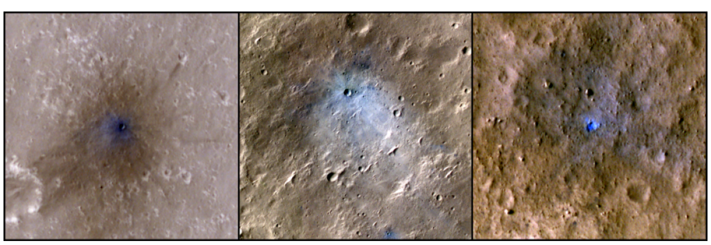
Martian Impacts Seen and Heard

Linking acoustic and seismic signals from meteorite strikes to orbiter images is a step toward mapping the planet's interior.

By **Rachel Berkowitz**

NASA's InSight lander team recently discovered that meteorites crashing down on Mars can produce distinctive sounds in the form of low-frequency "bloops." By combining these bloops with seismic-wave data, the researchers have now identified the corresponding craters in satellite images [**1**]. Further analysis has revealed 1200 recently made craters, providing a toolbox for interpreting Mars' history and internal structure and suggesting that these impacts are more frequent than previously thought [**2**]. Ingrid Daubar from Brown University in Rhode Island presented the findings at the **54th Meeting of the American Astronomical Society's Division for Planetary Sciences** in London, Canada, earlier this month.

The **InSight** lander arrived on Mars in 2018, equipped with a seismometer, pressure sensors, a heat probe, and other geophysical instruments. One of its main goals is to study the interior of Mars by measuring the planet's seismic activity. Much of what we know about Earth's interior comes from measuring how seismic waves propagate from an earthquake at one location to detectors at distant locations. InSight has cataloged over 1000 **marsquakes**, but the amount of information provided by these data is limited because of uncertainty about where the waves originated. Meteorite strikes could offer an alternative source of seismic waves, but they are only recognizable in retrospect by identifying the crater site. One of InSight's seismic tasks is to record these events and verify their location via images of new craters.

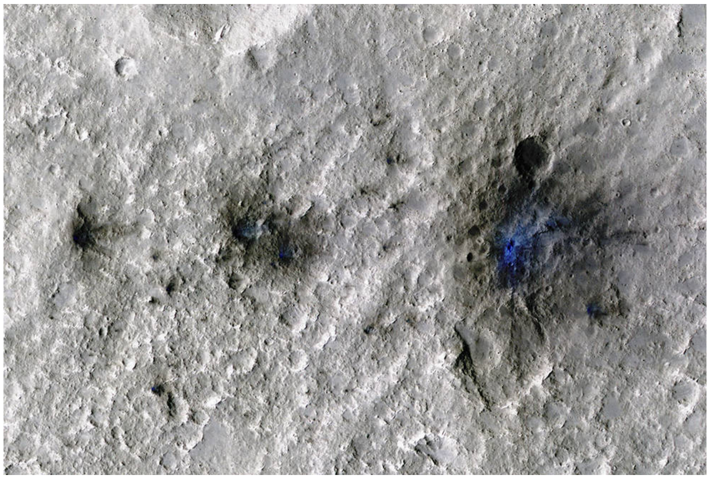


Craters formed by meteorites impacting Mars in 2020 and 2021. Enhanced blue color highlights dust and soil disturbed by the impact.
Credit: NASA; JPL-Caltech; University of Arizona

In September 2021, the InSight pressure sensors picked up a bloop sound, characterized by lower frequencies arriving before higher-pitched ones. The InSight scientists recognized the bloop as an acoustic wave traveling through a heated, postsunset atmosphere—a similar sound effect is observed in deserts on Earth. "This was really exciting," says Daubar, as a meteorite strike was the most likely source of these sound waves.

Sifting through seismometer data revealed corresponding seismic signals that traveled through the ground from the impact, and calculations showed that the time it took for both to reach the lander matched models for a Martian impact. To verify that the signals came from a meteoroid (as a meteorite prior to hitting the ground is called), the team had new images of the predicted crash site taken by NASA's Mars Reconnaissance Orbiter (MRO)—a satellite that has been orbiting the red planet since 2006. "We were happy to find fresh-looking craters that weren't there in older images," says Daubar.

The impact had actually resulted in a cluster of craters, formed when the meteoroid broke up in the atmosphere and landed about 85 kilometers from the lander. "It had three distinct 'bloops,' which we were able to link to the explosion in the atmosphere and the impact on the ground," says Daubar. The team also identified in archived seismic data three other impacts that had occurred in 2021 and had been recorded by



A bloop sound can be heard in this September 5, 2021, recording from the InSight lander. Subsequent analysis matched the audio event with the fresh meteorite impacts pictured here.
Credit: NASA; JPL-Caltech; University of Arizona

InSight's seismometers and MRO.

With a clear picture in mind of what a newly formed crater looks like, the researchers continued to comb through older MRO records for "before" and "after" images of Mars' surface near InSight. They procured a catalog of 1200 recently created impact craters, recording their sizes, ages, and visible features such as radial streaks and reflectivity. "We can use this information to learn more about what types of materials hit Mars, how strong they are, and how they break up in the atmosphere," she explains.

The crater datasets revealed that the impact rate in studied regions appears higher than previously measured, and slightly higher than predicted. Such observations could provide a clearer picture of near-Earth-objects that rain down on Mars and might be a hazard for future space missions or for the Earth.

Next, the researchers plan to correlate observed impacts with four years of archived seismic-wave data from InSight. Daubar imagines that there should be other meteorite strikes producing observable seismic signals—besides the four that they recently identified. Connecting these datasets could provide a map of impacts with known magnitudes and locations, allowing detailed measurements of how long it takes for seismic energy to travel from each to the seismometer. That's the key to deciphering the shallow structure of Mars' crust and, by modeling the associated acoustic waves, deciphering the planet's atmospheric layers.

The work demonstrates the value of combining seismic, acoustic, and imaging tools on other objects in the Solar System. NASA's Dragonfly mission to Saturn's icy moon Titan is scheduled to launch in 2026 and arrive in 2034 with seismic- and acoustic-wave detectors. Daubar wonders if bloop-like sounds will help researchers study that celestial body. "Does Titan's thick atmosphere result in different acoustic signals?" she asks. Since the first modern seismograph recorded tremors on Earth two centuries ago, researchers have continued to increase knowledge about the layers of material that make up our planet. The possibilities for other planets are just as enticing.

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REFERENCES

1. R. F. Garcia *et al.*, "Newly formed craters on Mars located using seismic and acoustic wave data from InSight," **Nat. Geosci. 15 (2022).**
2. I. J. Daubar *et al.*, "New craters on Mars: An updated catalog," **JGR Planets 127 (2022).**