Infrasound from rocket launches and reentries observed at the IMS

Christoph Pilger, Patrick Hupe, Peter Gaebler

Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany

INTRODUCTION AND MAIN RESULTS

An increasing number of rockets per year are launched for space missions worldwide. Infrasound from these launches, but also from the atmospheric reentry of man-made objects, is regularly detected by infrasound arrays of the IMS.

The investigation of these events provides information on the IMS detection capability. Furthermore this supports estimation of the source characteristics as well as the signal propagation of these atmospheric, explosion-like sources.

SnT 2025 — 8 SEPTEMBER ONLINE DAY — 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE

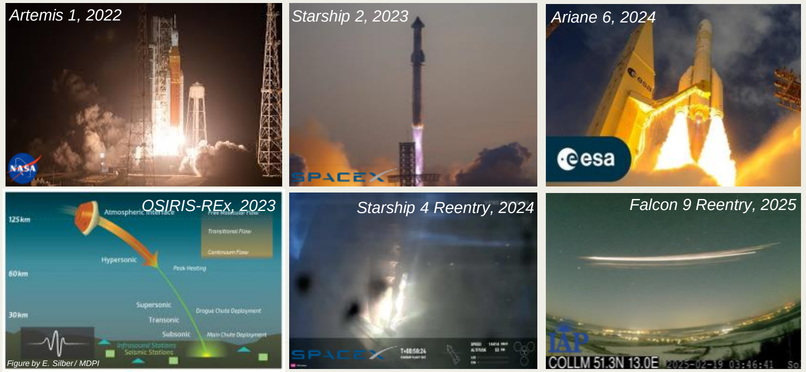
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Infrasound from rocket launches and reentries observed at the IMS

Christoph Pilger, Patrick Hupe, Peter Gaebler

P2.1-548

Special Rocket Launch and Reentry Events



The infrasonic signature of rocket launches for space missions and reentries of space vessels or debris are investigated using infrasound arrays of the IMS.

Highlights are some of the strongest rocket launches of recent years, detected at five to eleven IMS stations and at distances of thousands of kilometers. These rockets with enormous thrusts generate infrasound signals from their ignition, supersonic movement, explosive failure or reentry in the atmosphere.

Since location and trajectory are mostly well known, these ground-truth sources with signatures similar to those of atmospheric explosions, are valuable objects of study in the context of Nuclear Test Ban monitoring.

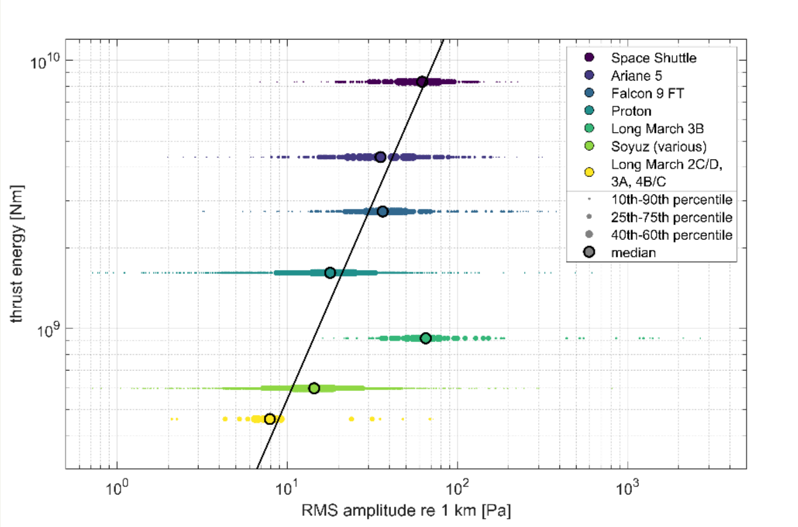
Pilger, C., Hupe, P., Gaebler, P., Ceranna, L., 2021, Geophysical Research Letters, 1001 Rocket Launches for Space Missions and Their Infrasonic Signature, doi: 10.1029/2020GL092262.

Previous Study: 1001 Rocket Launches

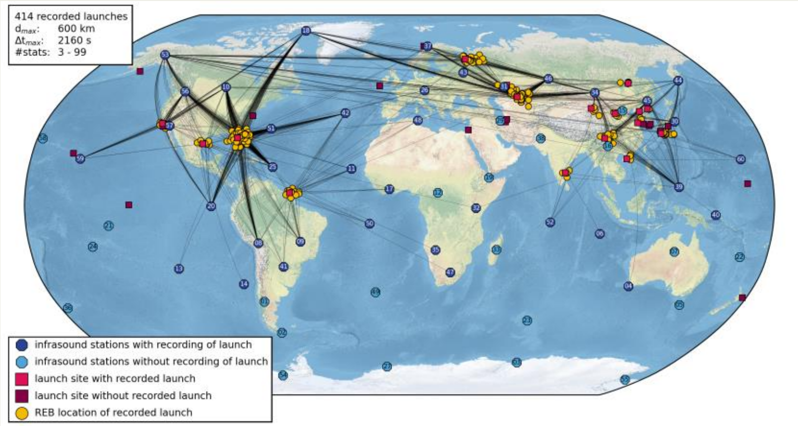
Pilger et al., 2021 systematically investigated the detection capability of the IMS regarding 1001 rocket launches for space missions from 2009 to mid 2020.

The investigation included launches from 27 spaceports, using 76 different rocket types, and signal detections associated to these rockets at one or more infrasound stations were made in 73% of the cases.

An empirical relation between rocket thrust energy and acoustic amplitude was derived from the dataset that provided a first estimate of the expected acoustic signal solely depending on rocket specifications.



Upcoming Study: >2000 Rocket Launches



A follow-up study with five more years of rocket launches until mid 2025 and more than 1001 additional events, featuring further world-wide spaceports and also novel rocket types, is currently under preparation.

A first screening of IDC's Reviewed Event Bulletins (REB) reveals that more than 20% of these launches have been detected by three or more infrasound arrays.

This means that rocket launches are an increasing source of infrasound noise and analyst work on the one hand, but also a wealth of ground-truth, explosion-like infrasound signals for further civil and scientific studies on the other hand.

BGR Federal Institute for Geosciences and Natural Resources

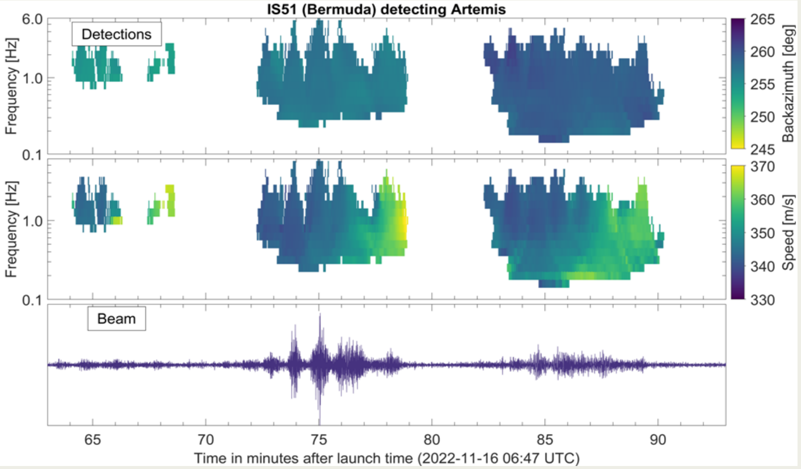
SnT 2025
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Infrasound from rocket launches and reentries observed at the IMS

Christoph Pilger, Patrick Hupe, Peter Gaebler

P2.1-548

Artemis 1 (Space Launch System), 2022



Infrasound from the launch of NASA's Artemis 1 Moon mission using the Space Launch System in 2022 was investigated by **Pilger and Hupe, 2024**.

Clear signals from the rocket liftoff, sonic boom and separation of the boosters were detected at station IS51, amongst others. Pressure pulses from the lift-off in Florida arrive later than those from the flight, since the rocket supersonically moves towards IS51 on Bermuda.

Multi-path propagation of infrasound is observed, where different pressure pulses within the same signal family have different apparent speeds due to different paths.

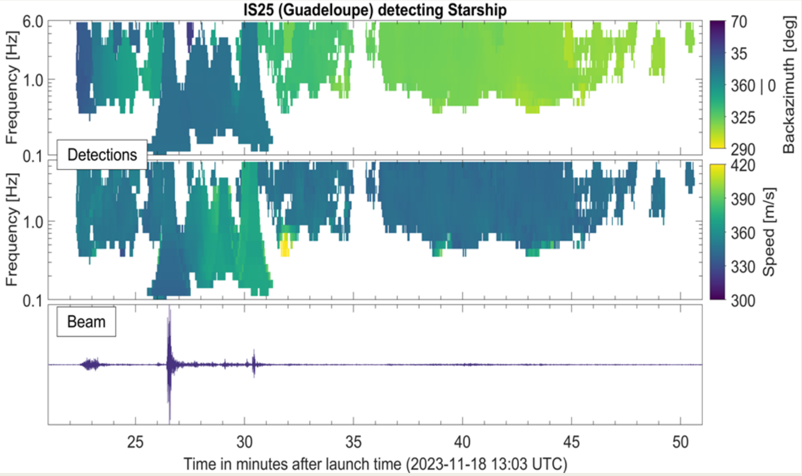
Pilger, C., Hupe, P., 2024, Proceedings on Meetings in Acoustics,
The infrasonic signature of three exceptional rocket launches,
doi: 10.1121/2.0001861.

Starship (Integrated Flight Test 2), 2023

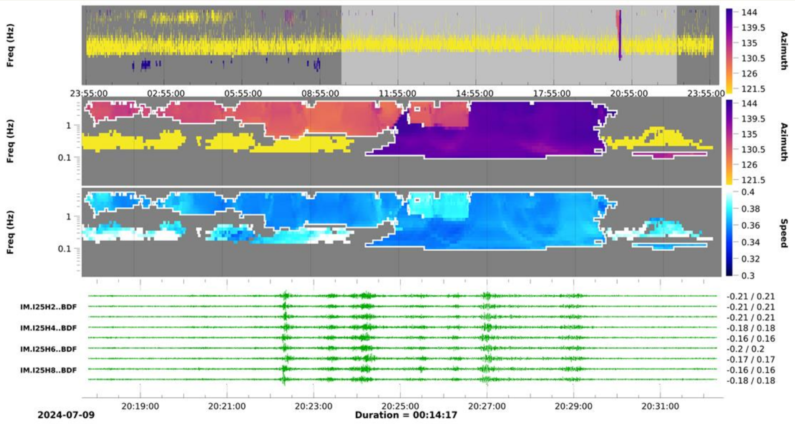
Infrasound from the second flight of SpaceX's Starship in 2023 was also studied by **Pilger and Hupe, 2024**.

The successful liftoff in Texas and eastward movement along its trajectory was recorded by station IS25 on Guadeloupe, amongst others. The rocket flight can be well observed by this station as a moving infrasound source with changing backazimuth directions.

After stage separation at around 90 kilometers altitude, the booster violently exploded and produced a major pressure pulse. The booster signals overlay the signals from the rocket movement and again appear as multi-path signals with different apparent speeds.



Ariane 6 (Maiden Flight), 2024



The maiden flight of ESA's new Ariane 6 rocket in 2024, starting from Kourou, French Guyana, was observed by a number of IMS infrasound arrays, including IS25.

The liftoff and trajectory over the Atlantic Ocean can be identified in the station recordings, discernible by the different azimuth directions. Pressure pulses were observed along multiple atmospheric propagation paths.

Many Ariane 5 launches were also conducted from Kourou in previous years, often recorded by nearby IMS stations. Ariane as well as Proton, Soyuz, Long March and Falcon launches were/are the backbone of space missions of the last decade(s).

BGR Federal Institute for Geosciences and Natural Resources

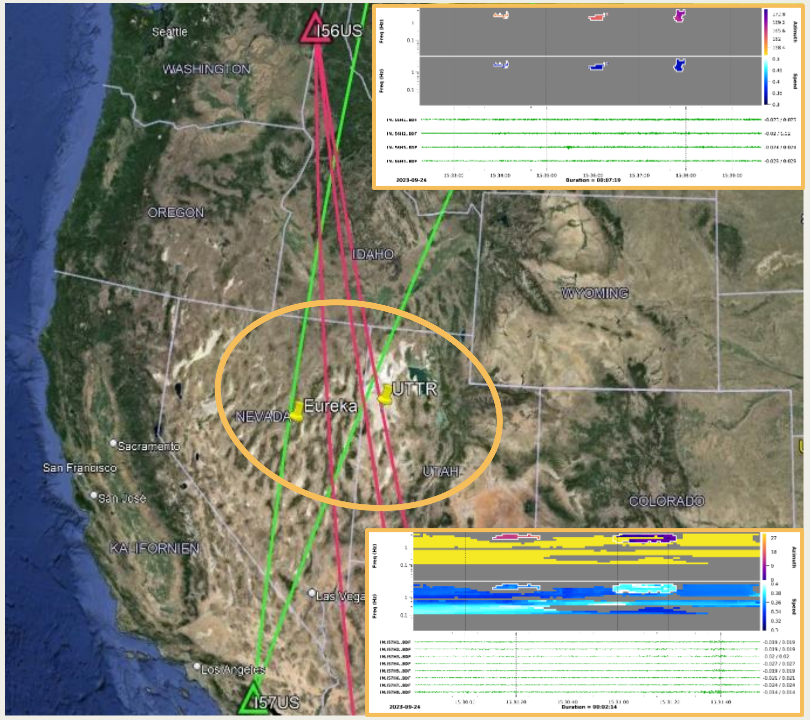
SnT 2025 — 8 SEPTEMBER ONLINE DAY — 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE — CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Infrasound from rocket launches and reentries observed at the IMS

Christoph Pilger, Patrick Hupe, Peter Gaebler

P2.1-548

OSIRIS-Rex Reentry, United States, 2023



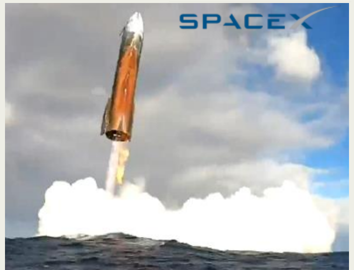
The scheduled reentry of the sample return capsule from asteroid Bennu at Utah Test and Training Range in 2023 was recorded by a large number of instruments temporarily installed nearby for this purpose.

But also two IMS infrasound arrays were able to record remote, weak signals of the reentry, with azimuth, origin time and cross-bearing location fitting quite well.

Starship Reentries, Indian Ocean, 2024(+)

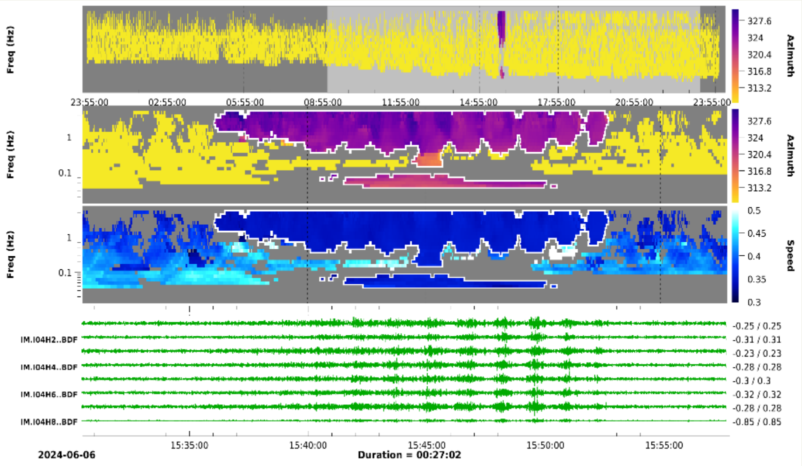
Since 2024 and the third integrated flight test of Starship, the upper stage also performed reentries over the Indian Ocean and aimed at controlled splashdowns.

The fast reentry into the atmosphere as well as the engine firing for deceleration of the starship produces infrasonic signals that can be observed by IMS stations.

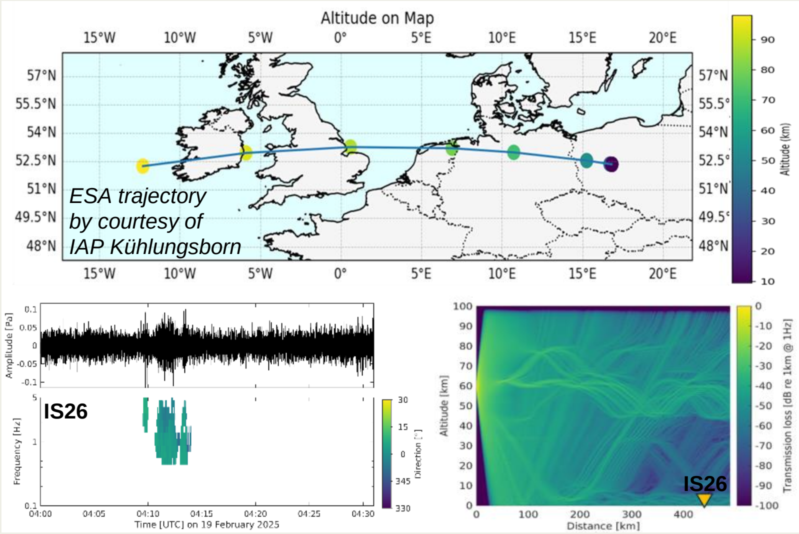


Starship IFT-10 reentry, 27 August 2025

The fourth integrated flight test from June 2024 was identified in the REB with four infrasound stations. Recordings of station IS04 in Australia are shown.



Falcon 9 Reentry, Europe, 2025



A reentry of Falcon 9 rocket debris over Ireland, UK, the Netherlands, Germany and Poland on 19 February 2025, 03:46:41 UTC was observed by multiple national infrasound arrays and IMS station IS26 in Germany.

The reentry trajectory and corresponding infrasound propagation modeling agree well to observations of line-source infrasound by different arrays along the path.

With the increasing number of rocket launches for space missions, the number of either controlled or accidental reentries will likely grow as well, as also probably their detection.

BGR Federal Institute for Geosciences and Natural Resources