Low-Frequency Sound from Explosive Sources

MTV Workshop, 2021

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Introduction, Motivation, Relevance

TA3. Nuclear Explosion Monitoring
Explosion monitoring and forensic analysis are traditionally relevant mission across DOE, DOD, and other US and international agencies (e.g. CTBTO).

TA3.1. Infrasound
• Address diversity of emplacement conditions and delivery systems for low, high, and nuclear explosives.
• Apply new blast pulse scaling and parametrization to near-surface and airborne stationary, subsonic, supersonic, and hypersonic explosive sources.

Ph.D. Students on Infrasound Thrust
• Kei Takazawa, Jonathan Tobin, Sarah Popenhagen, Yusuke Hatanaka

Lab Collaborations
• INL: David Chichester, Edna Cardenas, Scott Watson.
• LLNL: Keehoon Kim, Steven Magana-Zook.
• NNSS: Cleat Zeiler, Kale McLin.
• SNL: Daniel Bowman.
Blasts: from kilotons to kilograms

Modernize geophysical sensing systems and methods that can be deployed globally to effectively monitor explosive events and fuel cycle activity.

Tumbler Snapper
(LLNL YouTube Channel)

High Explosive NE Proxies at NNSS & INL

SpaceX Falcon 9 Rapid Scheduled Disassembly at Mach ~2 (supersonic)

Supersonic Propellant Blast Proxy

Smartphone data

UTC 2020/01/19

Launch and photo by D. Bowman.

http://redvox.io/@/a3a8

Airborne Collection Platforms
Ongoing Laboratory Collaborations

- LLNL blast pulse R&D, continuation and maturation from CVT.
- SNL airborne platforms collection of NNSS blasts. Smartphone collection and analysis.
- Supersonic and hypersonic signatures (shocks). Smartphone collection and analysis.
Technical Approach

Collect, Analyze, Develop, Publish


• Takazawa S., M. A. Garcés et al. (2021, in progress). Constant-Q Frequency Bands for Spectral Representations of Explosions Recorded on Smartphones for Machine Learning Application (WIP)


UH Student Posters (this meeting)

• Takazawa, S., M. Garcés, K. Kim, **Explosion Yield Estimation using Machine Learning Methods**

• Tobin, J., M. Garcés, D. Chichester, J. Hix, Scott Watson, **Inferring UAV Position Relative to Smartphone Sensors Based on Acoustic Characteristics.**

• Popenhagen, S. and M. A. Garcés. **Rocket Ignition Detection Using Data Collected by Smartphones.**
2020 Collection Highlights: INL Blasts and UAV

• Excellent collaboration and tech transfer cycle
• More collections anticipated in 2021 with new apps (FY21Q3)
• Papers and presentations in progress
• Nashville at MINOS net
2020 Collection Highlights: NNSS and SNL

- Airborne platforms recordings of surface blast: Samsung S10
2020 Collection Highlights: NNSS and SNL

- Airborne platforms recordings of surface blast: Samsung S10
2020 Collection Highlights: Skyfall

- Stratospheric (30km) drop test of Samsung S10

Hypersonic shocks

• Start with acoustic parameters from formulations for hypersonic meteor impacts
• Hypersonic: Mach = v/c > 5
• Earth’s speed: 30 km/s (~Mach 100)
• Leonids speed: 72 km/s (~Mach 200)
• Mean specs for meteor impacts with Earth:
  ➢ Diameter: 2 x 10^{-2} cm
  ➢ Mass: 10 micrograms
  ➢ Impact rate: 10^8/day
  ➢ Deposition rate: 10^5 tons/year

8 hours
Exotic Hypersonics

- Axion Quark Nuggets (AQN) are candidates for dark matter.
- They are dense (tiny neutron stars)
- It has been postulated that AQN antimatter annihilation on impact with Earth can generate acoustic and seismic signals.
- Predicted atmospheric acoustic parameters are derived from formulations related to those of hypersonic meteor impacts.
- Estimated infrasonic frequency of 5 Hz and overpressure of 0.3 Pa for large (B=10^{27}), infrequent dark matter nuggets are within present-day sensor specs.
- Proverbial needle in the haystack.

Many thanks to John Learned!

Key specs for spaceborne Earth impacts:
- AQN Baryon number (B): 3 x 10^{24} - 10^{28}
- AQN Spectrum: (10-50) keV (beyond 1-10 eV optical)
- Expected values:
  - AQN size, mass, B: 10^{-5} cm, 10 g, 10^{25}
  - AQN impact rate: 1/day/(100km x 100km)
  - AQN deposition rate: 5 x 10^2 tons/year
  - Meteor size, mass: 2 x 10^{-2} cm, 10 microg
  - Meteor impact rate: 10^8/day
  - Meteor deposition rate: 10^5 tons/year
Impact and Conclusions

• Advancing explosion monitoring mission.
• Addressing emerging WMD delivery systems.
• Facilitating agile collections.
• Internships, workshops, cross-disciplinary collaborations.
• Tech transfer: due to pandemic, all collections were performed by Lab personnel.
• Coordination with DOE, DOD and other Federal agencies (e.g. Nashville blast).
Next Steps: From statement of work

• **Y1:** Build and validate generalized signal-specific models and methods using transportable, scalable metrics (Garces, 2020; Schnurr et al., 2020)

• **Y2:** Integrate traditional and mobile smartphone networks for localization of stationary signals (Ongoing)

• **Y3:** Expand network detection, localization and characterization to moving sources (Initiated)

• **Y4:** Expand network detection, localization, and characterization to moving sources and moving sensor networks (e.g. balloon and ocean glider systems)

• **Y5:** Fuse physics and information theory principles to expedite rapid source identification at regional and global scales from heterogeneous sensor network data
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