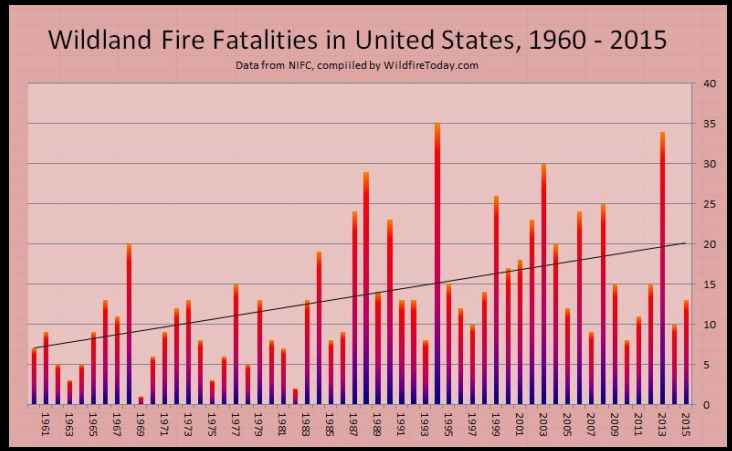
loss of infrastructure and cultural resources

degraded air quality

loss of natural resources

degraded water quality

- Biomass burning plays a key role in biogeochemical cycling
  - A key element of the carbon cycle (e.g.,13-40% of global emissions during 1997 El Niño)
  - The second largest source of trace gases
- Biomass burning has highly uncertain implications on global radiative budgets
  - Largest global source of primary $PM_{2.5}$, but unknown secondary
- Wildfire can have costly sociocultural impacts



Global State of Wildfire

- Area burned declining globally, but growing in some parts of the world
- Increasing fire danger
  - Growing wildland urban interface
  - Longer fire seasons
  - More extreme fire events

Relevance to JPL

- JPL 2025
  - Quest 7: to use JPL unique expertise to serve the nation
    - Loss of life and cost
    - 2018 Omnibus Bill included wildfire disaster (H.R. 2862)
  - Quests 2 and 4: planetary exploration
    - Advance TRL of UAS autonomy (navigation and mapping) in low visibility and highly variable temperatures and winds
- ESAS 2017
  - Fire Science (H4-d: Important)
  - Cost-benefit analyses using drone technologies (p. 6-26)
- Builds on existing investments
  - AI drones for subterranean caves (8x and DARPA)
  - Mars Rover-Copter coordination and navigation
  - AUDREY AI for first responders (3x and DHS)
  - AI vs. man (Google)
  - Barn Owl (Angel Investor) night flying
  - TEFIM
- Strategic Partnerships
  - Australia, Greece, Canada
  - CalTech Center for Autonomous Systems and Technology (CAST)

Current State of UAS Technologies for Fire Science and Management

US Federal land agencies already use UAS technologies for situational awareness when piloted aircrafts are grounded for pilot safety:

- Monthly meetings by the interagency UAS Advisory Group (UASAG)
- Commercial drones and instruments, but require pilots and data managers

Current Limitation	Current Efforts	Opportunity for Advancement
Operating Costs: training and man hours		Autonomy
FAA Restrictions	NASA Ames (privacy)	Autonomy (line of site)
Flight Duration/ UAS Endurance	Commercial Sector	
Affordable, small, multi-rotar UAS	Commercial Sector	
Improved Traffic Collision (w/ other aircraft systems)	Commercial Sector	
Working offline from DJI Network		
Tactical Missions: Cargo transport	CalTech CAST, Uber	
Near Real Time Situational Awareness		NRT Data and Information System
Social Acceptance (privacy concerns)	UASAG	

Future Potential for UAS in Fire Science and Management

		Functionality Needed (Use Case)						
		Autonomy	Distributed Autonomy	Autonomous Sensing	Swarm Mechanics	Data and Information Systems	Hydro Propulsion	Mobile, AI-deployed Infrasound Projectors
Application (utility)	Pre-Fire: Fire Danger Assessment (low)	X	X	X	X	X		
	Active Fire: Situational Awareness (high)	X	X	X	X	X		
	Active Fire: Logistics Transport (high)	X	X	X	X			
	Active Fire: Suppression (low)	X	X	X	X	X	X	X
	Post-Fire: Damage Assessment (high)	X	X	X	X	X		

Findings

- With small to moderate scale investment there is a lot of technology that can be developed for fire management that is synergistic with JPL investments
- Technologies can be developed for single UAS, but the full benefit comes from UAS swarms
- There are a number of domestic and international organizations working to develop technology (and UAS) for fire management, but none offer the expertise that JPL has

*recommended for investment

Use Case	Impact Stakeholder Priority	Maturity Current TRL/ ARL	Feasibility		
			End TRL/ARL (delta TRL/ARL)	Investment Cost ($k)	Potential Funding Sources
*MAV Autonomy over fire	High	2	6 (4)	Moderate	NASA ASP; NASA Planetary Flight; DARPA; ONR; NSF
Distributed MAV Autonomy	High	2	6 (4)	Moderate	
*Autonomous Sensing over fire	High	2	6 (4)	Low	
Swarm Mechanics for fire	Med	2	6 (4)	Moderate	DARPA, ONR, ARMY
Data and Information Systems: Escape Routes	Low	1	4 (3)	Low	NASA ASP; NASA AIST; CalFire; USFS; DHS (e.g., AUDREY)
Data and Information Systems: Person Location (no GPS)	Low	3	6 (3)	Low	
Data and Information Systems: Person Geolocation (GPS)	High	3	7 (4)	Low	
* Data and Information Systems: Active Fire Local Environment Mapping	High	1	4 (3)	Low	
Data and Information Systems: Vegetation Stress	Low	3	6 (3)	Low	
Data and Information Systems: Damage Assessment	High	1	4 (3)	Low	
Hydro Propulsion	Low	2	5 (3)	Low	Private Sector investors (Fire, Oil, Agriculture, Mining, etc.); NIST; USFS
Mobile, AI-deployed Infrasound Projectors	Low	1	3 (2)	Moderate	NASA, ONR, DARPA, ARMY

Recommendations

- Develop single micro-aerial vehicle (MAV) autonomy, autonomous sensing over fire, and the associated data and information system for active fire local environment mapping
- Develop these technologies with CalTech CAST and outside (domestic and international) organizations to ensure utility of the technology for fire science and management applications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