NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

December 10, 2014

Sound Spectrum Study

Specialist's Study Report
By Christopher Babcock

1. EVENT

Location:	South Bend, Indiana
Date:	March 17, 2013, 1623 Eastern Daylight Time (EDT)
Aircraft:	Hawker Beechcraft 390
Operator:	Private
Registration:	N26DK
NTSB Number:	CEN13FA196

2. GROUP

A group was not convened.

3. SUMMARY

On March 17, 2013, a privately operated Beechcraft 390, registration N26DK, collided with residential structures and terrain following several aborted landing attempts at the South Bend Regional Airport in South Bend, Indiana. The flight was operating under Title 14 Code of Federal Regulations (CFR) Part 91 as a passenger flight from Tulsa, OK, to South Bend, Indiana. The pilot and copilot sustained fatal injuries. The two passengers and one person on the ground received serious injuries.

The solid-state cockpit voice recorder (CVR) from the aircraft was sent to the National Transportation Safety Board's Audio Laboratory for evaluation. This sound spectrum study supplements the CVR Group Chairman's Factual Report which contains a complete transcript for the entire 31 minute and 11 second recording.[1]

4. DETAILS OF INVESTIGATION

A sound spectrum study was performed to evaluate the sound spectrum of audio recorded by the cockpit area microphone after engine power was lost at 1614:27 EDT. The audio recorded by the cockpit area microphone (CAM) was recorded at 16,000 Hz. The bandwidth of the CAM is 8,000 Hz. This audio was compared with audio recorded during ground testing on an exemplar Beechcraft 390 on September 10, 2013.

[1] See Group Chairman's Cockpit Voice Recorder Factual Report in the public docket for this accident

4.1. Spectrum Study

4.1.1. Williams International FJ44-2A Engines

The accident aircraft was equipped with two Williams International FJ44-2A turbofan engines. According Williams the low pressure rotor (N1) reference speed (100% N1) is 17,245 revolutions per minute (rpm). The high pressure rotor (N2) reference speed (100% N2) is 41,200 rpm. The N1 shaft contains a single stage fan with 16 blades which correspond to an N1 fundamental shaft frequency of 287.4 Hz and a blade passage frequency of 4,598.7 Hz at the N1 reference speed. The N2 shaft contains a single stage compressor that contains 32 blades which correspond to an N2 fundamental shaft frequency of 686.7 Hz and a blade passage frequency of 21,973 Hz at the N2 reference speed.

4.1.2. Accident Engine Start Attempt

Figure 1 shows a spectrogram of the audio recorded after the loss of engine power prior to the accident.[2] A spectrogram is a plot showing frequency content of audio over time with time on the x-axis, frequency on the y-axis, and intensity displayed as color. Timing on all spectrograms is displayed in elapsed times from the start of the recording. Crew discussion around the time of the power loss indicated the aircraft was descending to 3000 feet and slowing to 200 knots. According the airplane flight manual, either an air start or a starter assisted engine start is possible following a loss of engine power at this flight condition. A windmill start uses residual engine speed and engine igniters to relight the engine and regain power. A starter assisted start uses electrical power to increase the N2 shaft to a point where the igniters can restart the engine.

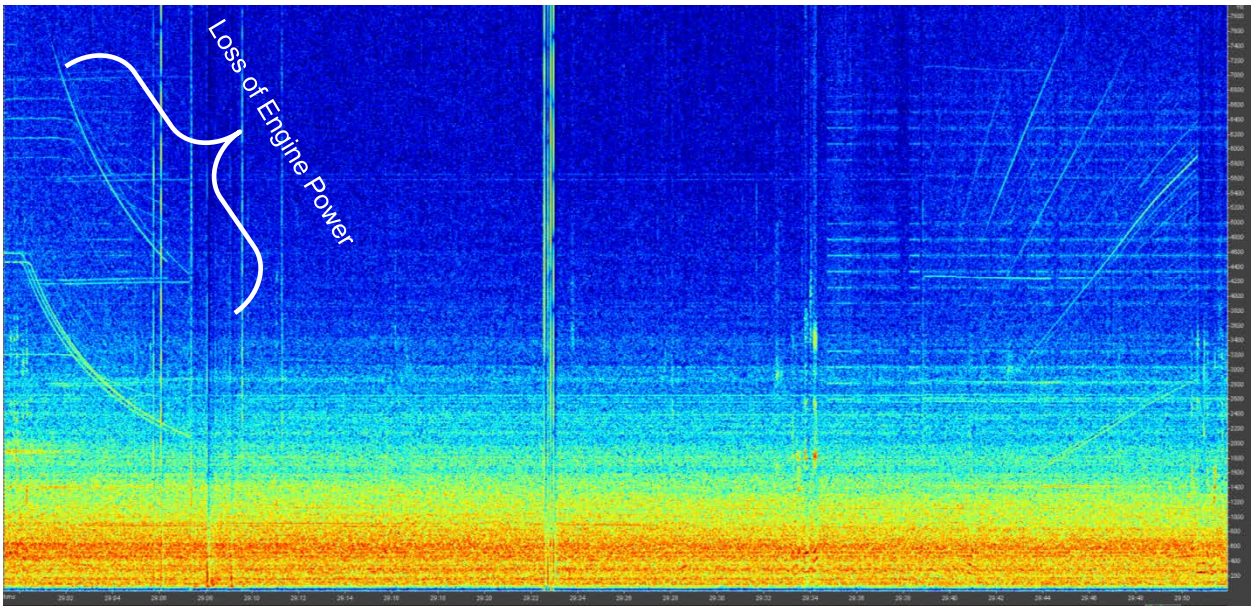

Figure 1. Spectrogram of loss of power on accident flight.

[2] The color map in each spectra has been optimized to best show the frequency content in the selected window. Full resolution spectrograms are available as an attachment to this report.

4.1.3. Starter-Generator Functional Test

Figure 2 shows a spectrogram of audio recorded during a functional test of the accident aircraft's starter/generator at a test facility. The plot has been cropped to show the same bandwidth of the audio recorded on CAM channel of the CVR (8 kHz). The starter/generator was tested by itself with no other accessories present.

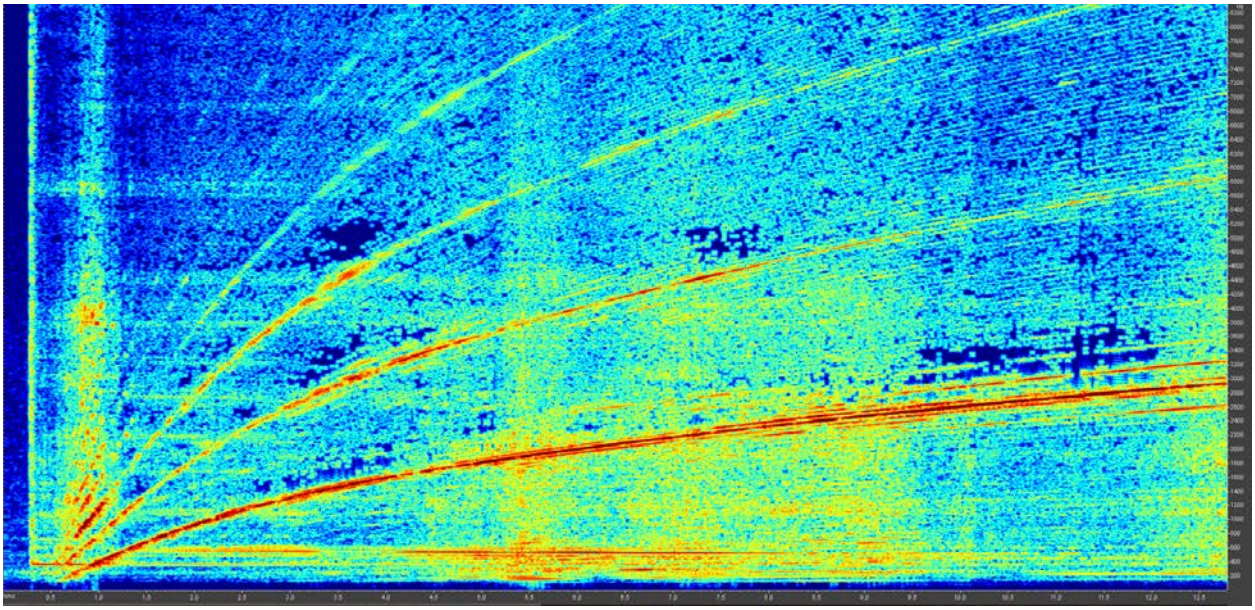

Figure 2. Spectrogram of functional test on the accident aircraft's starter/generator (SN 461AB).

A comparison between the spectrogram in Figure 2 and a similar spectrogram recorded after the loss of engine power on the accident flight (Figure 3) indicate that the crew attempted a starter assisted start in an attempt to restart the engine. Both spectra show similar frequency content, harmonics, and duration.

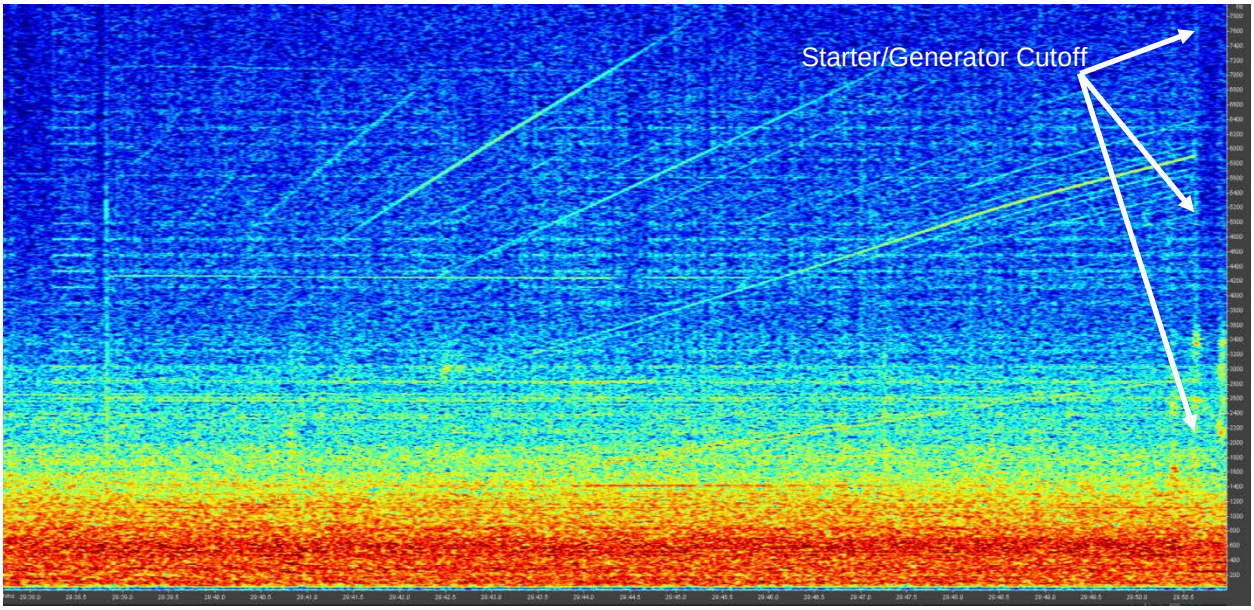

Figure 3. Spectrogram of restart attempt on accident flight.

4.1.4. Exemplar Engine Start

During the ground testing, an exemplar engine start was recorded with the aircraft's installed CVR as well as a handheld audio recorder. Figure 4 shows the spectrogram for this engine start. The electrical interference sound of the igniters is clearly present. These sounds are not normally audible to the ear, but are commonly present as electrical interference on Beechcraft 390 CVR channels.

The traces of the engine shafts spooling up to ground idle is also clearly seen after the starter/generator cuts out at approximately 40-45% N2, according to the manufacturer. While CVR systems normally employ a high pass filter with a cutoff frequency of approximately 150 Hz, some audio characteristics may be visible below 150 Hz if the signal is high enough. Figure 5 shows the N1 shaft spooling up to 85 Hz, equivalent to a ground idle speed of 29.5% N1. Figure 6 shows the same engine start as Figure 5, but at a higher frequency window on the y-axis. While faint, the blade passage trace for the N1 shaft with 16 compressor blades, corresponding to the N1 shaft spool up, can be seen increasing to approximately 1,360 Hz.

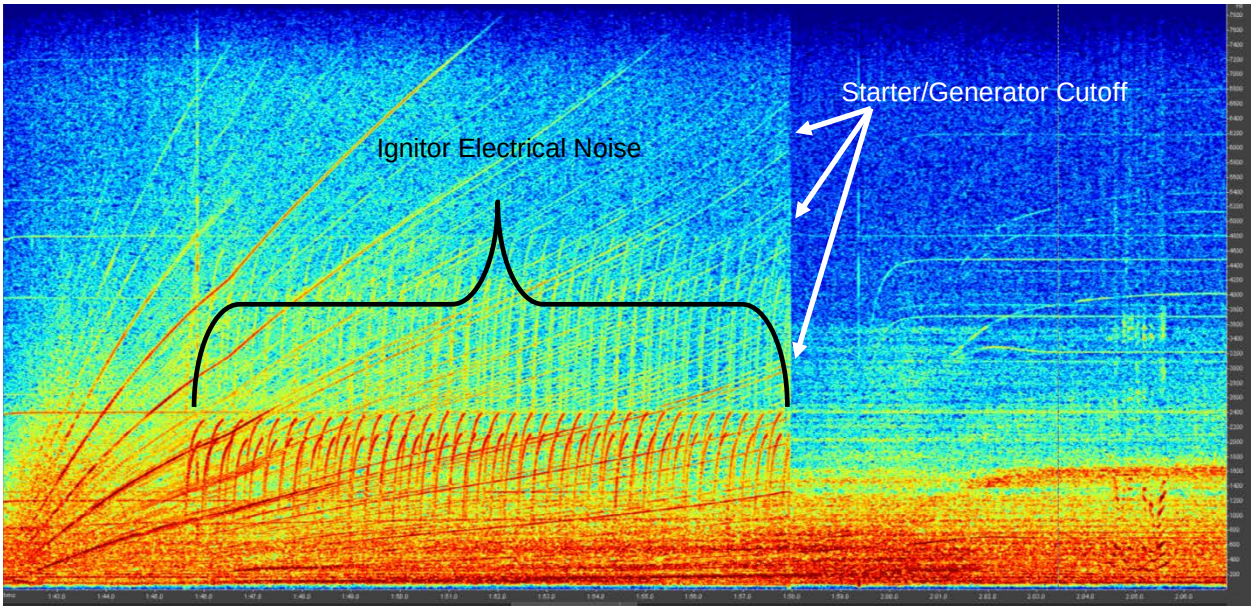

Figure 4. Spectrogram of left engine start during ground test.

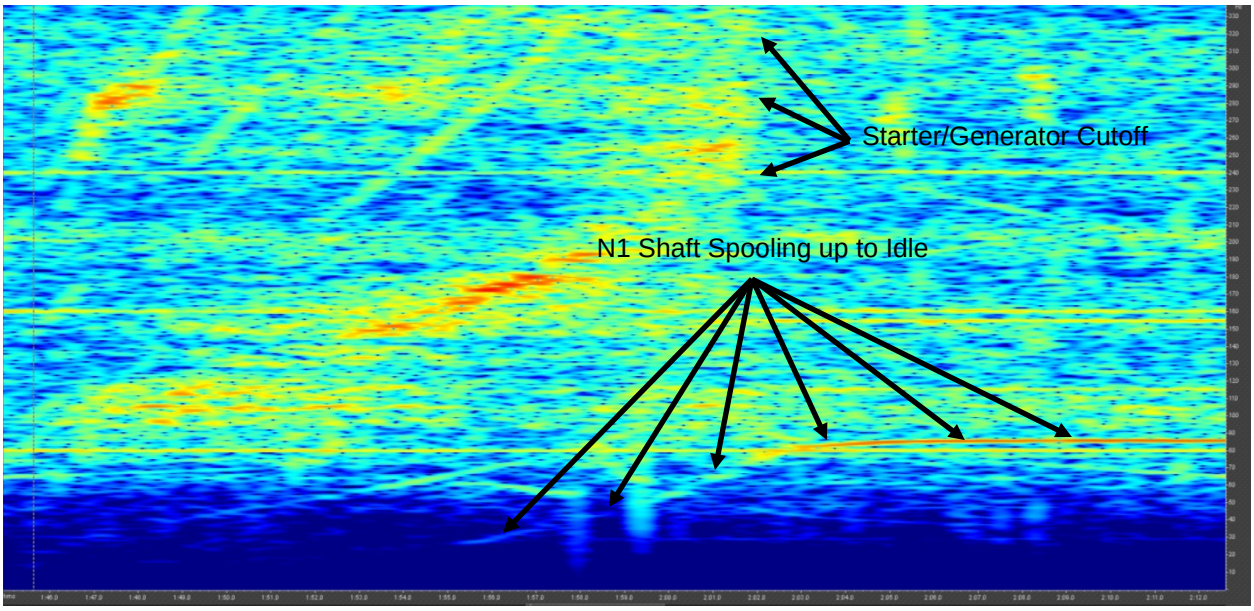

Figure 5. Spectrogram showing N1 shaft spool up during ground test.

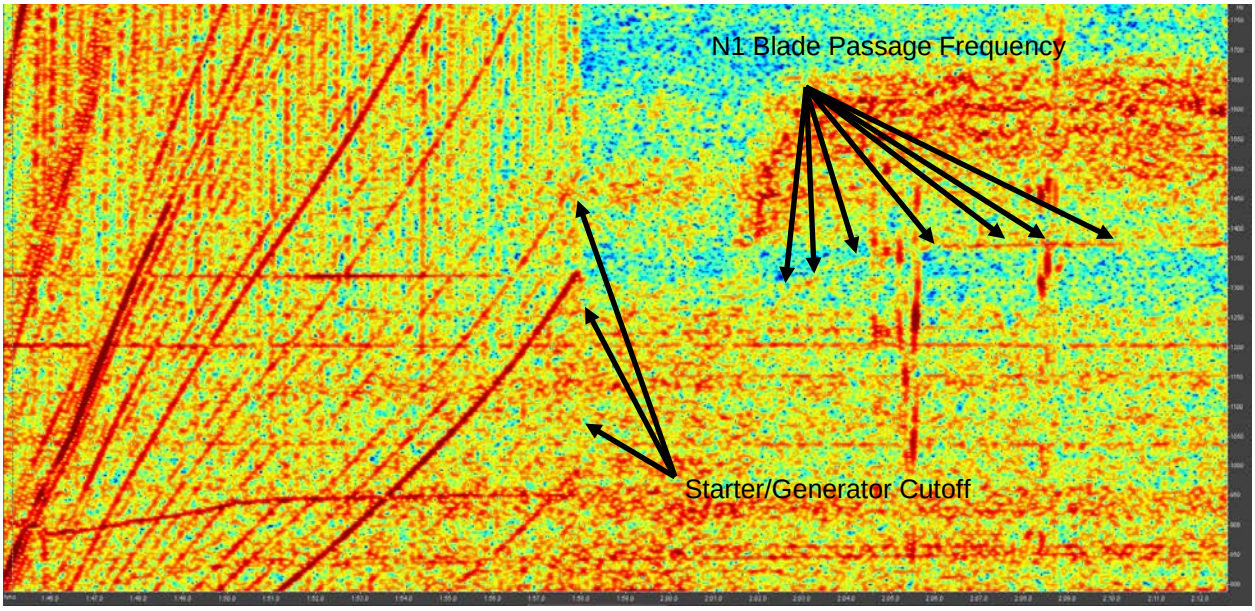

Figure 6. Spectrogram showing N1 blade passage frequency during engine start ground test.

4.1.5. Observations

Figure 3 shows that the electrical noise from the engine igniters is not present during the accident flight. In contrast to the normal ground start procedure, the air start procedure from the flight manual requires that the igniter switches be switched to the "ON" position prior to an inflight start attempt.

While several frequency traces of engine shafts and accessories spooling up are present in the exemplar ground start, none are visible for the period after the start attempt through the end of the CVR recording 64 seconds later (Figures 7 and 8) during the accident flight.

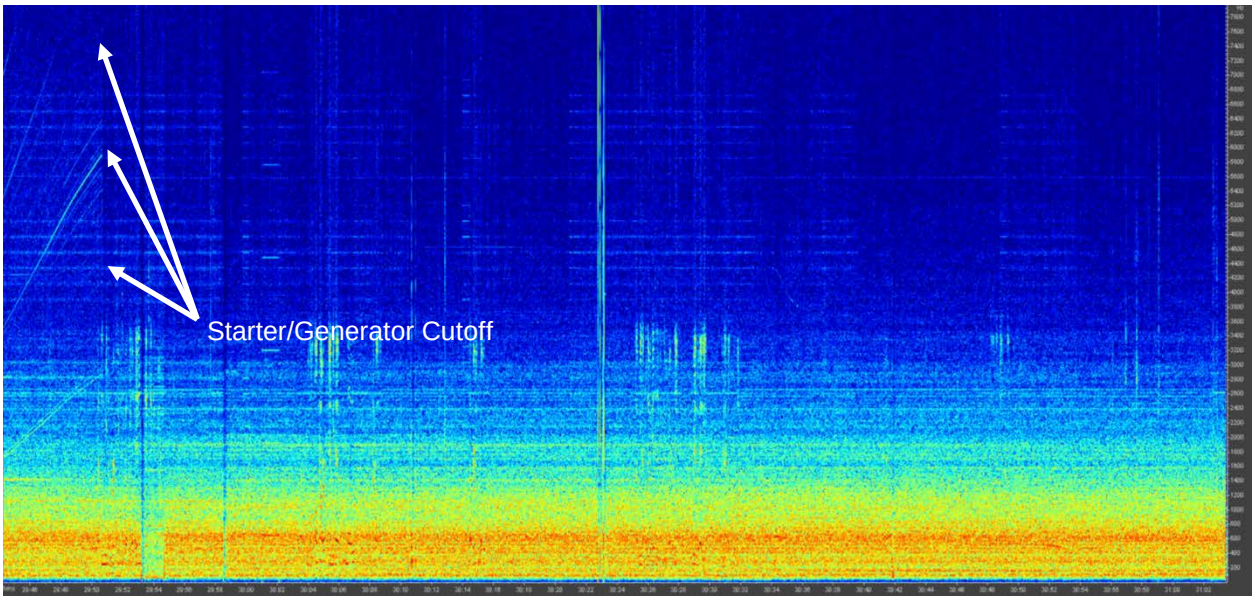

Figure 7. Spectrogram of period after start attempt until the end of recording (full bandwidth).

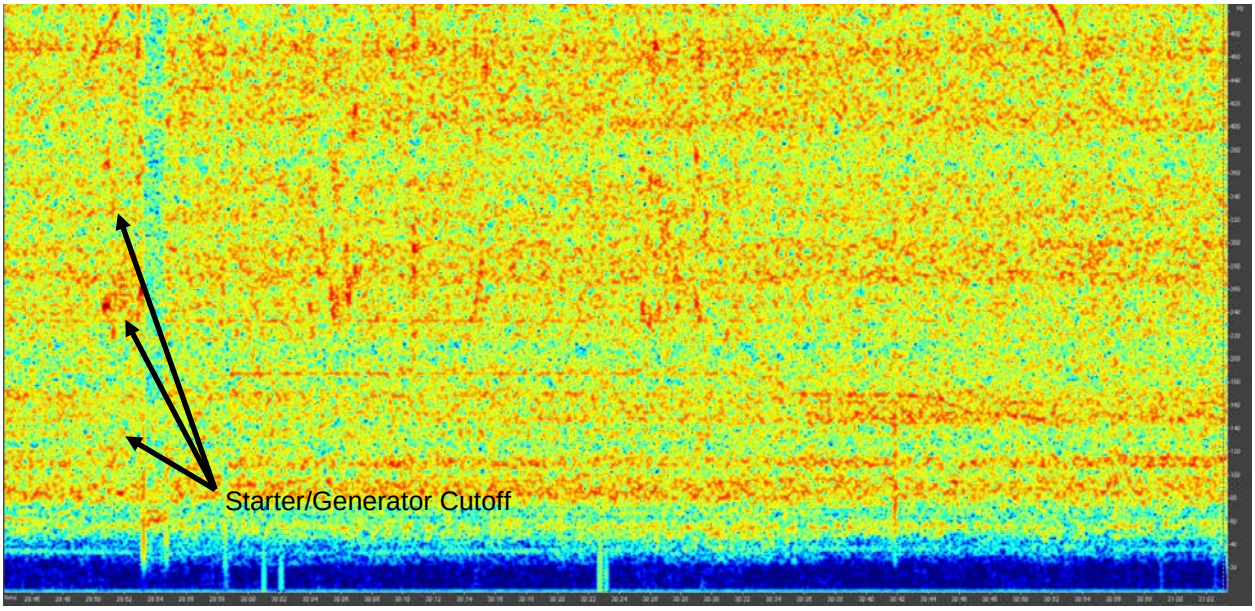

Figure 8. Spectrogram of period after start attempt until the end of recording (0-500 Hz).

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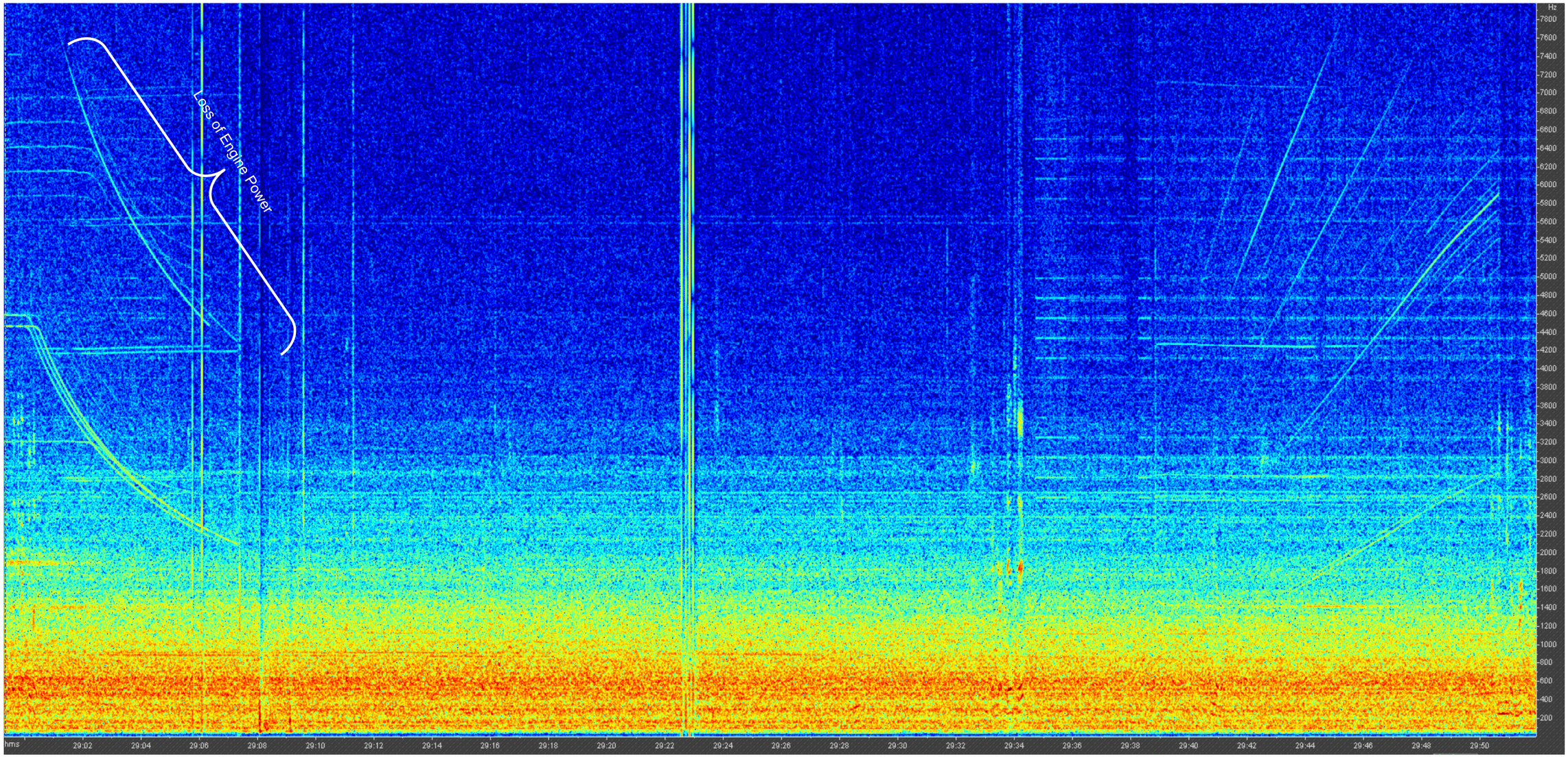


Figure 1. Spectrogram of loss of power on accident flight.

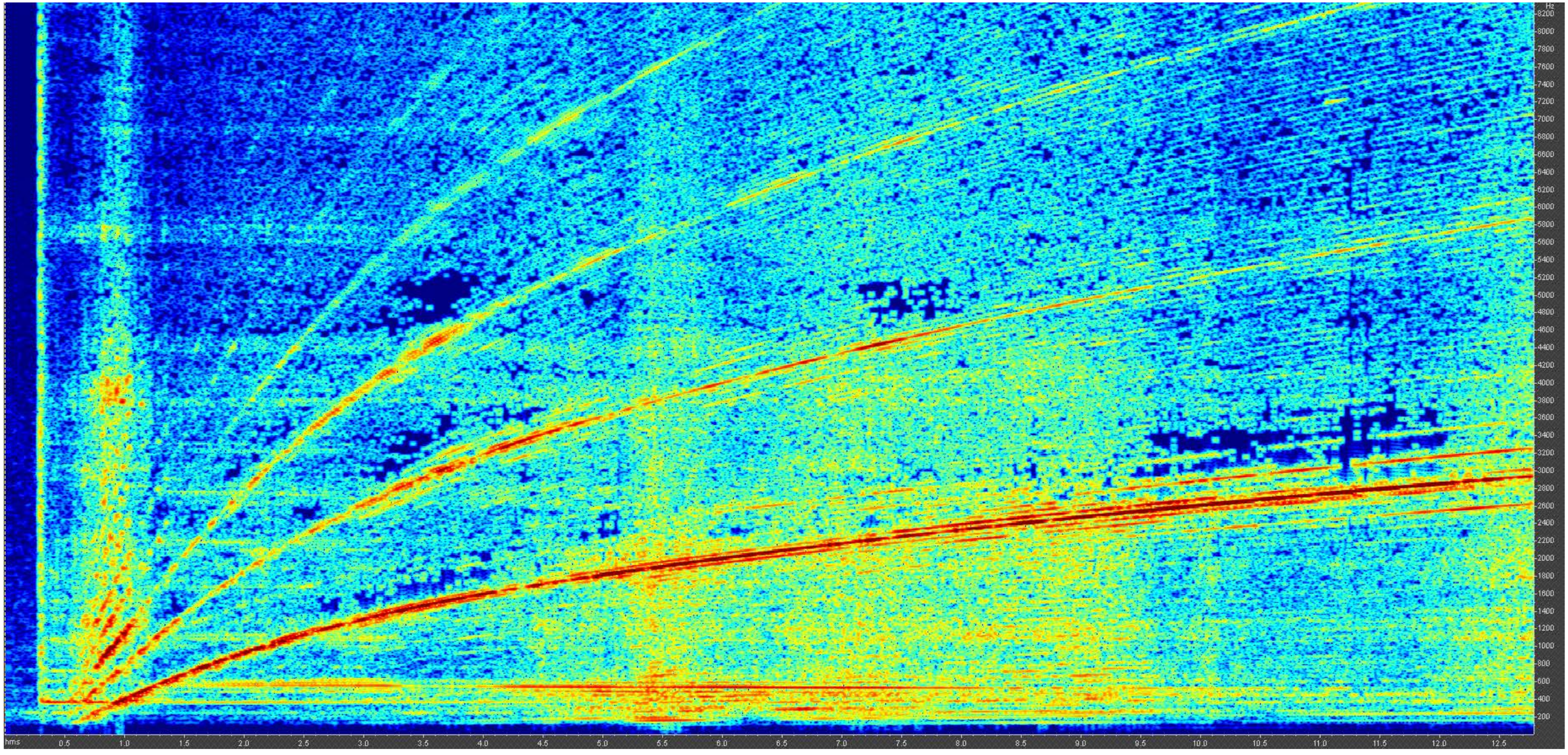


Figure 2. Spectrogram of functional test on the accident aircraft's starter/generator (SN 461AB).

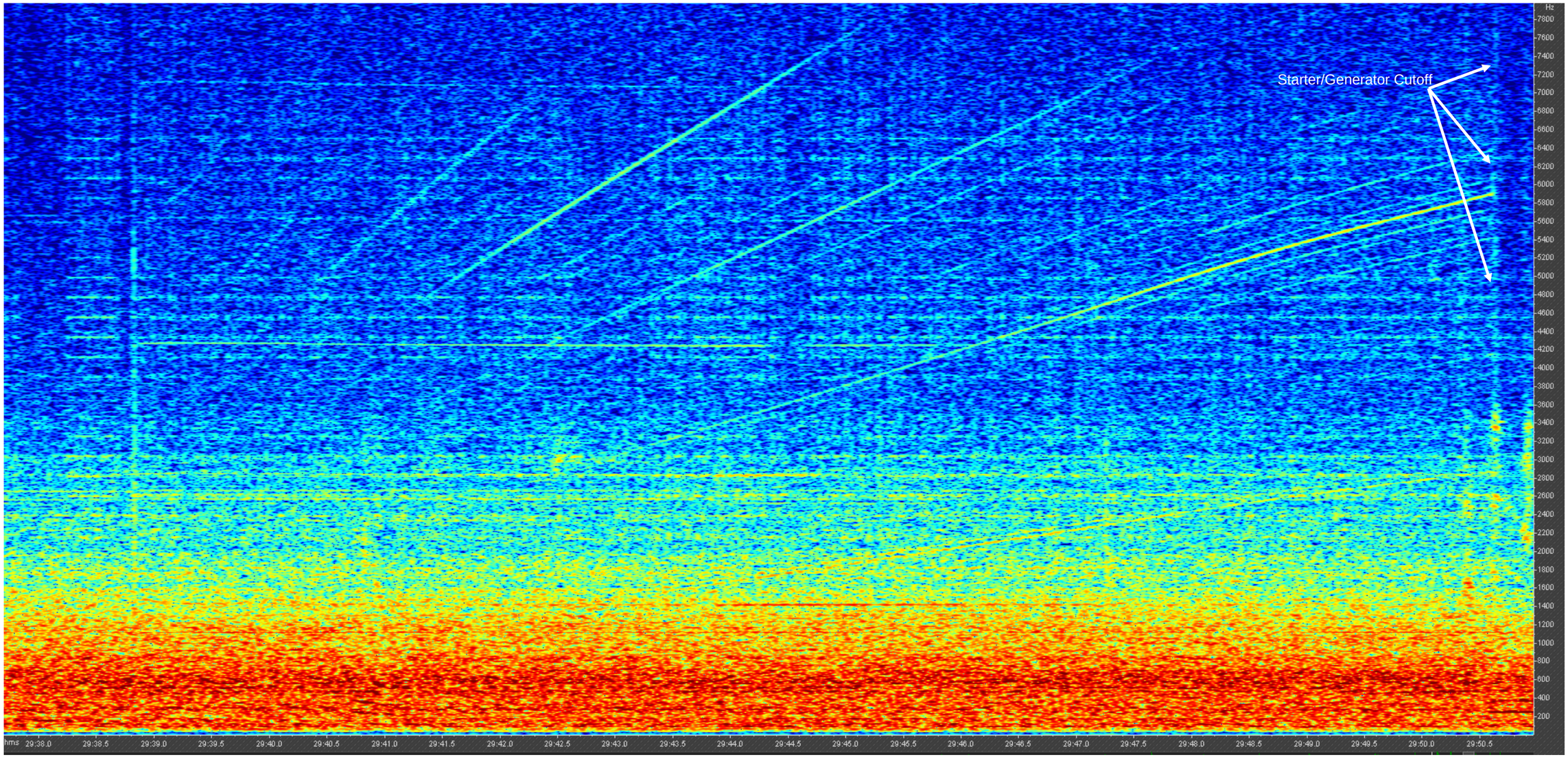
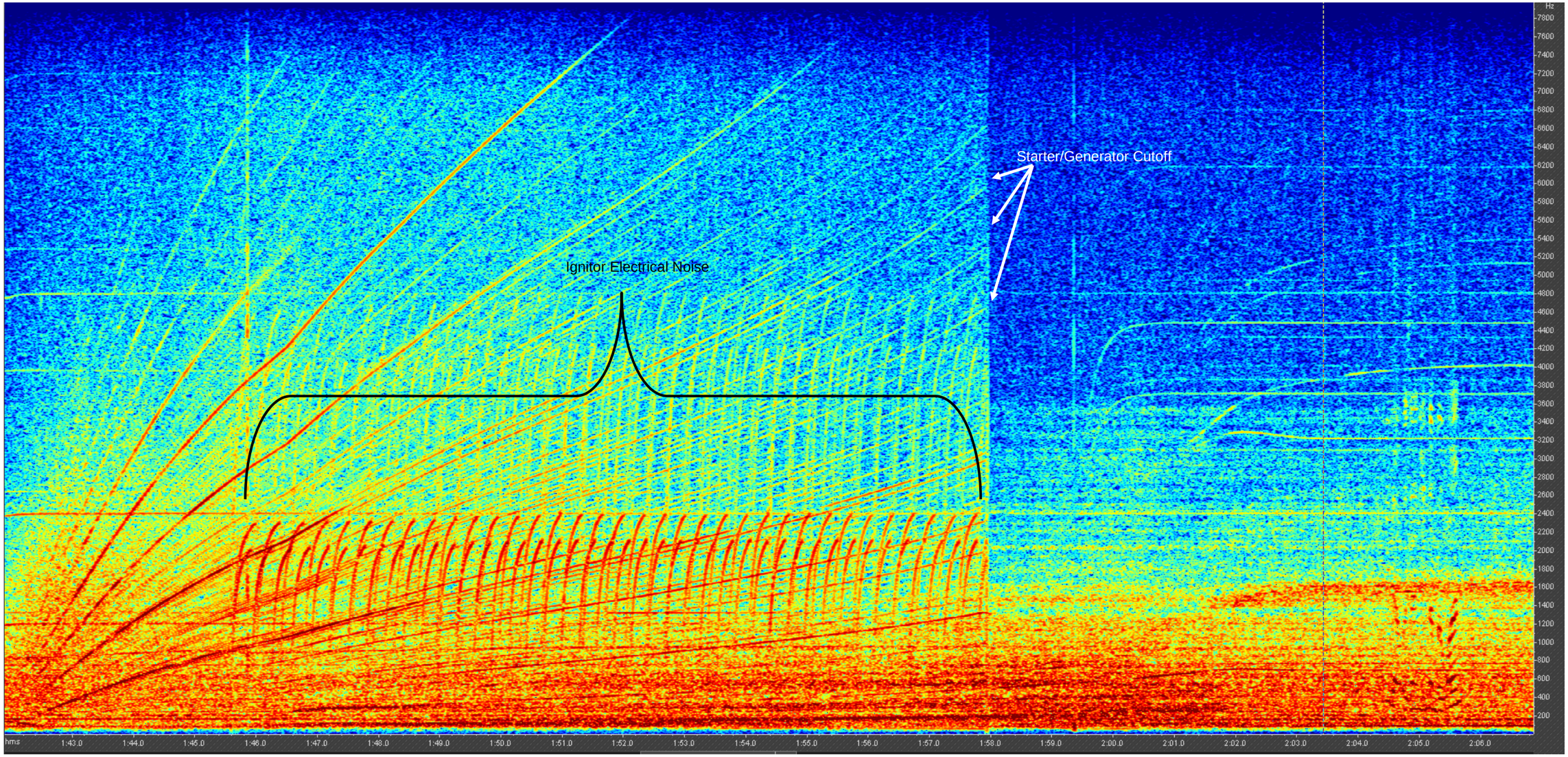


Figure 3. Spectrogram of restart attempt on accident flight.



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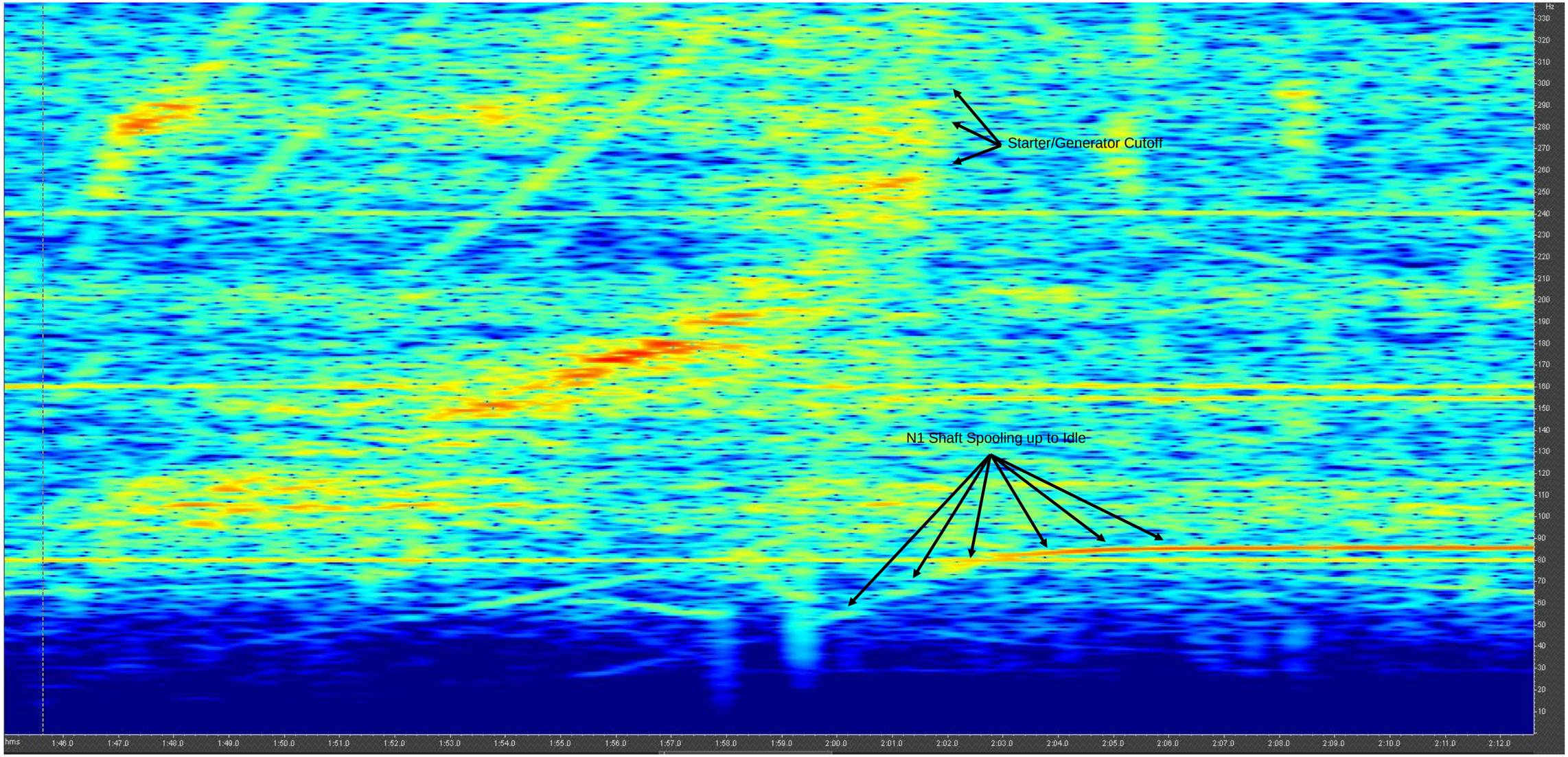


Figure 5. Spectrogram showing N1 shaft spool up during during ground test.

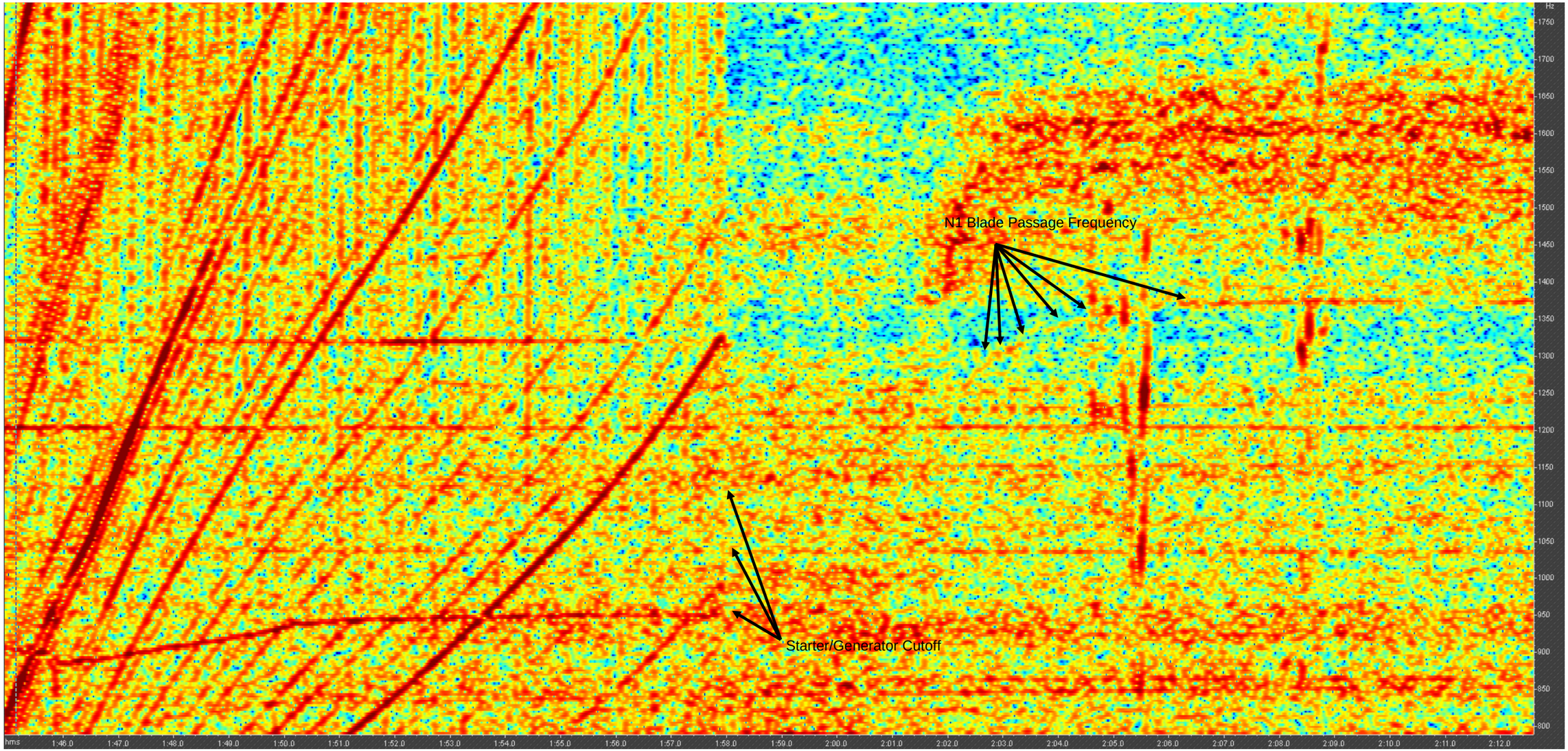
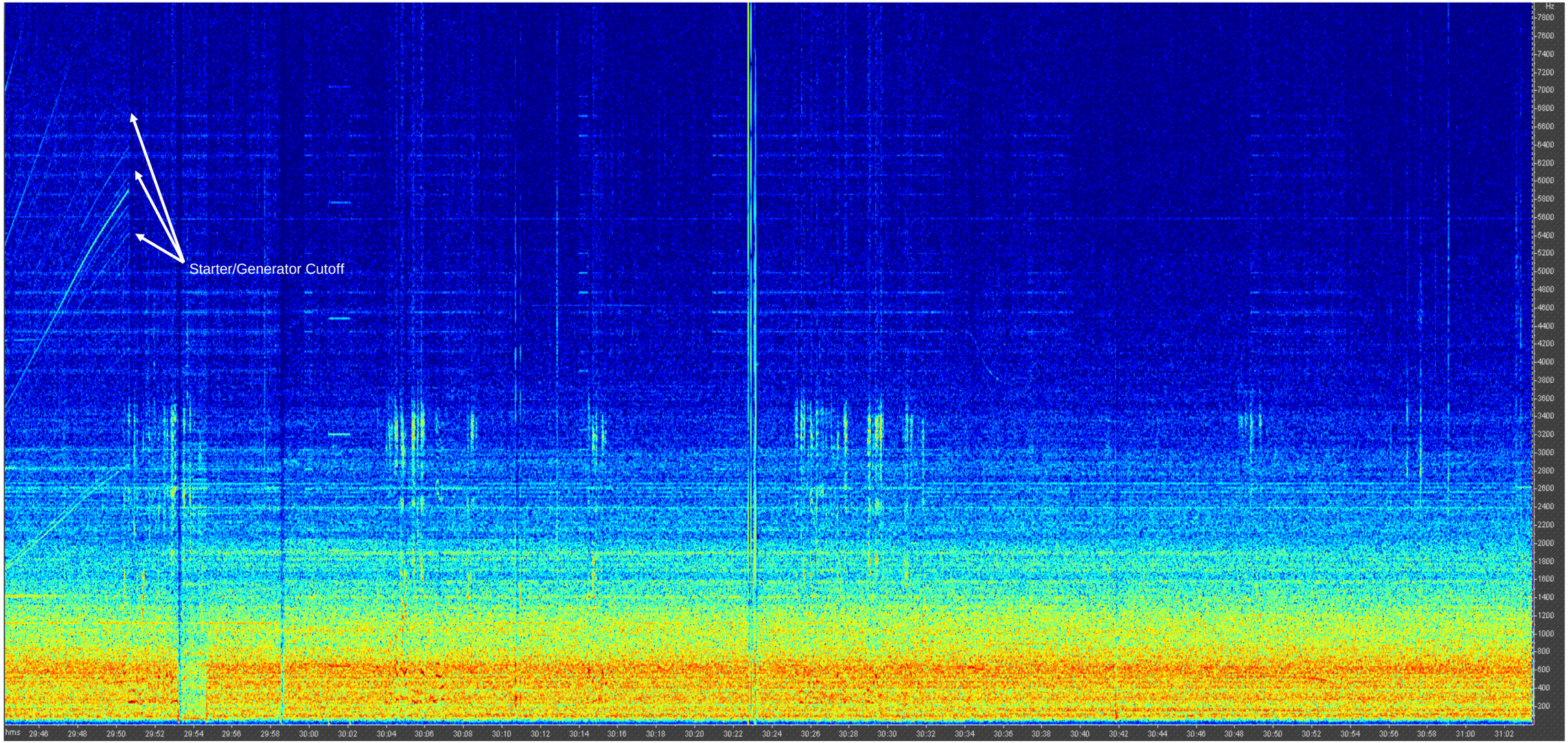


Figure 6. Spectrogram showing N1 blade passage frequency during engine start ground test.



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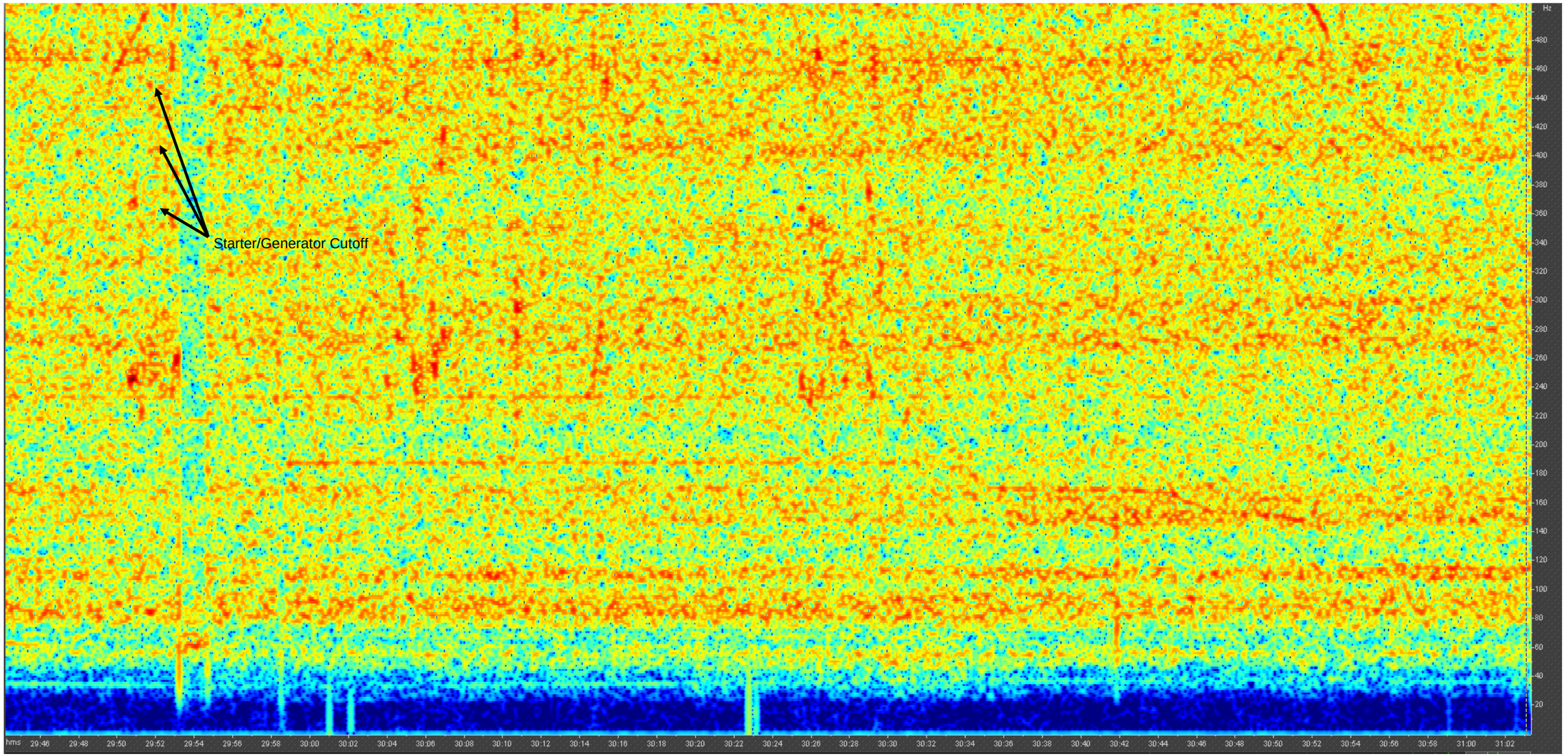

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