Determination of OB/OD/SF Emission Factors Using Unmanned Aerial Systems

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2017 Global Demilitarization Symposium & Exhibition, 22-25 May 2017, Lancaster, PA

OB/OD/SF

- Open Burning of propellants
- Open Detonation of explosives
- Static Firing of rockets

OB/OD/SF is employed for hazardous materials, manufacturing wastes, and off-specification ordnance where recycling, neutralization, and enclosed destruction pose too great a risk to the personnel handling the material and the processing equipment.

Emission Factors

EF = mass of a pollutant emitted/initial mass of ordnance

- Used for operating permit limits on demilitarization processes
- Historically have been determined by extrapolation from small scale BangBox tests and limited airplane plume sampling
- The representativeness and costs of these methods have been issues.
- Often there are simply no direct data upon which to base operational limits.

DoD Efforts since 2010

- Strategic Environmental Research and Development Program (SERDP)
  - With Defense Ammunition Center, funded a 3-year program with EPA's ORD, Army Corps of Engineers for testing at Tooele Ammunition Depot
- Department of National Defence (Canada)
  - With Joint Munition Command (JMC), funded an emission study at Camp Dundurn, Saskatchawan.
- Environmental Security Technology Certification Program (ESTCP)
  - Funded an emissions/deposition study with Army Cold Regions Engineering Laboratory
- Radford Army Ammunition Plant (AAP)
  - Funded an emission study of open burning
- JMC
  - Funded an emission study of open burning at McAlester Army Ammunition Plant

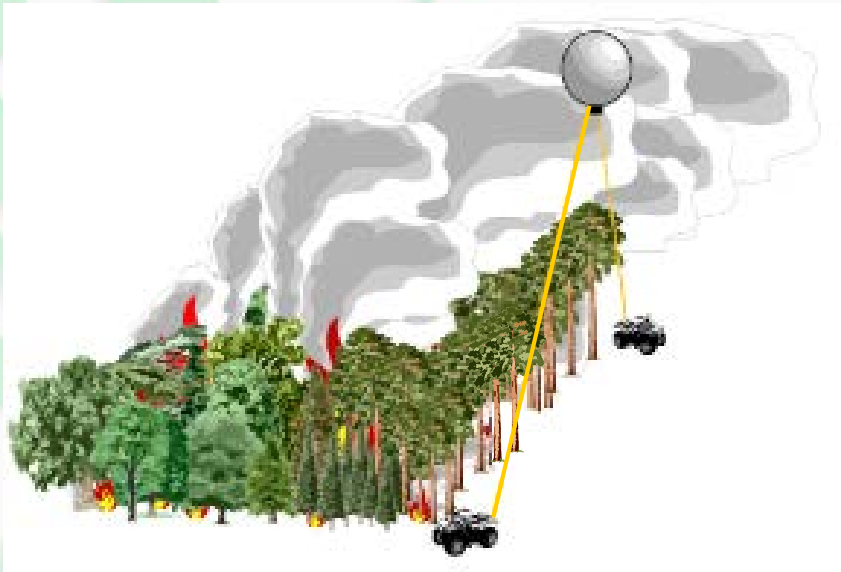
The Issues

How do we efficiently and safely sample these plumes?

- Getting into the plume
- Finding the plume
- Fully measuring every pollutant of interest
- Ensuring sample quality:
  - Sufficient sample to avoid non-detects,
  - Representative sample
  - Repeatable results
- Frag hazard for people and equipment
- Thermal hazard for equipment

An Unmanned, Aerostat Carrying a Novel Instrumentation System

The EPA "Flyer": An unmanned, telemetry-controlled sampling system.



The Aerostat/Flyer Applied to OB/OD at Tooele Army Ammunition Depot

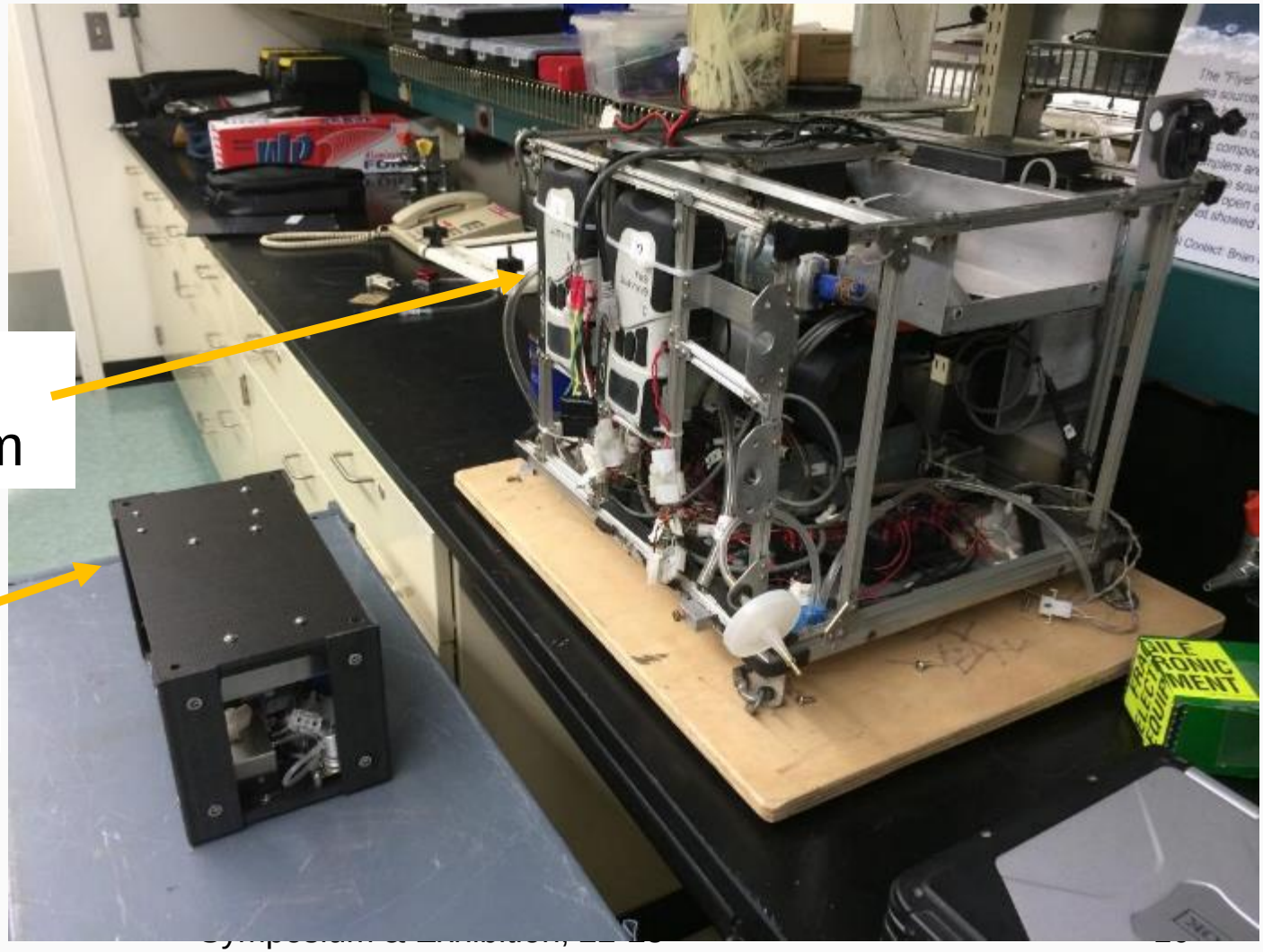
OB (27 S) AND OD (30 S) MOVIES, ON L DRIVE, FLYER PRESENTATIONS, AWMA PRESENTATION SUBFOLDER

Limits on Aerostat/Flyer Method

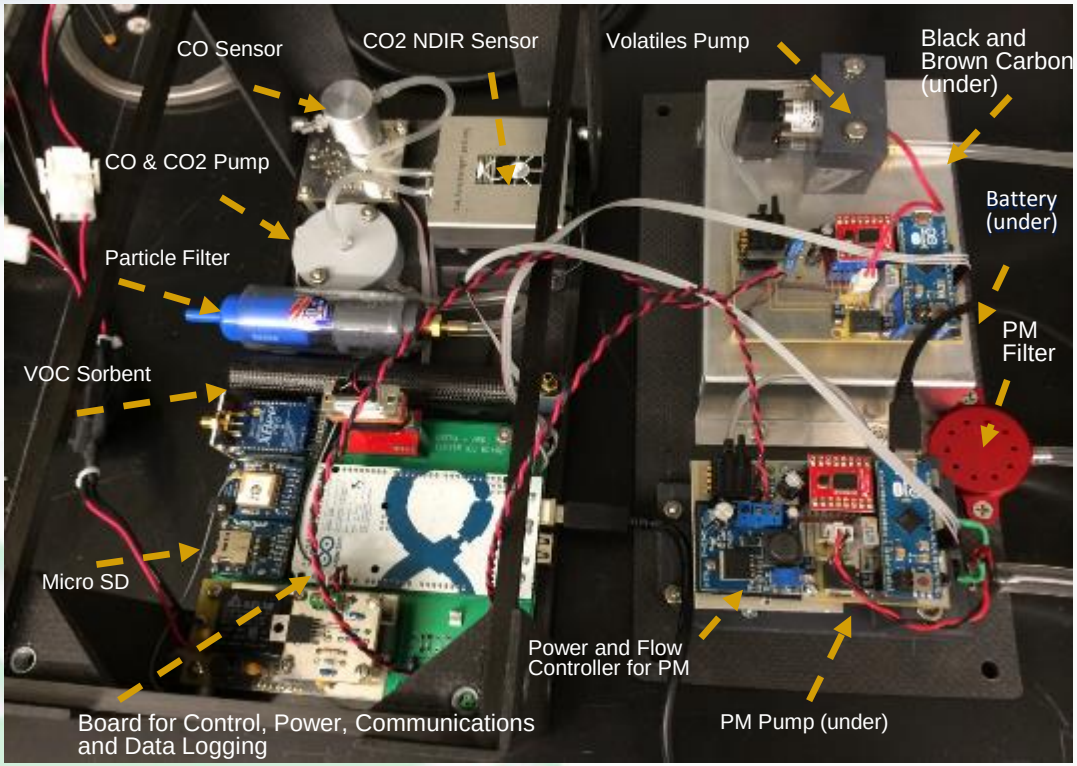
Tethered aerostat/Flyer sampling has worked well in measuring OB/OD/SF emission factors, but has constraints:

- Maneuverability.
  - Tethers (trees, power lines)
  - Need 1 or 2 winch-mounted ATVs
  - Limited 3D range (wind shifts, plume drift)
  - Terrain and boundary limits
- Resource requirements.
  - Large team
  - Large equipment (and helium)
  - Cost
- Balloons don’t like holes

Development of a Smaller, Lighter Sampler



The “Kolibri”: A Lightweight, Small Sensor/Sampler



The Kolibri is 3.56 kg and can measure

- CO2
- CO
- PM (all sizes)
- metals, ions
- Volatile organics, carbonyls
- Black Carbon, Brown Carbon
- PAHs, PCDDs/PCDFs,
- Energetics, nitroaromatics
- Cl, perchlorate
- Cr(VI)

The Kolibri attaches to an Unmanned Aerial System (UAS, aka “drone”).

NASA-owned and flown UAS hexacopter

UAS/Kolibri sampling OB plume at Radford AAP

RADFORD GOPRO OB MOVIE

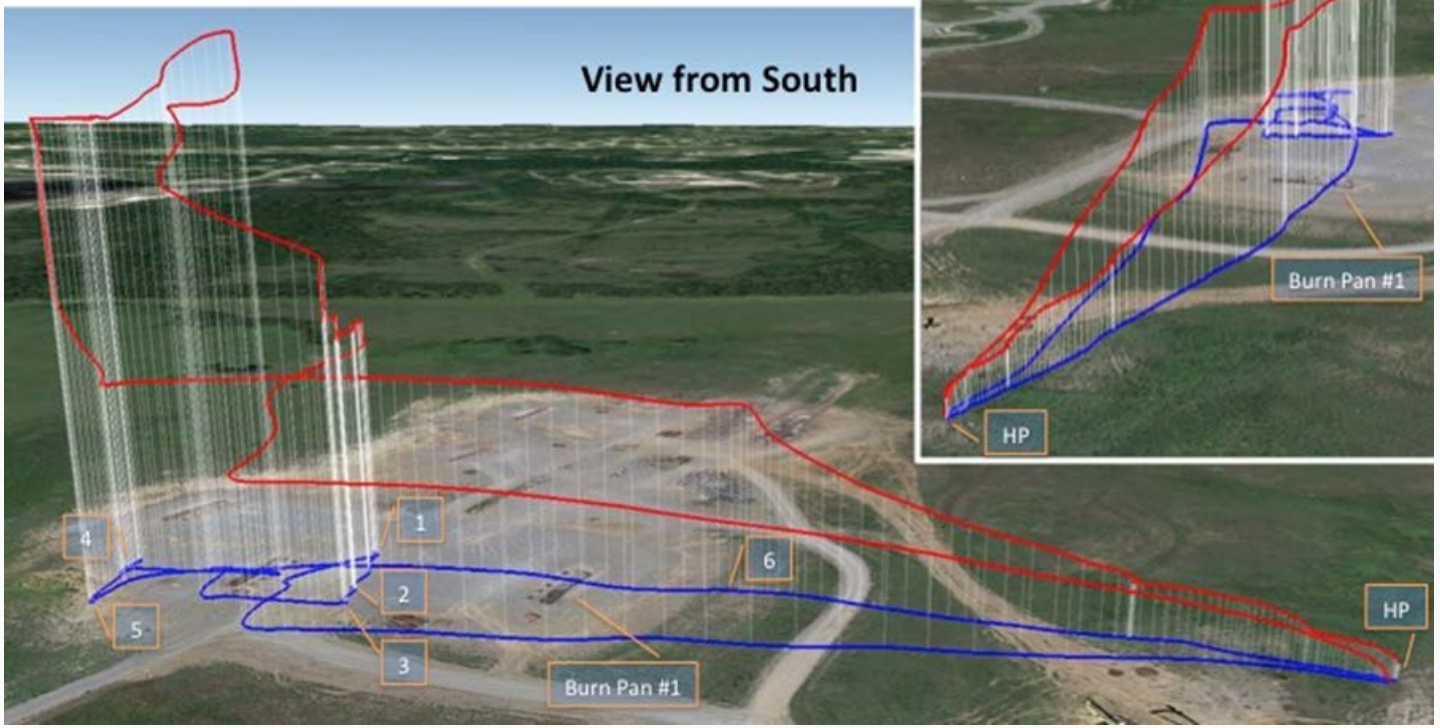
UASs

- Advances in GPS, carbon fiber, computer, and battery technologies have led to UAS development, particularly for multicopters.
- They are varied in size and capability; some as small as a dollar bill.
- They are operator controlled or fly programmed paths
- They have auto-return, boundary, and auto-land features
- Personnel are safely at a distance
- Recent designs can carry payloads of 5 kg for 15-20 minutes.
- They are portable (fold up) and fast to deploy
- They do not have a disturbance footprint
- Require only two people
- Costs range from $50 - $20K

What we've accomplished

Path of NASA's UAS/Kolibri During Open Burn Sampling at McAAP

Mark [#]	Time [mm:ss]	Distance [m]	Height [m]	Battery [%]
1	00:30	187	36	96
2	01:00	179	41	94
3	01:30	177	56	92
4	02:00	231	80	90
5	02:30	227	61	88
6	03:00	112	30	86



MCALESTER SONY GROUND-BASED OB MOVIE

Results

- First-ever plume measurements of PM2.5
- First-ever measurements on covered OD
- First-ever measurements of SF
- Metal partitioning to air vs ash
- No nitroaromatic or nitrocellulose detection
- Most comprehensive UAS-based pollutant measurements

Future

- UAS/Kolibri sampling at Tooele AAD
  - Static Firing, rocket motors (August 2017)
  - Open Detonation, covered (April 2018)
- New Instruments
  - Gimbal-mounted, high density camera on UAS
  - IR, hyperspectral measurements
  - Time-, size- and GPS-resolved PM measurements
- The ORD/NASA team is available for future partnering arrangements

Publications

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Special thanks to our hosts and the team!