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Abstract

During NASA Increment 3 (September 1996 to January 1997), about 5 gigabytes of acceleration data were collected by the Space Acceleration Measurement System (SAMS) onboard the Russian Space Station, Mir. The data were recorded on 11 optical disks and were returned to Earth on STS-81. During this time, SAMS data were collected in the Priroda module to support the following experiments: the Mir Structural Dynamics Experiment (MiSDE) and Binary Colloidal Alloy Tests (BCAT). This report points out some of the salient features of the microgravity environment to which these experiments were exposed. Also documented are mission events of interest such as the docked phase of STS-81 operations, a Progress engine burn, attitude control thruster operation, and crew exercise. Also included are a description of the Mir module orientations, and the panel notations within the modules. This report presents an overview of the SAMS acceleration measurements recorded by 10 Hz and 100 Hz sensor heads. Variations in the acceleration environment caused by unique activities such as crew exercise and life-support fans are presented. The analyses included herein complement those presented in previous mission summary reports published by the Principal Investigator Microgravity Services (PIMS) group.

Abbreviations and Acronyms

BCAT	Binary Colloidal Alloy Tests
BKV-3	Vozdukh dehumidifier (Russian acronym)
BTS	Biotechnology System
DMT	Decreed Moscow Time (year day/hour:minute:second)
EORF	Enhanced Orbiter Refrigerator/Freezer
f_c	cutoff frequency (Hertz)
f_s	sampling rate (samples per second)
g_o	Acceleration due to Earth's gravity (9.81 m/s^2)
Hz	Hertz
LeRC	Lewis Research Center
μg	microgravity (1/1,000,000 of g_o)
MGBX	Microgravity Glovebox
MIM	Microgravity Isolation Mount
MiPS	Mir Payload Support
MiSDE	Mir Structural Dynamics Experiment
MRD	Microgravity Research Division
PIMS	Principal Investigator Microgravity Services
PSD	power spectral density
RCS	reaction control system
RMS	root-mean-square
SAMS	Space Acceleration Measurement System
STS	Space Transportation System
TSH	triaxial sensor head
WWW	world wide web
X_h, Y_h, Z_h	X-, Y-, Z-Axis for unspecified SAMS sensor head.
$X_{h,A}, Y_{h,A}, Z_{h,A}$	X-, Y-, Z-Axis for SAMS TSH A
$X_{h,B}, Y_{h,B}, Z_{h,B}$	X-, Y-, Z-Axis for SAMS TSH B
X_B, Y_B, Z_B	X-, Y-, Z-Axis coordinate system for Mir Base Block.

Table of Contents

List of Tables

List of Figures

Acknowledgments

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1. Introduction

The NASA Microgravity Research Division (MRD) sponsors microgravity science experiments on several carriers, which include the Shuttle Orbiter and the Mir Space Station. The MRD sponsors the Space Acceleration Measurement System (SAMS) at the NASA Lewis Research Center (LeRC) to support microgravity experiments with microacceleration measurements. The LeRC Principal Investigator Microgravity Services (PIMS) project supplies principal investigators of microgravity science experiments and other experiment personnel with data to support the evaluation of the effects of microgravity on their experiments. PIMS also provides science experiment personnel with the special composition and magnitudes of on-orbit events such as exercise periods, equipment operation, reaction control system (RCS) jet firings, etc. to assist in the scheduling of the operation of their microgravity science experiments.

In 1994, a SAMS unit [1] was installed on the Mir Space Station to support U.S. and Russian microgravity experiments by measuring the microgravity environment during experiment operations. Previous reports [2-6] have summarized and evaluated the SAMS data acquired during the period from September 1994 to September 1996.

During the period from September 1996 to January 1997, the SAMS primary function was to support two experiments: Binary Colloidal Alloy Tests (BCAT) and the Mir Structural Dynamics Experiment (MiSDE). SAMS data were recorded during the operations of both BCAT and the MiSDE. Included in the data SAMS recorded in support of MiSDE and/or BCAT are mission events that are of interest in characterizing the microgravity environment of the Mir, such as:

- Progress engine burn
- Attitude control thruster firing
- Crew exercise
- Binary Colloidal Alloy Tests
- Life-support fans
- Shuttle/Mir docking
- Cyclic broadband behavior

This report provides an overview of the SAMS data recorded during the period from September 1996 to January 1997.

Appendix A describes the procedures that users should follow to access SAMS data via anonymous FTP, over the internet. Appendix B (available on the CD-ROM and WWW) contains plots of the SAMS TSH A (100 Hz) sensor head data, and Appendix C (available on the CD-ROM and WWW) contains plots of the SAMS TSH B (10 Hz) sensor head data. Appendix D contains a user comment sheet, which users are encouraged to complete and return to the authors.

This entire report is also available on the attached CD-ROM and on the WWW in PDF format. Adobe Acrobat Reader 2.1 or higher will be neccasary to open and/or print these files.

2. Data Acquisition and Processing

As noted in previous reports [2-6], the SAMS unit on Mir is connected to two triaxial sensor heads (TSHs) with different cutoff frequencies and sampling rates. TSH A has a cutoff frequency of 100 Hz, and a sampling rate of 500 samples per second. TSH B has a cutoff frequency of 10 Hz, and a sampling rate of 50 samples per second. During NASA Increment 3, the SAMS unit was turned on periodically to record microgravity accelerations in support of MiSDE and/or BCAT.

Eleven optical data disks were returned to Earth on STS-81, marking the completion of NASA Increment 3 in January 1997. These data were processed by the SAMS project at LeRC and placed on a NASA LeRC file server (beech.lerc.nasa.gov) to make them available to users. Appendix A of this report provides instructions for accessing these data.

SAMS data coverage for this mission is shown in Figure 1. It should be noted that for January 15 and 17 of 1997 (DMT 1997 days 15 & 17), the MiPS time synchronization was off by 23 hours, 54 minutes, and 30 seconds (almost 1 day). Therefore, the SAMS data which appears to be from days 16 and 18 are really from days 15 and 17. The data is still valid, but care must be taken when looking at the time.

3. Mission Configuration

3.1 Mir Configuration

Mir is a third generation Russian Space Station with roots that date back to 1971 space stations that could not be resupplied or refueled. The Salyut Stations of the late 1970s to early 1980s were predecessors to the Mir Station [7]. The Mir has been in orbit since February 1986 [8], and in the years since then, modules have been added until the Mir reached its present configuration of six modules. The current Mir Space Station consists of the Mir core module, the Kvant, Kvant-2, Kristall, Spektr (currently depressurized and uninhabitable), and Priroda Modules; it measures more than 107 feet in length with the docked Progress-M and the Soyuz-TM spacecraft and is about 90 feet in width across the modules [9]. Figure 2 shows a typical configuration of the Mir Space Station during the time covered by this report.

3.2 Mir Coordinate Systems

The Mir Space Station's basic coordinate system is that of the base module coordinate system that is shown in Figure 2. Each of the modules of the Mir station has its own coordinate system, which is based upon its orientation with respect to the Mir Core Module. The determination of the coordinate system is made by a simple procedure. If you "stand" in any module, such that your feet are on the floor, and you are facing towards the transitional node of the Base Block, then the coordinate system of that module is defined by the right hand rule, such that the direction you are facing is $+X_{module}$, the direction from your feet to your head is $+Y_{module}$, and the direction from your left to right is $+Z_{module}$. Figure 3 shows a graphical representation of these coordinate systems for the nominal Mir configuration (consistent with that shown in Figure 2). Table 1 shows a tabular representation of Figure 3.

Table 1: Tabular representation of Mir module orientations

Base	*Kristall*	*Kvant*	*Kvant-2*	*Priroda*	*Spektr*
$+X_B$	$+Z_{Kristall}$	$-X_{Kvant}$	$+Y_{Kvant\text{-}2}$	$-Z_{Priroda}$	$-Y_{Spektr}$
$+Y_B$	$-Y_{Kristall}$	$+Y_{Kvant}$	$-X_{Kvant\text{-}2}$	$-Y_{Priroda}$	$+X_{Spektr}$
$+Z_B$	$+X_{Kristall}$	$-Z_{Kvant}$	$+Z_{Kvant\text{-}2}$	$-X_{Priroda}$	$+Z_{Spektr}$

3.3 Mir Attitudes

The orientation attitudes of the Mir Space Station during the period from September 1996 to January 1997 are not known at this time. It is known, however, that the Mir attitude control jets are fired periodically to reorient Mir.

4. SAMS Triaxial Sensor Head Orientations and Locations

The SAMS TSHs are mounted to either the Mir structure or to an experiment. The TSHs can also be moved to other locations as required. Table 2 shows the TSH orientations and locations for the times during NASA Increment 3.

Table 2: Compilation of SAMS Sensor head locations and orientations for various times during NASA Increment 3

Dates	*DMT 1996 Day*	*Module*	*TSH A*	*TSH B*
17 June 1996	169	Priroda	MIM $X_{h,A}=+Z_{Priroda}$ $Y_{h,A}=+X_{Priroda}$ $Z_{h,A}=+Y_{Priroda}$	MGBX $X_{h,B}=+Y_{Priroda}$ $Y_{h,B}=-X_{Priroda}$ $Z_{h,B}=+Z_{Priroda}$
27 November 1996	332	Priroda	BTS $X_{h,A}=-Y_{Priroda}$ $Y_{h,A}=+X_{Priroda}$ $Z_{h,A}=+Z_{Priroda}$	MGBX $X_{h,B}=+Y_{Priroda}$ $Y_{h,B}=-X_{Priroda}$ $Z_{h,B}=+Z_{Priroda}$

5. Experiments Supported

5.1 Mir Structural Dynamics Experiment (MiSDE) [10]

In order to mitigate the risks associated with the construction of the International Space Station, researchers will use the results from MiSDE to characterize the loads on the Mir Space Station and to try to determine how the Mir structure responds to vibration forces.

5.2 Binary Colloidal Alloy Tests (BCAT) [11]

BCAT enabled researchers to study the long-term behavior of binary colloidal alloys without being subjected to the gravitational forces that ground-based experiments experience. Binary colloidal alloy crystals take longer to form than single particle crystals. This long-duration Mir mission enabled researchers to process samples designed for both rapid, and slow growth. The slow growth regions of these crystal alloys have not been previously investigated in a long-term orbital mission.

6. Data Analysis Techniques

SAMS data are generally presented and plotted in one of several forms for evaluation: acceleration versus time, power spectral density (PSD) versus frequency, and spectrogram (PSD versus frequency versus time). The form used depends on what aspect of the data is of interest.

Acceleration versus time plots are used to display the microacceleration levels recorded by the SAMS sensor head. These data could then be used by experiment personnel to correlate time-specific experiment results with the measured microgravity environment. This form of data display gives the most time-accurate representation of the microgravity environment.

A plot of the interval average acceleration in units of g versus time gives an indication of net accelerations which last for a number of seconds equal to or greater than the interval parameter. Shorter duration, high amplitude accelerations can also be detected with this type of plot. However, the exact timing and magnitude of specific acceleration events cannot be extracted, a plot of the interval root-mean-square acceleration in units of g versus time gives a measure of the oscillatory content in the acceleration data. For the period of time considered, this quantity gives an indication of the time-averaged power in the signal due to purely oscillatory acceleration sources.

Power Spectral Density (PSD) calculations and plots are used to examine and display the frequency content of SAMS data during relatively short periods of time (on the order of seconds to minutes). Analysis times may be chosen based upon some specific event or experimental run. The mathematics used to transform the time-domain SAMS data to the frequency domain are described in [12].

The PSD has units of (units of original function)^2/Hz. For SAMS data, these units are g^2/Hz. This method for computation of the PSD is consistent with Parseval's Theorem, which states that the RMS value of a time signal is equal to the square root of the integral of the PSD across the frequency band represented by the original signal [11]:

$$x_{RMS} = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt} = \sqrt{\int_0^\infty PSD(f)df} \quad .$$

Spectrograms are analogous to 3-dimensional plots, but in this instance the third dimension is color, so all the data can be presented on a 2-dimensional plot. Spectrograms can be used to evaluate how the microgravity environment varies in intensity with respect to both the time and frequency domains. A description of how data are manipulated to produce a spectrogram is contained in [12].

7. Microgravity Environment

7.1 Progress Engine Burn

As part of the Mir Structural Dynamics Experiment (MiSDE), the SAMS unit was activated to record a firing of the Progress vehicle's engine, while the vehicle was docked to Mir. Firings of the Progress engine have been used in the past to raise Mir's altitude [6], as well as to perform specific experimental objectives, as was the case with this firing. Figures 4 and 5 show 1 second interval averages of SAMS TSH A (f_c=100 Hz), and TSH B (f_c=10 Hz) data, respectively. These figures indicate that the primary result of this firing was an acceleration in the $+Z_{h,A}$, and $+Z_{h,B}$ directions. Using Table 1 and 2, it may be seen that the transformations for both of these directions yield an acceleration in the $-X_B$ direction. This is consistent with a Progress vehicle docked to the Kvant module, as is illustrated in Figures 2 and 3. Both of the acceleration plots show a dc-offset of approximately 400 μg. The duration of this firing was just under 6.5 minutes.

Figures 6 and 7 show color spectrograms of the SAMS TSH A and TSH B data, respectively. Notice the increased signal strength in the period from t=11 to t=17 minutes. Specifically, there is an increase in the acceleration magnitude around the structural mode frequencies (approximately at 0.5, 0.8, 0.9, 1.0, 1.3, 1.9, and 4 Hz). Excitation of structural modes is a common occurrence when acceleration disturbances such as thruster firings and exercise occur. The cause for the second excitation of structural modes (between t=27 and 32 minutes) is unknown.

7.2 Attitude Control Thrusters

In addition to the engines on the Progress vehicle, the Mir station also has attitude control thrusters, which are used for attitude maintenance. These thrusters were fired on 30 December 1996 as part of the Mir Structural Dynamics Experiment (MiSDE) tests. Figure 8 shows a plot of acceleration versus time for SAMS TSH B (f_c=10 Hz), for a time period spanning the event. The acceleration peaks visible on the $X_{h,B}$ and $Y_{h,B}$ axes around t=26, 27, 28, 30, and 33 minutes in the plot are believed to be caused by the thruster firings. The cause for the acceleration increase at t=19 minutes, and subsequent decrease at t=34 minutes is unknown.

Figure 9 shows a color spectrogram of the same time period. Notice the increase in overall energy in the t=19 to 34 minute region, as well as the broadband increases (vertical stripes tending towards red) which occur at times coincident with the data peaks noted above. The cause for the frequency excitations at 1.38, 2.42, 3.11, 3.60, 4.06, 4.90, 5.40, 6.18, 7.29, 7.86, 9.63 Hz are unknown. These may be related to a "firing frequency" within the thruster system (i.e. if the thrusters are pulsed, as has been seen on the Shuttle Orbiter). Their source, however, is unknown.

The appearance of some of these disturbance frequencies (particularly the 2.42 and 4.90 Hz signals) resembles crew exercise. However, this is unlikely, as [13] does not mention that exercise should be performed during this MiSDE experiment. No explanation for this similarity can be offered at this time.

7.3 Crew Exercise

SAMS was activated to record the acceleration environment which resulted during a crew exercise period as another part of the Mir Structural Dynamics Experiment (MiSDE) tests. Since the MiSDE tests were designed to gain insight into the Mir structure, and the impact of a variety of activities on the structure, exercise (running on a treadmill) is an effective way to excite the vehicle's structural modes so that they may be studied.

For this test, SAMS was located in the Priroda module (as shown in Table 2). The treadmill exercise was performed in either the Base Block, or the Kristall module. Figures 10 and 11 show color spectrogram plots of SAMS TSH A and B data, respectively, for a time period encompassing this test. Notice the increased magnitude of structural mode resonance (0.67, 0.85, 1.07, 1.36 and 1.88 Hz) around t=6 to t=25 minutes in these plots. This structural excitation is a consequence of the crew member's exercise. Also notice the 2.7, 4.0, and 4.3 Hz signals which alternately appear and disappear between t=7 and t=21 minutes in the plot. It is believed that these result from higher exertion levels (i.e. faster running). The "off" times for these signals could indicate the use of the expander devices, or of a primary exercise frequency which is very close to one of the excited structural modes of the station.

A plot of acceleration versus time may be seen in Figures 12 and 13 for SAMS TSH A and B, respectively. Figure 13 shows the acceleration signal's periodicity quite clearly in all three axes. Such regular periodicity is indicative of treadmill-type exercise. Since the SAMS unit was located in a module other than that where the exercise was conducted, SAMS is recording the response in Priroda to treadmill exercise conducted in either the Base Block, or in the Kristall module. It is important to stress that these measurements are the results of the exercise which were transmitted (via a structural path) to the SAMS sensor head locations.

7.4 Binary Colloidal Alloy Tests (BCAT)

The formation of binary colloidal crystal alloys is inherently slow. The Mir space station provides the opportunity for studying the long-term behavior of binary colloidal alloys in a reduced gravity environment. The reduced-gravity environment offers investigators the ability to study these materials while the effects of sedimentation and buoyancy are minimized. This experiment consisted of placing a number of colloidal alloy samples (covering a wide range of concentrations) into the BCAT apparatus housed in the microgravity glovebox (MGBX) facility, which is located on the 200-plane of the Priroda module.

These samples were allowed to process for days, while still photographs of these samples were taken periodically to document any changes in appearance [14,15]. During NASA Increment 3, the SAMS recorded over 190 hours of acceleration data in support of the BCAT. These recordings spanned the majority of DMT 1996 274/18:30 through 285/20:30. During this time, SAMS TSH A (f_c = 100 Hz) was mounted to the Microgravity Isolation Mount (MIM), 400-plane, and SAMS TSH B (f_c = 10 Hz) was mounted to the under-side of the Microgravity Glovebox (MGBX), 200-plane, in the Priroda module.

As seen in the first 37 figures of Appendix B [16,17], the microgravity environment during BCAT operations in the 0.01 to 100 Hz range was dominated by the omnipresent life-support equipment disturbances in the 40 to 45 Hz and the 80 to 90 Hz ranges. Occasionally, as ambient humidity conditions dictated, the BKV-3 compressor, part of a dehumidifier system in the Core Module, was turned on. This imparts significant disturbances at a fundamental frequency of approximately 24 Hz along with its 2^{nd} - 4^{th} harmonics. As a means of displaying the relative distribution of the energy with respect to frequency for these disturbances, Figure 14 shows PSDs which were computed using Welch's method [18] for times when the BKV-3 compressor was on (the red trace) and for times when it was off (the blue trace), over the majority of the period spanning DMT 1996 274/18:30 through 285/20:30. The traces shown are comprised of the spectral averages of PSDs computed approximately every minute for the times when the compressor was on (spectral average of 3,101 intervals) and when the compressor was off (spectral average of 6,816 intervals). The row of arrows at the bottom of the plot point to the BKV-3 compressor's signature (spectral peaks at about 24, 48, 72, and 96 Hz on the red trace). Further information about the BKV-3 compressor may be found in [6].

It is also interesting to note that in Figure 14, the microgravity environment below about 20 Hz or so is somewhat less intense for the compressor-off intervals (blue trace) than for the compressor-on intervals (red trace). This is due primarily to the fact that, for these intervals, the compressor was running only during periods when the crew was awake. Crew activity tends to heighten the response in this region of the spectrum (below 20 Hz or so). Another difference between the PSDs appears at around 80 Hz. The compressor-on PSD shows more of a heightened response spread over frequencies in the 79.5 to 81.5 Hz range. This is attributable to a rogue spectral peak that wanders within this range while the compressor is running. Figure 15 of Appendix B [16,17] shows the start-up of this activity just after DMT 1996 278/09:10, and Figure 33 of Appendix B [16,17] clearly shows this rogue spectral peak riding just above 80 Hz, and stopping as the compressor cycles off just after DMT 1996 284/19:40. The exact cause of this disturbance is unknown other than it is somehow tied to the BKV-3 compressor operation. Another interesting trait of the BKV-3 compressor is the periodicity of its intensity. Figure 15 shows that the RMS acceleration of this disturbance varies with a period of approximately 92 minutes (6 cycles in 9.2 hours), which is nearly the orbital period of Mir [19]. The fundamental frequency does not vary significantly during this time, only the intensity in the 23.9 to 24.4 Hz region.

In order to quantify the contribution of the primary microgravity disturbance sources during BCAT operations, the PSDs shown in Figure 14 were integrated over some frequency ranges of interest. The results of these calculations are tabulated below. Table 3 shows values calculated when the BKV-3 compressor was on, and Table 4 for when it was off. The first column in these tables specifies the frequency band considered. The second column displays the g_{RMS} value for the band. The third column shows the mean-square acceleration for the band (the square of the second column), the fourth column shows the percent contribution for the given frequency band to the overall mean-square acceleration value in the 0.01 to 100 Hz range and the fifth column shows the disturbance source. The frequency range for the last row of each table is the remainder of the spectrum not accounted for in the previous five rows.

Table 3. Quantification of strong spectral components with BKV-3 Compressor ON:

Frequency Range (Hz)	RMS Acceleration (g_{RMS})	Mean-Square Acceleration (g^2)	Contribution to Mean-Square Acceleration (%)	Disturbance Source
0.01 - 100.00	2.86e-03	8.16e-06	100.00	
23.84 - 24.31	1.32e-03	1.74e-06	21.38	BKV-3 compressor (fundamental)
47.71 - 48.42	6.33e-04	4.00e-07	4.90	BKV-3 compressor (2nd harmonic)
71.99 - 72.60	1.87e-04	3.51e-08	0.43	BKV-3 compressor (3rd harmonic)
96.14 - 96.68	1.69e-04	2.84e-08	0.35	BKV-3 compressor (4th harmonic)
39.51 - 40.41	2.09e-03	4.35e-06	53.34	Life-support fans
balance in 0.01 - 100	1.26e-03	1.60e-06	19.60	

Table 4. Quantification of strong spectral components with BKV-3 Compressor OFF:

Frequency Range (Hz)	RMS Acceleration (g_{RMS})	Mean-Square Acceleration (g^2)	Contribution to Mean-Square Acceleration (%)	Disturbance Source
0.01 - 100.00	2.42e-03	5.88e-06	100.00	
23.84 - 24.31	1.34e-05	1.78e-10	<0.01	Ambient
47.71 - 48.42	1.93e-05	3.74e-10	<0.01	Ambient
71.99 - 72.60	3.21e-05	1.03e-09	0.02	Ambient
96.14 - 96.68	9.55e-05	9.12e-09	0.16	Ambient
39.51 - 40.41	2.10e-03	4.40e-06	74.91	Life-support fans
balance in 0.01 - 100	1.21e-03	1.46e-06	24.91	

7.5 Life-Support Fans

Note from Tables 3 and 4, the large contributions of the life-support fans around 40 Hz to the overall microgravity environment. Reference [6] has shown that the signal in the 40 Hz region is comprised of a number of discrete frequency contributions. This suggests there are a number of fans, all operating in a narrow frequency region. These fans were on for the duration of BCAT operations. On occasion, the fundamental frequencies and 2nd harmonics deviate from their nominal values of about 40 and 80 Hz, respectively. An example of these spectral deviations is shown in Figure 16. It is not known what caused these variations, but changing loads on the station's power system may play a role.

7.6 Shuttle/Mir Docking

Previous PIMS Mission Summary Reports have documented the microgravity environment of the Shuttle/Mir complex, with data being recorded in the Kristall module of Mir [4,5,6], and in the SPACEHAB double module of the Shuttle Atlantis [20]. The docking of Atlantis during STS-81 provided the opportunity to record the docking event while the SAMS unit was located in the Priroda module of Mir. The change in the environment due to the docking of the shuttle is markedly different in the Priroda module, as compared with that previously recorded in the Kristall module.

Figure 17 shows a color spectrogram of SAMS data, acquired in the Kristall module during the STS-74 docking of Atlantis. Notice the appearance (hard-dock around t=22 minutes) of a red/yellow horizontal line at 17 Hz, and the yellow signature in the 20-22 Hz region, which turns on and off. These disturbance sources are the 17 Hz dither of the Orbiter's Ku-band communication antenna, and the Enhanced Orbiter Refrigerator/Freezer (EORF) located in the forward middeck locker. This plot shows that acceleration disturbances on one vehicle (Atlantis) can be transferred to the other vehicle (Kristall module of Mir). In addition to these higher frequency disturbances, also notice the change in structural modes (under about 5 Hz) around t=22 minutes. These new modes are a result of two independent vehicles forming a single vehicle, once the hard-mate was established. It should be noted that the Shuttle docks into the Kristall module's docking adapter, and the SAMS unit was located in the Kristall module for this data acquisition (i.e. the contact point and recording locations were close together).

Figure 18 shows a similar color spectrogram (created with the same spectrogram parameters), but this data was recorded in the Priroda module, and supported the STS-81 docking of Atlantis. The hard-mate of the two vehicles occurred around t=26 minutes into this plot. Notice the addition of a 3.75 Hz signal around t=26 minutes into the plot. The spectrogram shows an apparent absence of the 17 Hz and 20-22 Hz signals after the hard-mate of the vehicles.

Figure 19 shows a comparison of PSDs computed for the period prior to the docking (DMT 1997 015/06:35:30 - 015/06:54:30, red trace), and after the docking event, while the vehicles were docked (DMT 1997 015/07:01:30 - 015/07:20:30, blue trace). Both of these periods are 19 minutes in length, and spectral averaging [18] was used to compute these PSDs. Notice that the "while docked" trace shows a 17 Hz peak that is not shown in the "before docked" trace. Also evident in this figure is the broadband increase in the 2-11 Hz region after the hard-mate was established. Notice that the PSD shows some structural mode shifts and additions, due to the Orbiter. The comparison of the PSD traces is a more precise method by which the microgravity environment of the Shuttle/Mir complex may be distinguished from that of the Mir station itself.

Comparing the data from the two dockings, it may be seen that the microgravity disturbance additions due to the Shuttle Atlantis are more noticeable in the Kristall module than in the Priroda module. This conclusion is not unexpected, as it seems obvious that a location farther from a disturbance source will register the source at a lower level.

To help quantify this conclusion, typical levels recorded aboard the Shuttle for the Ku-antenna dither range from 40-100 μg_{RMS} in the 16.92 - 17.12 Hz region. The STS-74 docking transferred 61.2 μg_{RMS} to the SAMS recording location in Kristall. The STS-81 docking transferred 0.5 μg_{RMS} to the SAMS recording location in Priroda.

7.7 Cyclic Broadband Behavior around 90-100 Hz

While the SAMS TSH A (f_c=100 Hz) sensor head was located on the MIM locker front door, a cyclical broadband disturbance source was recorded in the 90-100 Hz frequency range. The color spectrogram (Figure 2 in Appendix B [16,17]) shows this disturbance clearly. Notice the recurrent changes from signal type 1 (green and yellow) to signal type 2 (yellow and red). A comparison PSD may be seen in Figure 20, showing PSDs computed from separate 20-minute intervals, plotted on the same graph. Notice that signal type 1 is more intense in the 90-95 Hz region, and signal type 2 is louder in the 95-100 Hz region. This switching in the signals is seen throughout the data recorded in the MIM location, and may also be seen in [6]. When the sensor head was relocated to the BTS location and data recorded (see Figure 38 in Appendix B [16,17]), there is no further evidence of either of these two signal types. This lack of evidence could be due to the short recording times at the BTS location (typically 30-60 minutes in duration) obscuring the event of interest.

Since this cyclic behavior continues throughout crew sleep periods, it is unlikely that it is related to activity of the MIM facility (as the facility would have most likely been turned-off during sleep periods). Given the constant-on nature of these two signals, it is possible these are related to a life-support or similar "always on" system on Mir (or more specifically, in Priroda). If so, then their lack of appearance at the BTS location (assuming that the short recording times didn't prohibit their detection) suggests that the acceleration transfer path does not include the BTS panel. This is a prime example of how accelerations may transfer to one location, but not to another.

7.8 Spectrogram Analysis of a 24 hour period

The microgravity environment of a vehicle in a low-Earth orbit (such as Mir) is a complex phenomenon. Many factors can introduce acceleration disturbances, such as experiment operations, life support equipment and crew activity. Other contributions to the overall environment include aerodynamic drag, gravity gradient and rotational effects of the craft's motion around the Earth. These other contributors (all in the low-frequency regime) are not accurately measured by SAMS, and are excluded from further discussions.

Since the higher-frequency disturbances (equipment operation, crew activity, etc.) are not all active at the same time (not all of the on-board experiments are powered-up at the same time), the higher-frequency acceleration regime is very dynamic, and is dependent upon what equipment is operating at any given time. For this reason, no single day's worth of data can truly represent the total environment, but the analysis of the accelerometer data with respect to day-to-day operations can yield a number of interesting observations.

Figures 21 and 22 show SAMS color spectrograms for a 24 hour period (DMT 1996 277/00 - 278/00), for TSH A (f_c=100 Hz), and TSH B (f_c=10 Hz), respectively. Note that the colorbar limits for these two plots are not the same, so a direct color-to-color comparison would be invalid. Some features to note (some of which have been discussed previously in this report) include the BKV-3 compressor (24 Hz and harmonics), life-support systems (40 Hz and harmonics), structural modes (most noticeable in the frequency regime below 2 Hz), crew exercise (the specific frequencies depends on crew member and type of exercise, but usually causes increased structural mode excitation), and the unknown cyclic broadband behavior in the 90-100 Hz region.

Figure 21 shows that the BKV-3 compressor was turned-on a little after 10 am (DMT), and was turned-off a little before 7 pm (DMT). Other features to note are the crew exercise between the DMT hours of 12 - 14 and between 18 - 20. These two periods (afternoon and evening) of exercise, and the multiple exercise activities within each period (3 distinct activities for the first period, and 2 activities for the second period) show that each crew member may exercise multiple times in a single 24-hour period.

Figure 22 shows a significantly quieter low-frequency environment between hours 0 - 8 (DMT 1996 277/00 - 277/08). This time period corresponds with crew sleep, when microgravity disturbances caused by crew-supervised experiments, and crew activity in general, are minimal to non-existent. Although this quieter period may also be seen in Figure 21, Figure 22 shows it much more clearly, since this figure concentrates the focus on the frequency regime below 10 Hz. Some disturbances are seen in Figure 22 which are not believed to be typical of the Mir microgravity environment. These include the ramping frequency from 6 Hz at DMT 1996 277/00:00 to 10 Hz at DMT 1996 277/02:30, and the 7.5 and 8 Hz traces from DMT 1996 277/10 - 277/18. All of these signals are of unknown origin.

7.9 Unknown Disturbances: TSH A (f_c=100 Hz)

The correlation of accelerometer data with known events can be a difficult task, especially with little-to-no timeline information. Even detailed timeline information is not always sufficient, as experiment-induced acceleration disturbances are not necessarily all concentrated during turn-on and turn-off times. Further, timelines usually list only experiments, but not power cycling to Mir systems (such as life-support fans, dehumidifiers, CO_2 removal systems, etc.). As exact information is virtually impossible to obtain, the origin of many microgravity disturbances remains unknown. This section will attempt to characterize some (but not all) of these unknown events.

Figure 7 in Appendix B [16,17] shows two events of unknown origin. The first is an unusually large number of broadband disturbances (vertical yellow and/or red stripes) between DMT 1996 276/09:40 and 276/11:20. The second is a signal which starts around 65 Hz at DMT 1996 276/10:20, and decreases exponentially until it disappears at 57 Hz around DMT 1996 276/12:08.

Figure 22 in Appendix B [16,17] shows two unknown signals. The first starts around 70 Hz at DMT 1996 280/08:20, and decreases to approximately 56 Hz when data recording ceased shortly after DMT 1996 280/11:00. The second signal begins around 42 Hz, and increases to 45 Hz in the time period from DMT 280/09:30 through the end of data recording. Since these signals start at different times, they are believed to be independent phenomenon, and not directly related to each other. Of course, if they are different aspects of a single operation or experiment, then they could be related, but having different origins.

Figure 23 in Appendix B [16,17] shows a signal which appears to be recording similar to the lower frequency signal mentioned above. The signal is present at 42 Hz when data is turned-on around DMT 1996 282/10:45, and increases in frequency to 45 Hz, when it abruptly ceases around DMT 1996 282/11:30.

Figure 24 in Appendix B [16,17] shows a signal starting at DMT 1996 282/17:05 around 98 Hz. This signal slowly increases to just over 100 Hz, and abruptly stops at DMT 1996 282/18:35. The sudden appearance of this signal is coincident with a "slight deviation" in a known life-support frequency around 44 Hz, showing along with a "slight deviation" in its harmonic around 84 Hz. The initial appearance of this signal looks similar to compressor turn-on signals which have been previously studied by the PIMS group [6,21,22]. The turn-off of this signal appears to correspond with another (similar looking) "slight deviation" in the 44 and 88 Hz signals. This 98-100 Hz signal may be related to the life support systems (due to the coincident turn-on and turn-off times), but no definite conclusions can be reached at this time.

Figures 32, 33, and 35-37 in Appendix B [16,17] show a signal of unknown source which varies from about 79 to 81 Hz. The signal seems to stem from the 80 Hz life-support fan harmonic, and seems to only be active during active periods of the BKV-3 (24 Hz water dehumidifier) compressor. For example, variations in the 80 Hz signal begin with the start of the 24 Hz BKV-3 pump in Figure 32, and abruptly cease with the end of the BKV-3 use in Figure 33. Similar on-off correlation may be seen by analyzing Figures 32-37 in Appendix B [16,17]. It is possible that this 79-81 Hz variable signal is a harmonic of a signal in the 40 Hz region.

Figure 49 in Appendix B [16,17] shows a number of intermittent disturbances in the 85-93 Hz region. In fact, these signals have been intermittent in much of the previously recorded data (Figures 38-49), although the gaps are much more noticeable in Figure 49 due to the longer duration of this data period. These signals are of unknown origin, but have only appeared in the SAMS data recorded at the BTS location (panel 122), and not from the data recorded at the MIM location (400 plane). Whether or not this disturbance is localized is unknown, but it appears that there is no transmission path from the source to the sensor head at the MIM location.

An unidentified sequence of events took place around the following times: DMT 1996 276/01, 278/01, 284/21, 284/23, and 285/17. Figure 23 is representative of this series of events. As seen, five strong disturbances at approximately 40.6, 42.2, 43.8, 45.4, and 47.1 Hz started at about DMT 1996 276/00:46:42 and lasted for slightly less than 40 minutes. These are somewhat variable in frequency and are accompanied by a pair of strong disturbances at about 77.5 Hz that appear just before the 20 minute mark and just after the 50 minute mark, lasting for approximately 1.5 minutes each, and separated by about 32 minutes.

As shown in Figure 24, when the 5 disturbances in the 40.2 to 50 Hz range are present, the g_{RMS} level in this frequency range more than doubles, going from about 430 μg_{RMS} to about 1,100 μg_{RMS}. Similarly, when the brief disturbance at around 77.5 Hz is present, the g_{RMS} level in the 76.8 to 78.5 Hz range increases by nearly six times, going from about 68 μg_{RMS} to about 400 μg_{RMS}. The origin of these disturbances is as yet unknown, but the start times relative to crew sleep periods suggest unattended operations (i.e. they occur during crew-sleep periods).

One other significant unknown appears at least 8 times during the time frame from DMT 1996 274/18:30 to 285/20:30. It is a transitory spectral peak at about 19 Hz and is seen in Figure 4 of Appendix B [16,17], starting just before DMT 1996 275/15:00. It has a nominal duration of about 4.5 minutes and the RMS acceleration imparted is 40-50 μg_{RMS} in the 19.3 to 19.6 Hz frequency range.

8. Summary of Findings

This report presents analyses of the SAMS data recorded on the Mir Space Station from September 1996 to January 1997. During NASA Increment 3, the SAMS supported both MiSDE and BCAT.

The firing of the Progress vehicle engine while the vehicle was attached to Mir produced accelerations in the $+Z_{h,A}$, and $+Z_{h,B}$ directions of approximately 400 μg for the 6.5 minute duration of the engine burn. Both Z_h-axes correspond to the $-X_B$ axis.

During the Mir attitude control thruster firing in support of MiSDE, acceleration peaks exceeding 1000 μg were seen, primarily, on the $X_{h,B}$ and $Y_{h,B}$ plots. A color spectrogram of this event showed an increase in overall during this event.

A color spectrogram of crew treadmill exercise showed that a number of structural modes below 2 Hz were excited. Also, frequencies of 2.7, 4.0, and 4.3 Hz appeared and disappeared during the exercise period. These frequencies are assumed to be caused by faster running on the treadmill. Plots of acceleration versus time clearly show the periodicity of the acceleration signals in all three axes. This regular periodicity is indicative of treadmill-type exercise.

During BCAT operations, the microgravity environment in the 0.01 to 100 Hz range was dominated by life-support equipment disturbances in the 40 to 45 Hz and 80 to 90 Hz ranges. Occasionally, when ambient humidity conditions dictated, the BKV-3 compressor, which is part of the Core Module dehumidifier system, turned on. Compressor operation results in significant disturbances at a fundamental frequency of about 24 Hz along with disturbances at the 2^{nd} and 4^{th} harmonics.

The docking of STS-81 provided the opportunity to record the event with the SAMS installed in the Priroda module instead of in the Kristall module as had been done during previous missions. The color spectrogram of the STS-81 Shuttle/Mir docking shows that a disturbance of 3.75 Hz occurred, coincident with the hard-mate of the vehicles. The spectrogram did not show the appearance of the 17 Hz dither of the Orbiter's antenna or the LSLE R/F frequency of 20-22 Hz. A PSD plot of before and after docking shows the presence of a weak 17 Hz signal, as well as increased amplitudes in the 2-11 Hz region after the hard-mate. Under some circumstances, a PSD plot comparing the environment before and after an event may reveal information about the microgravity environment that a color spectrogram does not readily show.

When the SAMS TSH A sensor head was attached to the MIM locker front door, a cyclical broadband disturbance in the 90-100 Hz was clearly seen in color spectrograms. As was shown using a PSD plot, the 90-100 Hz range was divided into two signal types: signal type 1 was more intense in the 90-95 Hz region, and type 2 was more intense in the 95-100 Hz region. When the sensor head was moved to the BTS location, neither signal type was in evidence. This suggests that either the recording at the BTS location was not of sufficient duration to observe this disturbance, or the BTS panel was not in the transfer path of the disturbance. The latter being true would illustrate how acceleration disturbances can be measured at one location, but not another.

The color spectrogram of a 24-hour period showed that low frequency disturbances were significantly less intense during the crew sleep period than during crew awake periods. The 24 Hz frequency and harmonics of the Mir BKV-3 compressor and the 40 Hz frequency and harmonics of Mir life-support systems are clearly seen. Previous analyses of SAMS data have shown these disturbances to be present in the Kvant, Kristall, and Priroda modules, and it is believed that these disturbances occur station-wide. PIs with experiments that are sensitive to microgravity disturbances at these frequencies should use caution about running such experiments on Mir without vibration isolation.

Correlating accelerometer data with known events can be a difficult task, due in part to a lack of detailed timeline information. However, detailed timeline information is not the whole solution, as timelines usually list experiment start and stop times only, and not power cycling to Mir on-board equipment and systems. On this Mir mission, a number of disturbances of unknown origin were recorded by the SAMS TSH A sensor head. A significant disturbance was observed at 19 Hz. All of these disturbances have been examined, and in some cases possible origins of the disturbance have been suggested. As data from future missions are examined and data from past missions re-examined, solutions to these puzzles may become apparent.

9. References

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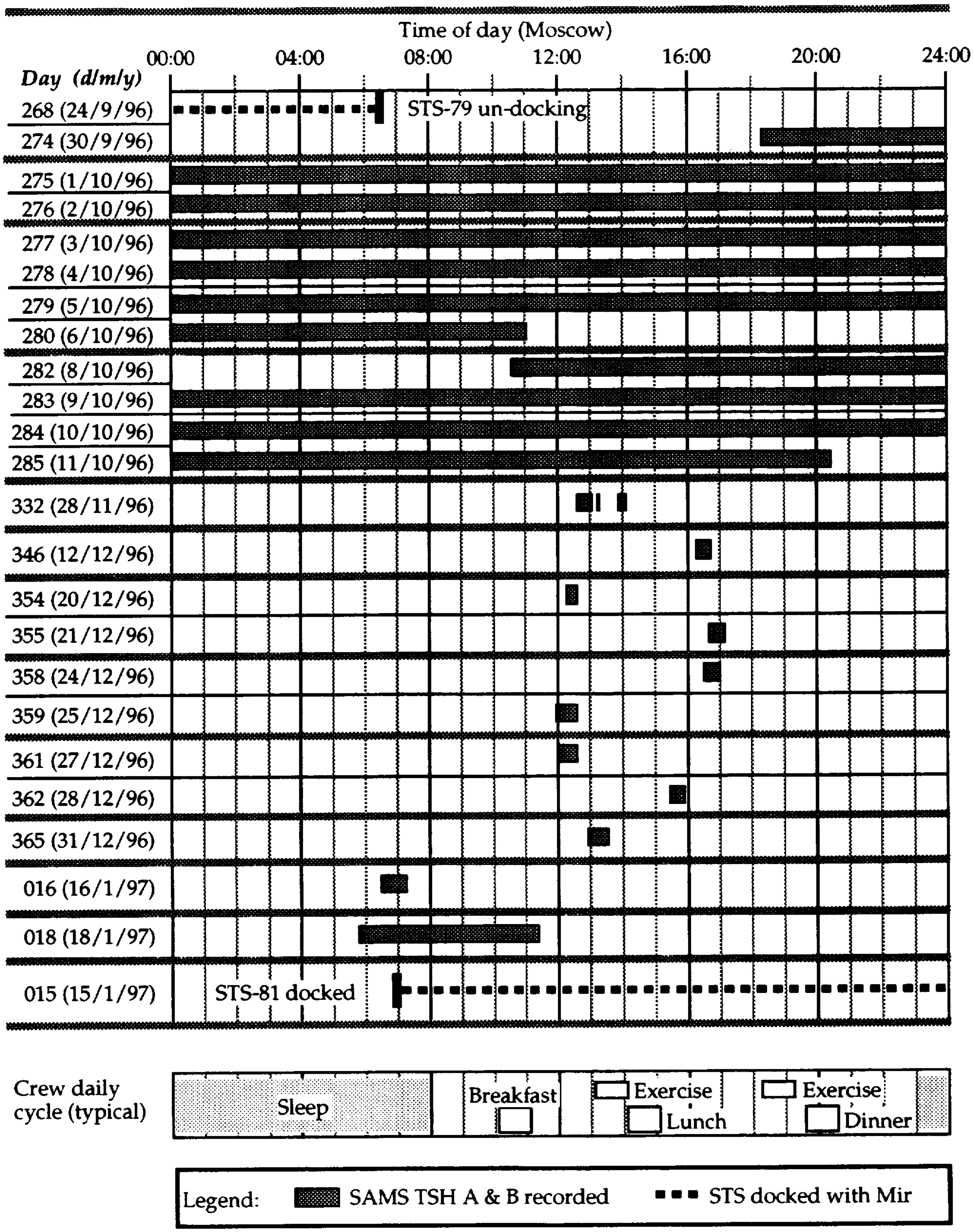
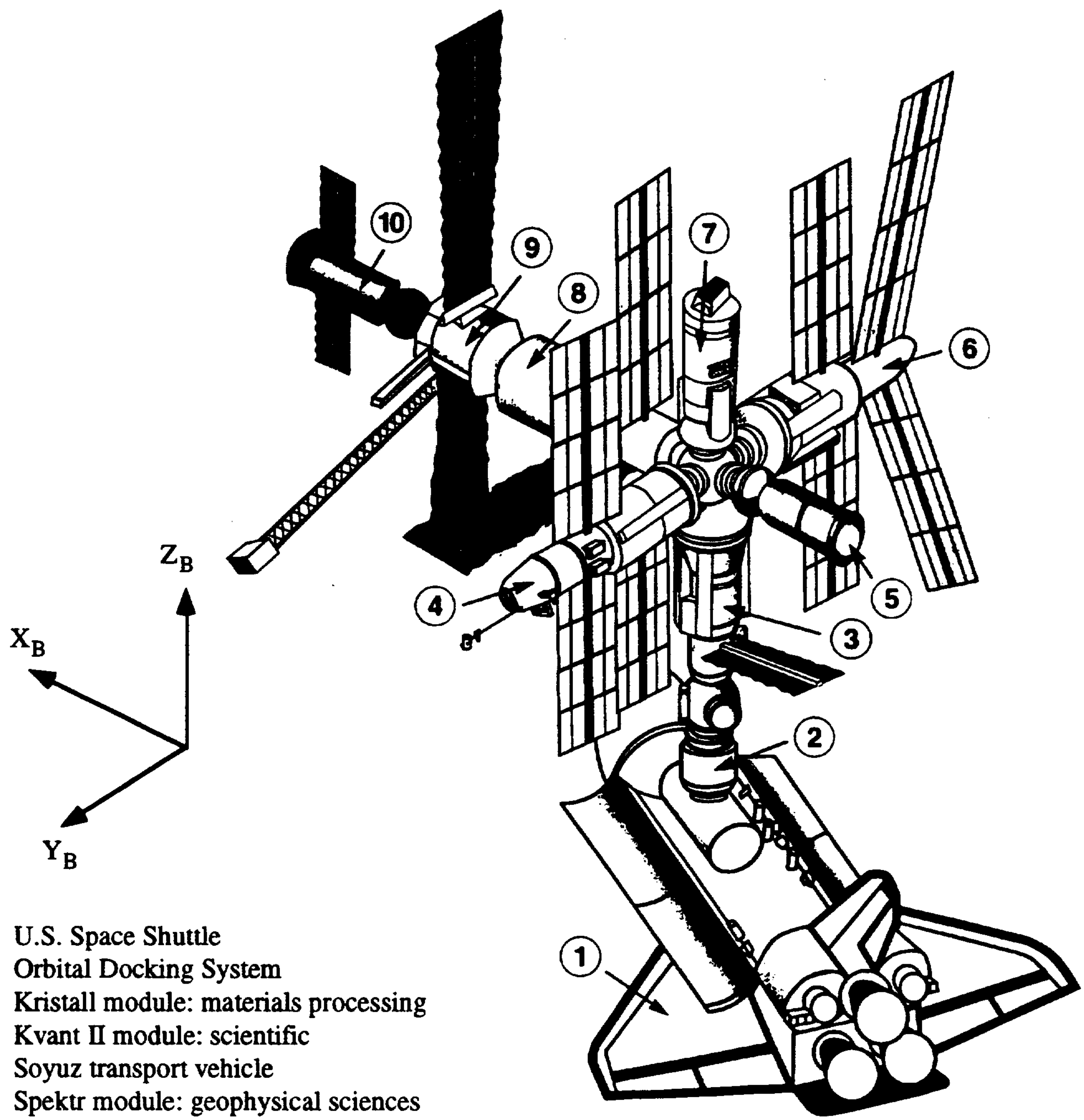


Figure 1. SAMS data coverage for this mission.



1) U.S. Space Shuttle
2) Orbital Docking System
3) Kristall module: materials processing
4) Kvant II module: scientific
5) Soyuz transport vehicle
6) Spektr module: geophysical sciences
7) Priroda Module: Earth remote sensing
8) Core module: habitation, power, life support
9) Kvant module: astrophysics
10) Progress vehicle

Figure 2. Typical Mir configuration with docked Orbiter.

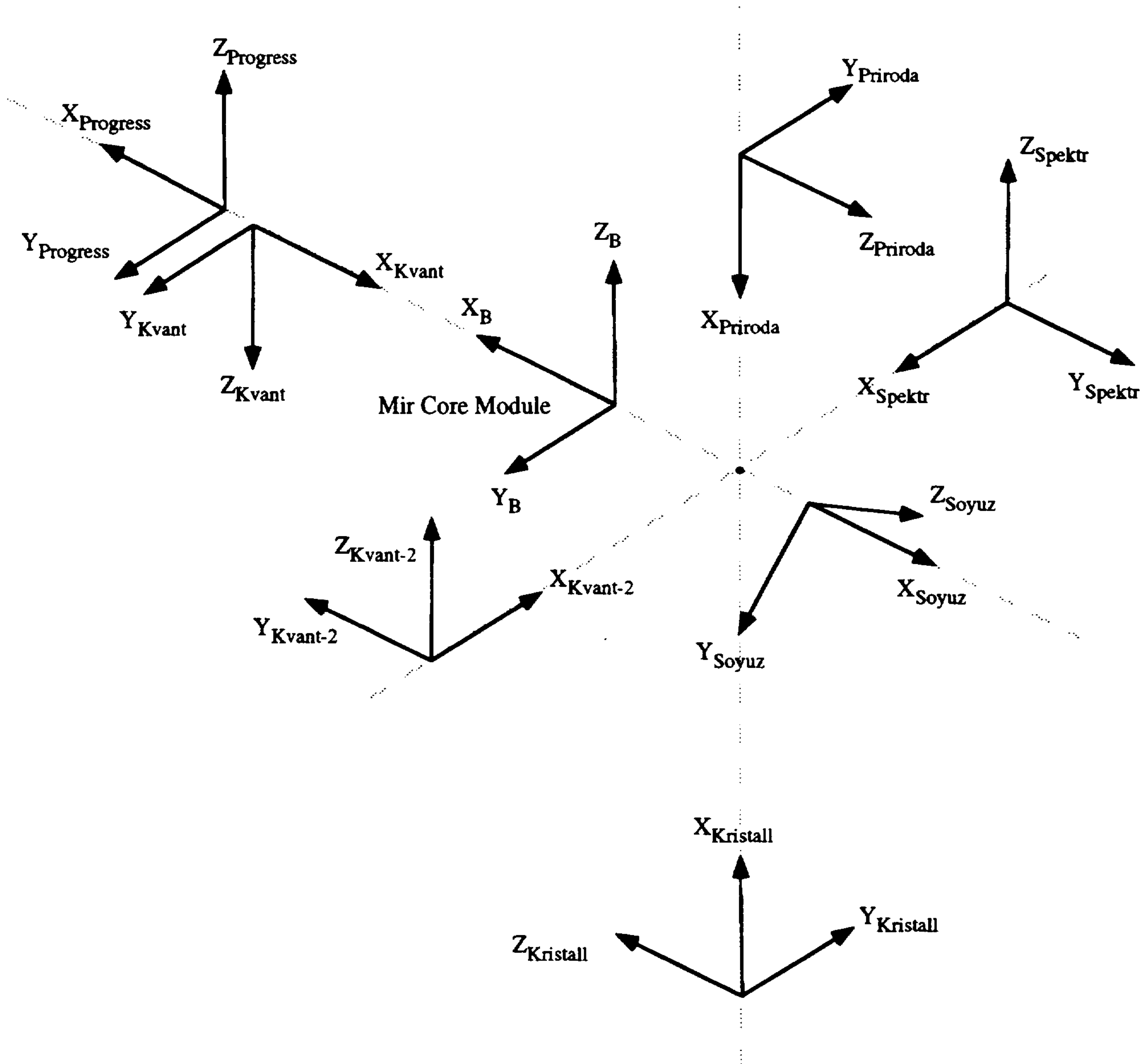


Figure 3. Mir module orientations.

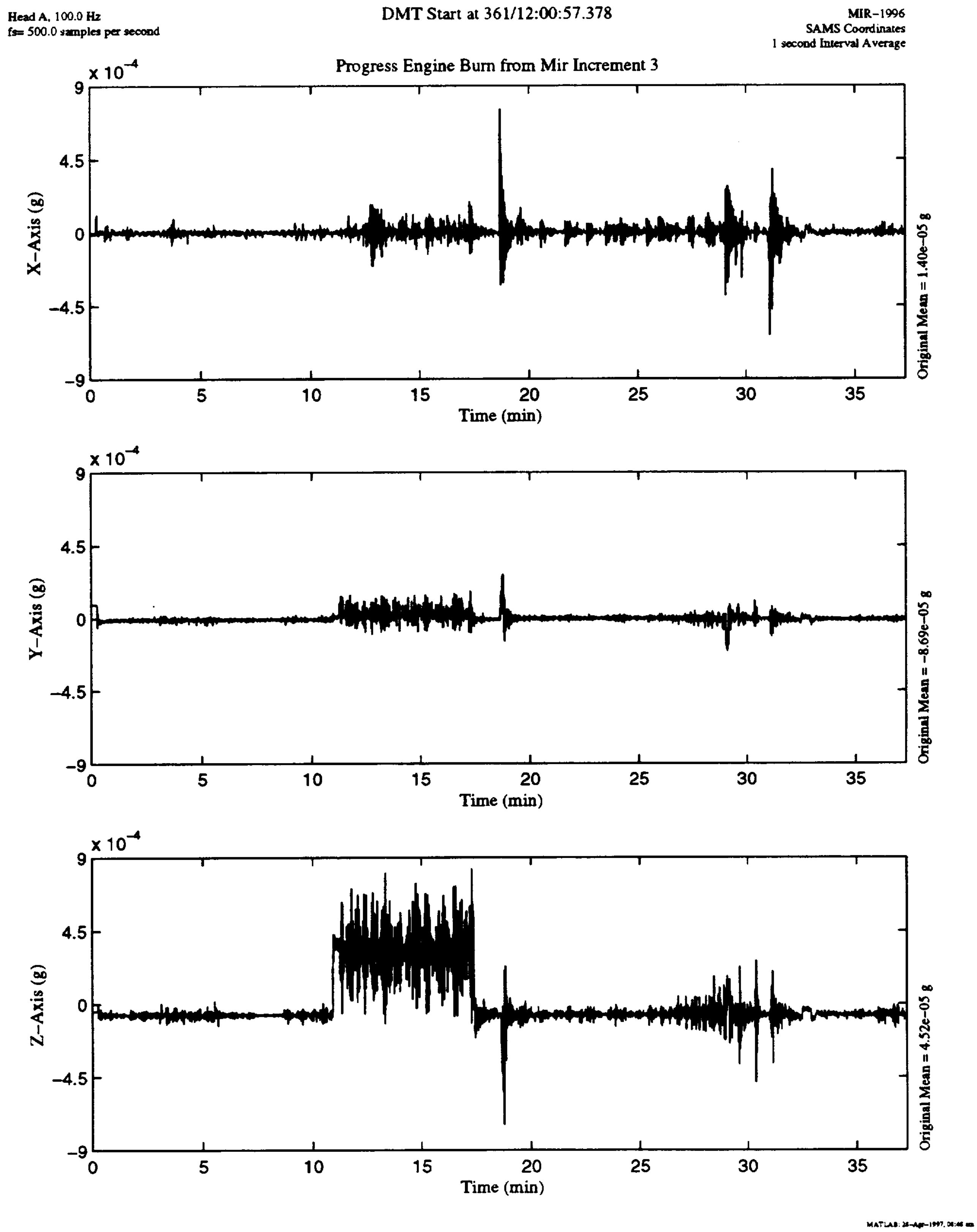


Figure 4. Progress Engine Burn: SAMS TSH A (f_c=100 Hz) Acceleration versus Time.

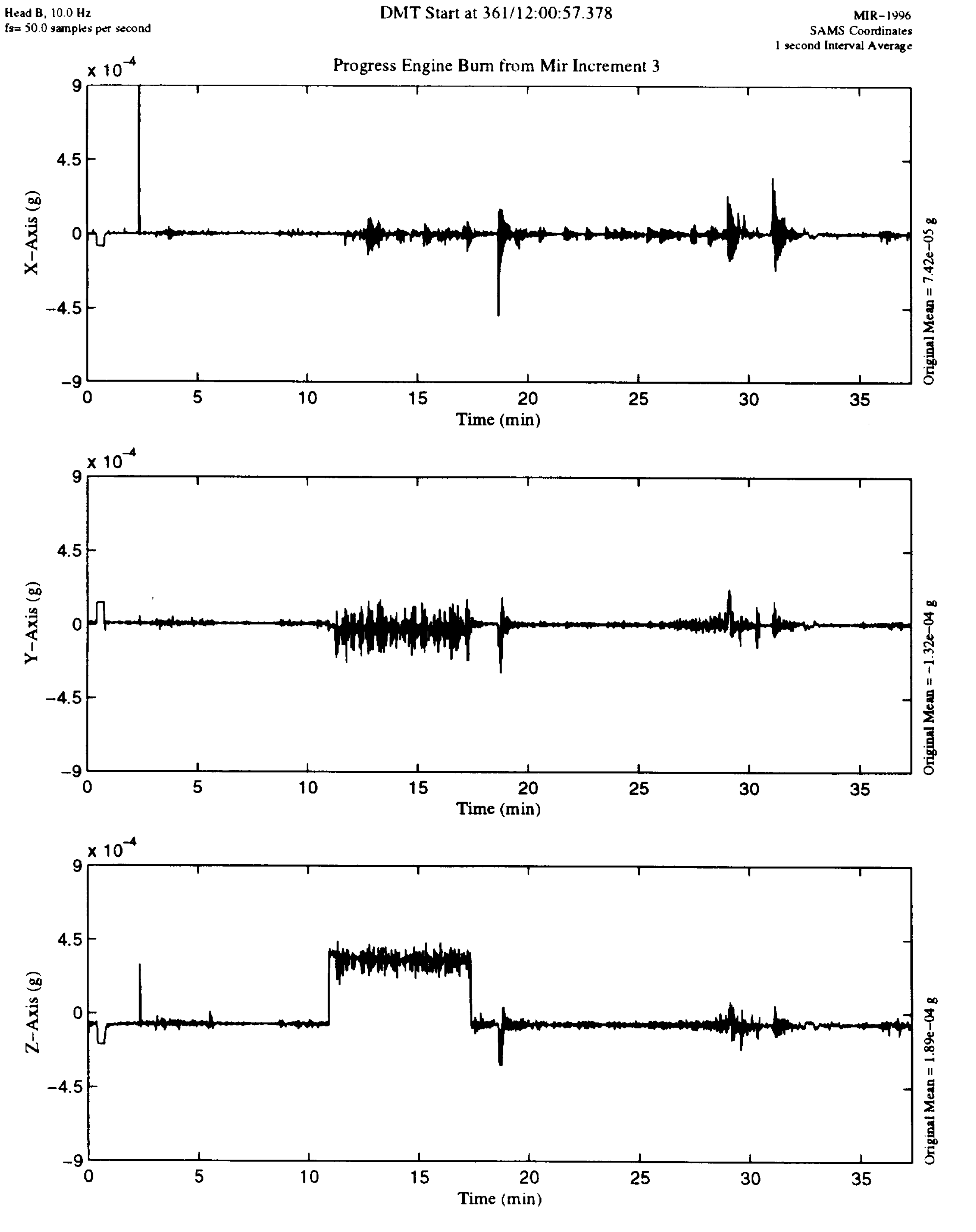


Figure 5. Progress Engine Burn: SAMS TSH B (f_c=10 Hz) - Acceleration versus Time.

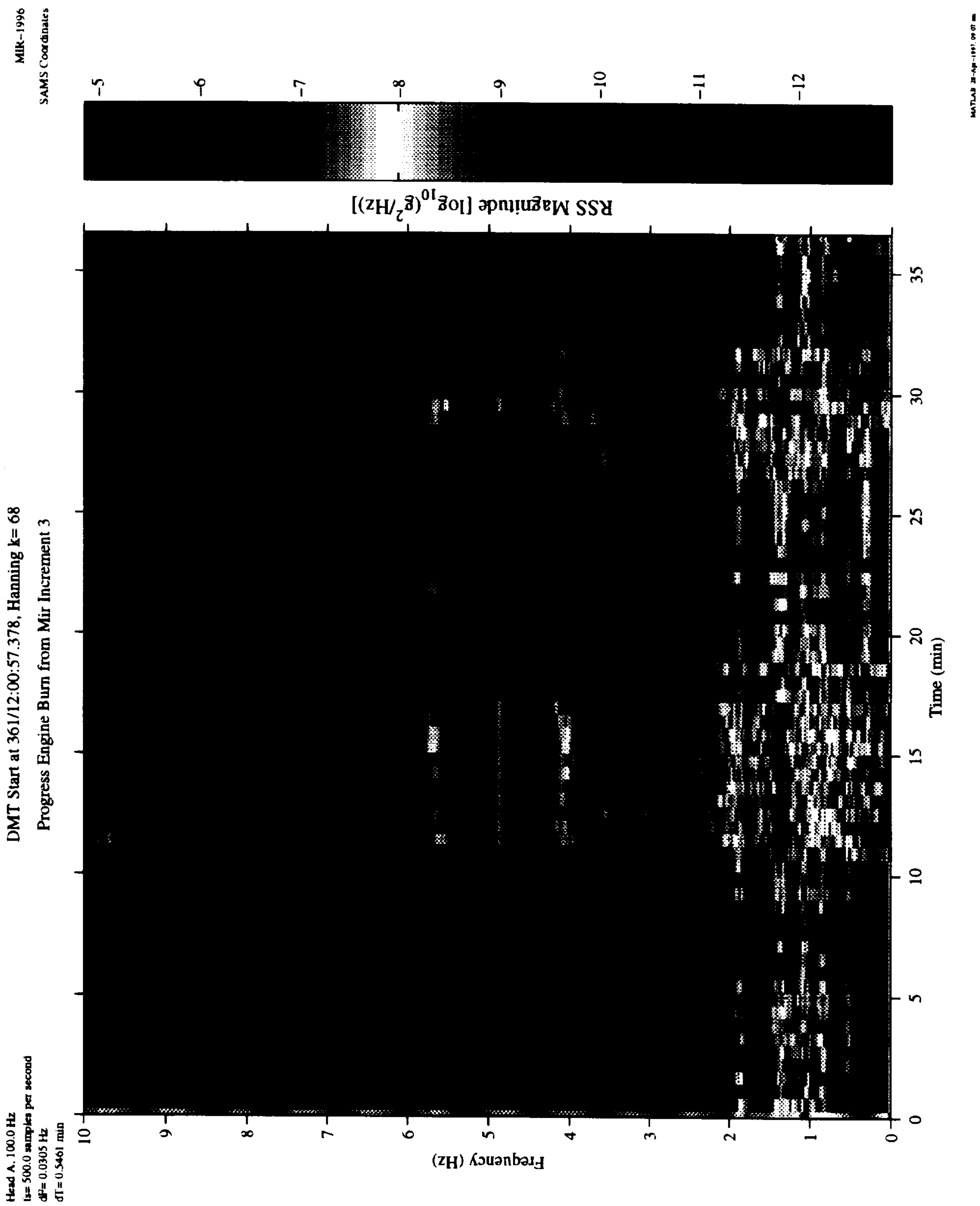


Figure 6. Progress Engine Burn: SAMS TSH A (f_c=100 Hz) - Color spectrogram.

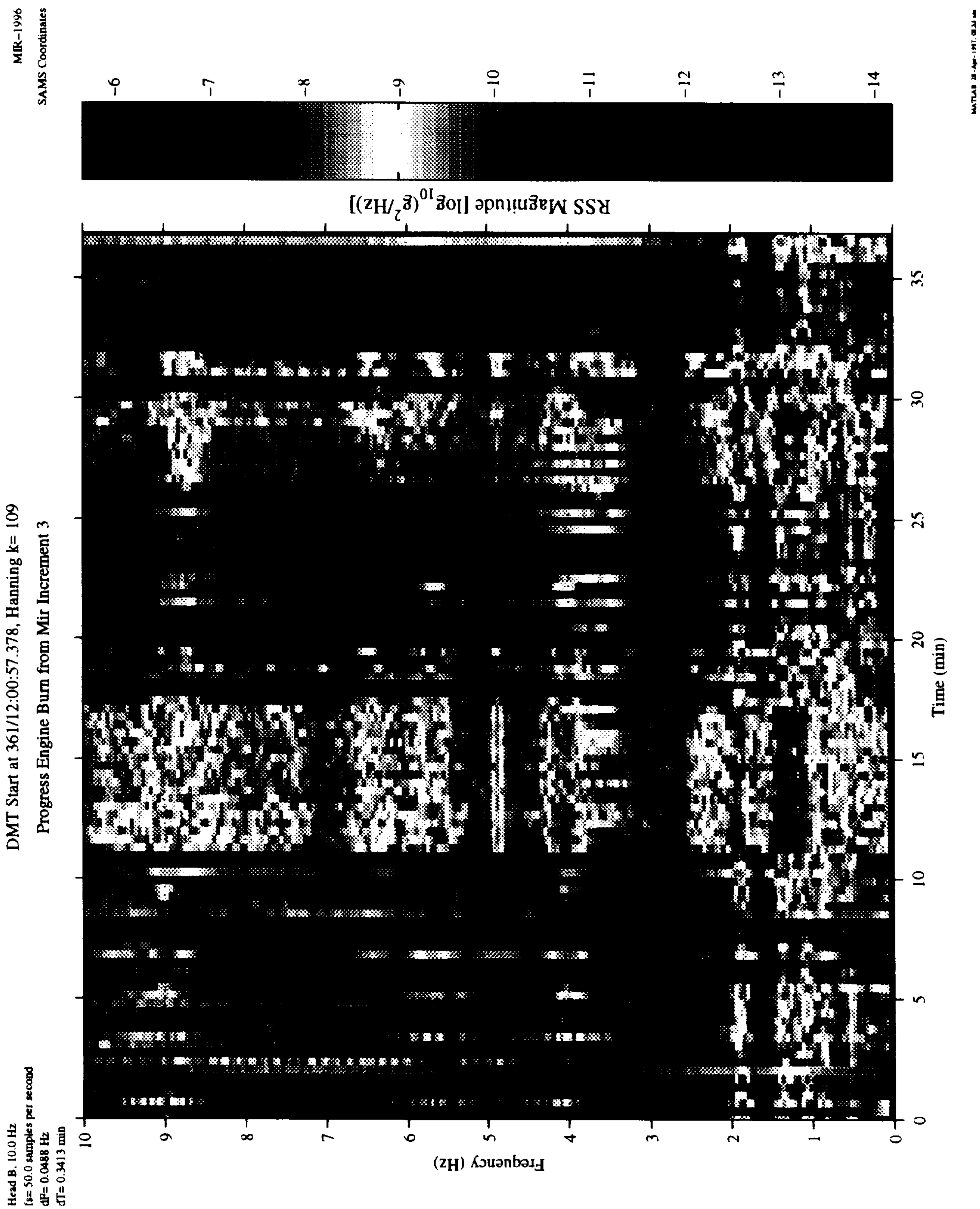


Figure 7. Progress Engine Burn: SAMS TSH B (f_c=10 Hz) - Color spectrogram.

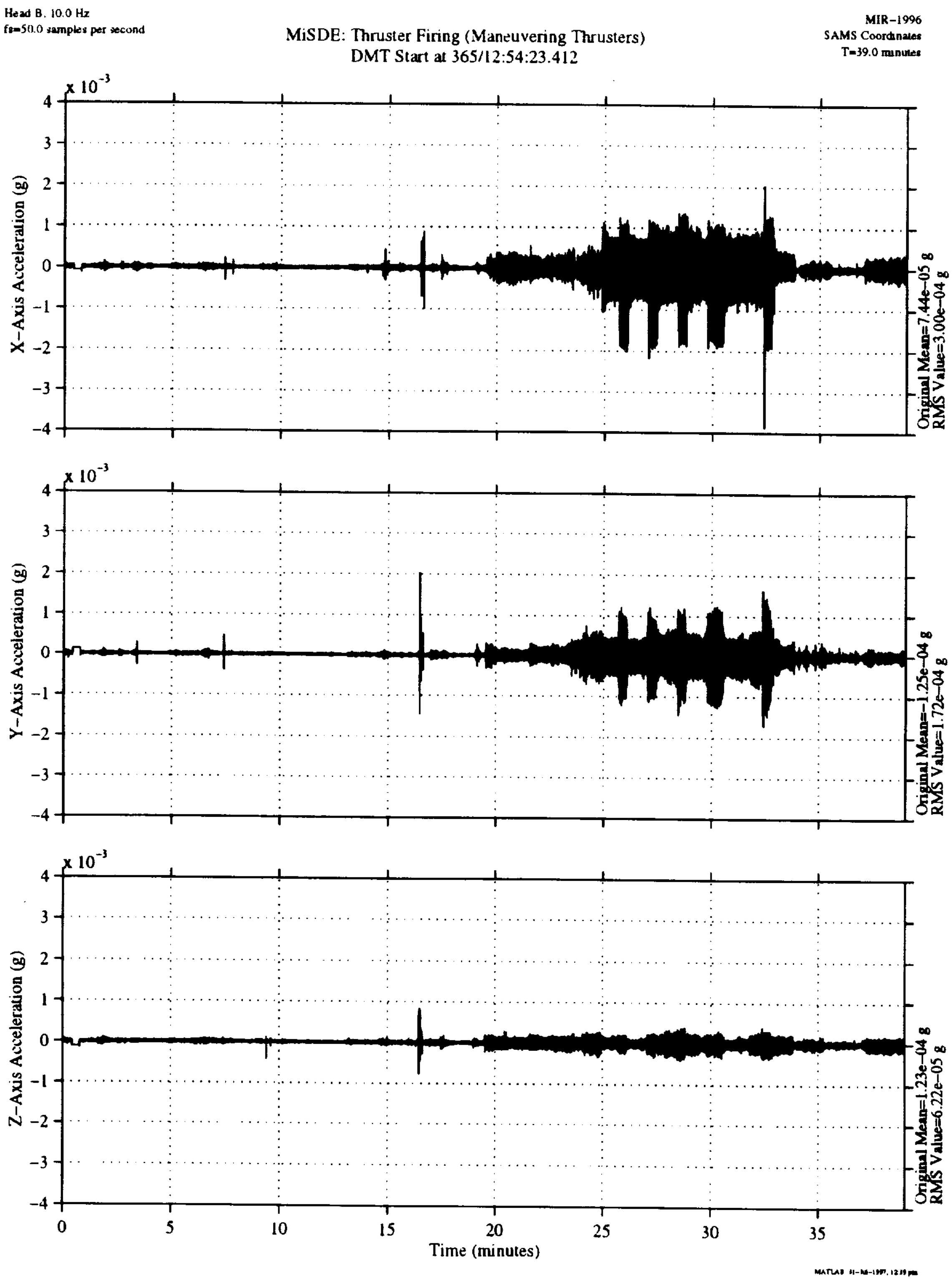


Figure 8. MiSDE Maneuvering Thruster Firing: SAMS TSH B (f_c=10 Hz) - Acceleration versus Time.

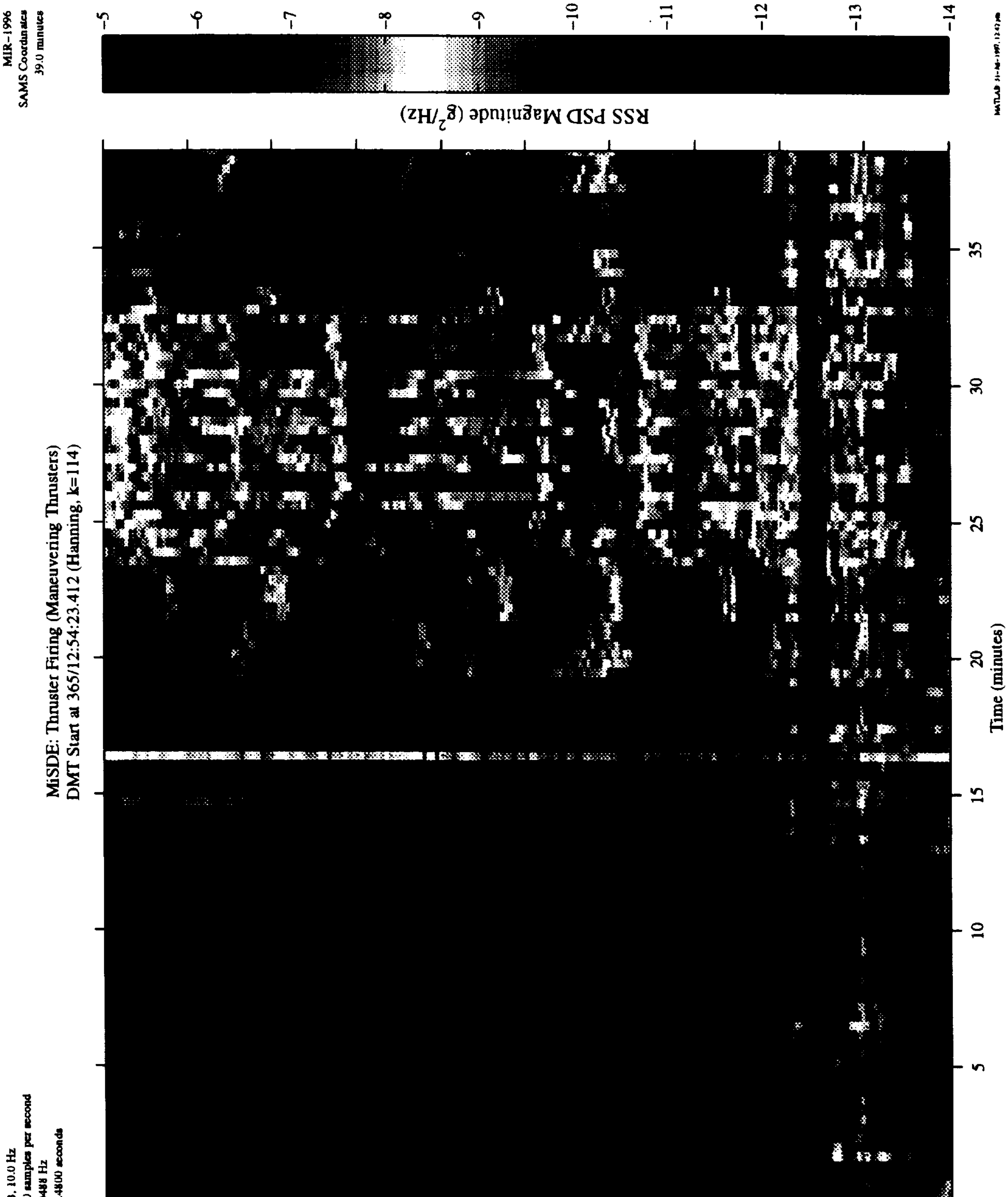


Figure 9. MiSDE Maneuvering Thruster Firing: SAMS TSH B (f_c=10 Hz) - Color spectrogram.

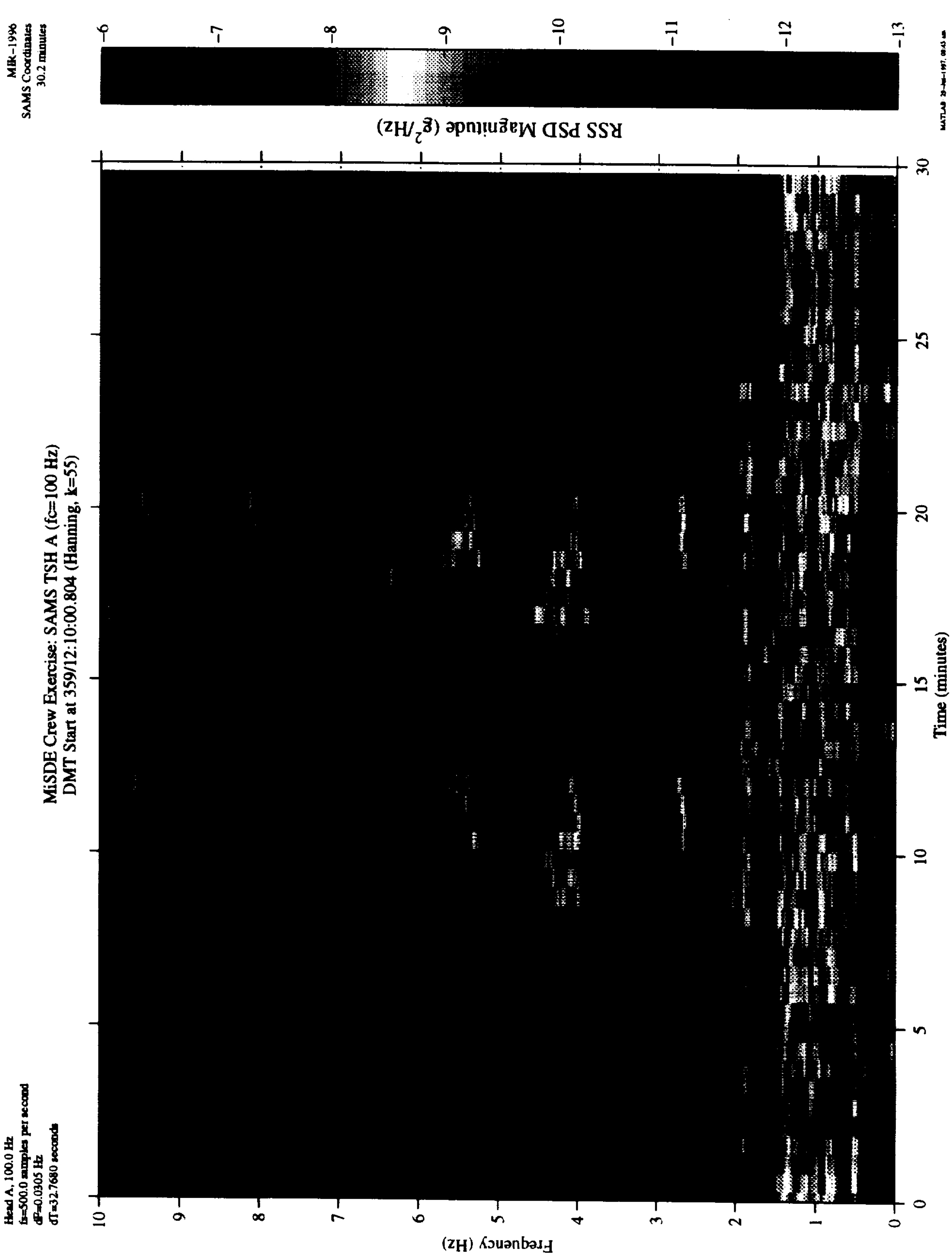


Figure 10. MiSDE Crew Exercise test: SAMS TSH A (f_c=100 Hz) - Color spectrogram.

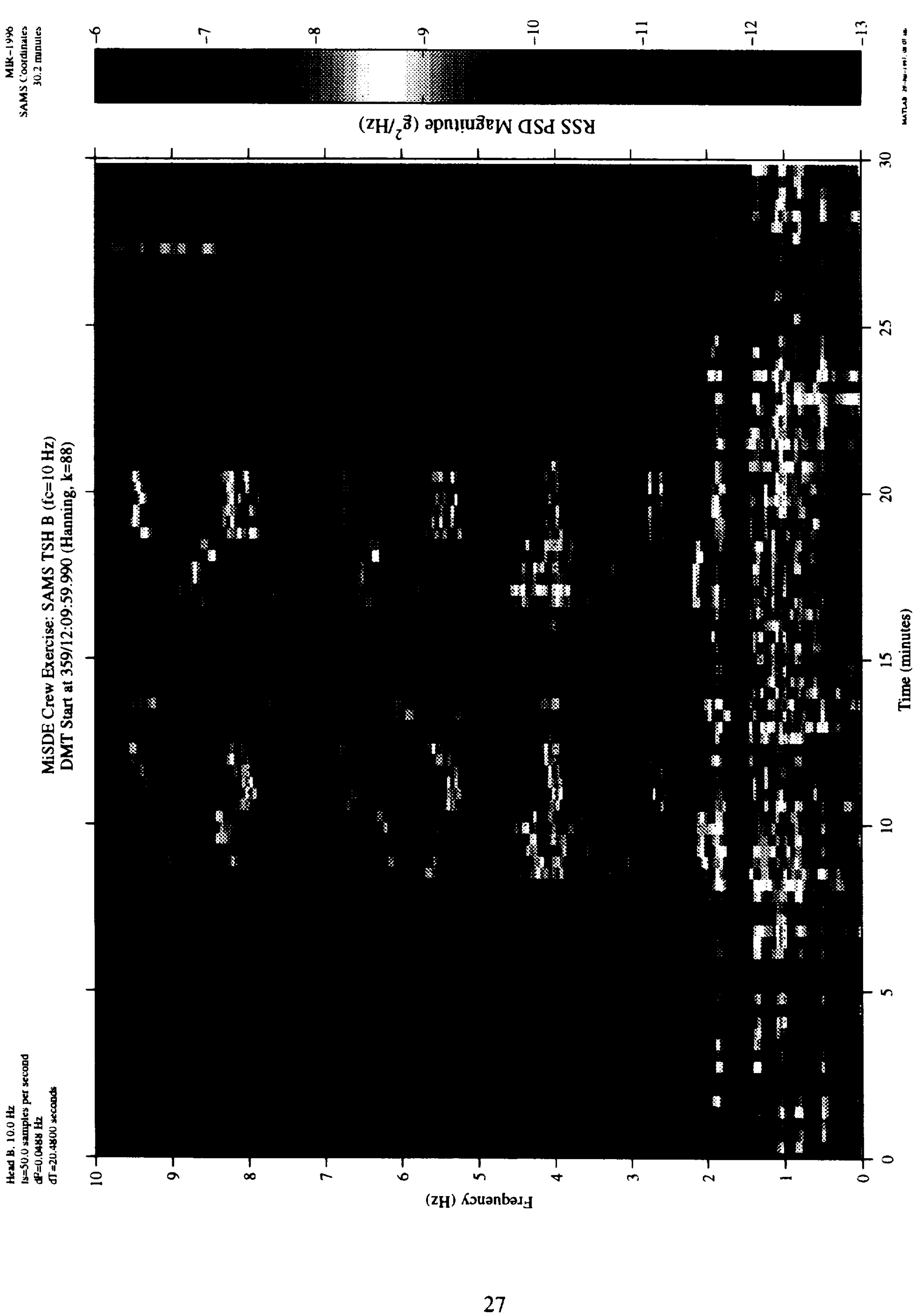


Figure 11. MiSDE Crew Exercise test: SAMS TSH B (f_c=10 Hz) - Color spectrogram.

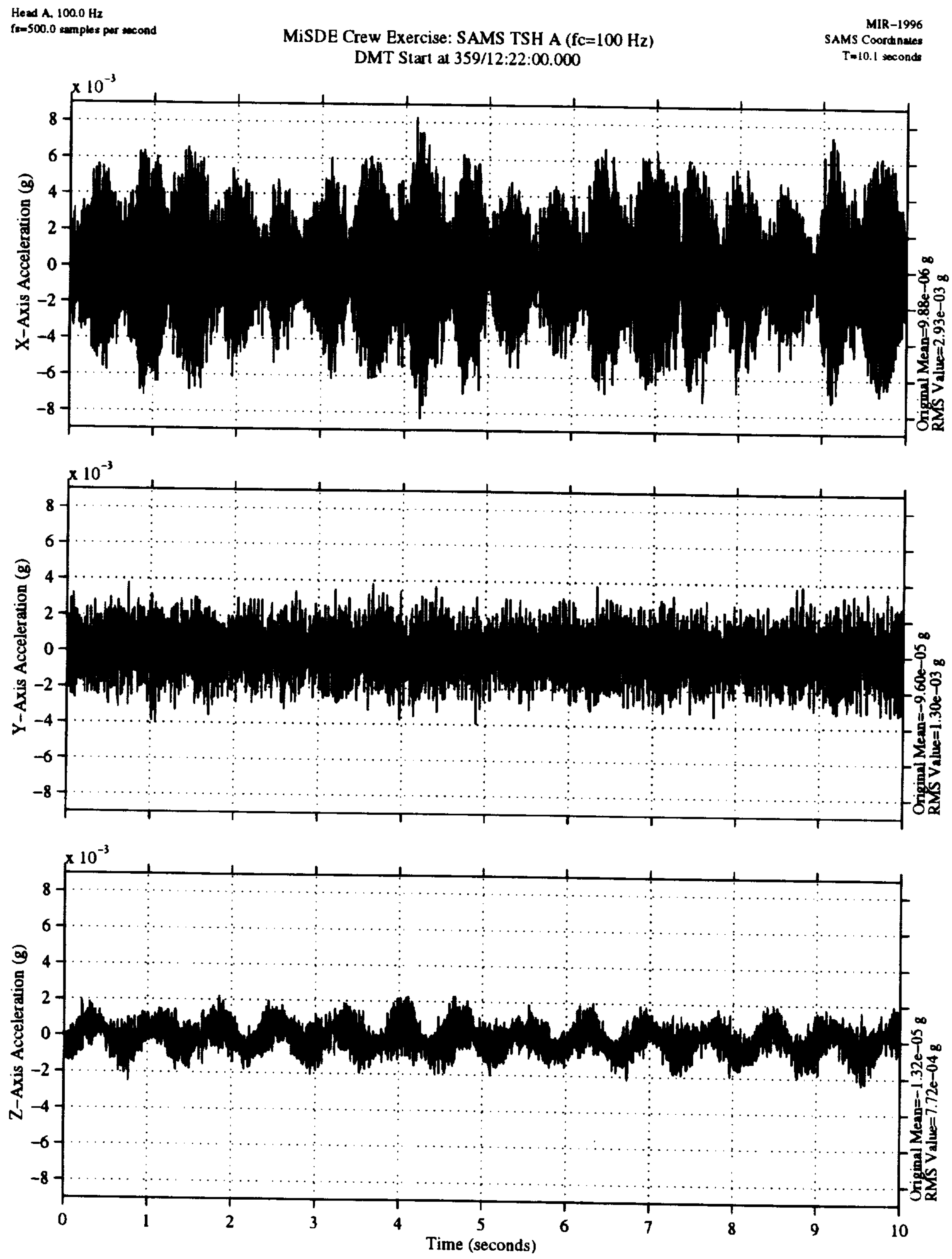


Figure 12. MiSDE Crew Exercise test: SAMS TSH A (f_c=100 Hz) - Acceleration versus time.

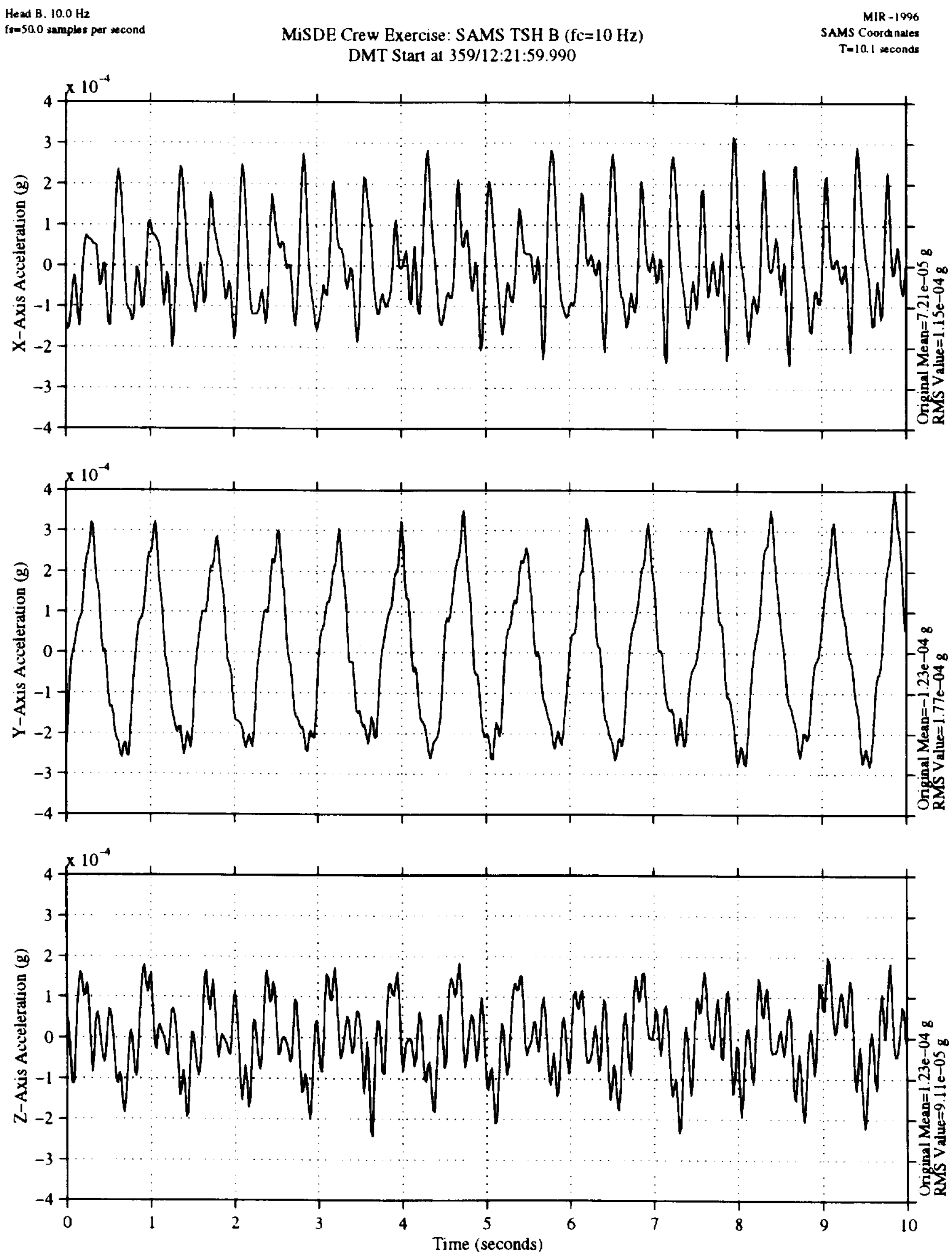


Figure 13. MiSDE Crew Exercise test: SAMS TSH B (f_c=10 Hz) - Acceleration versus time.

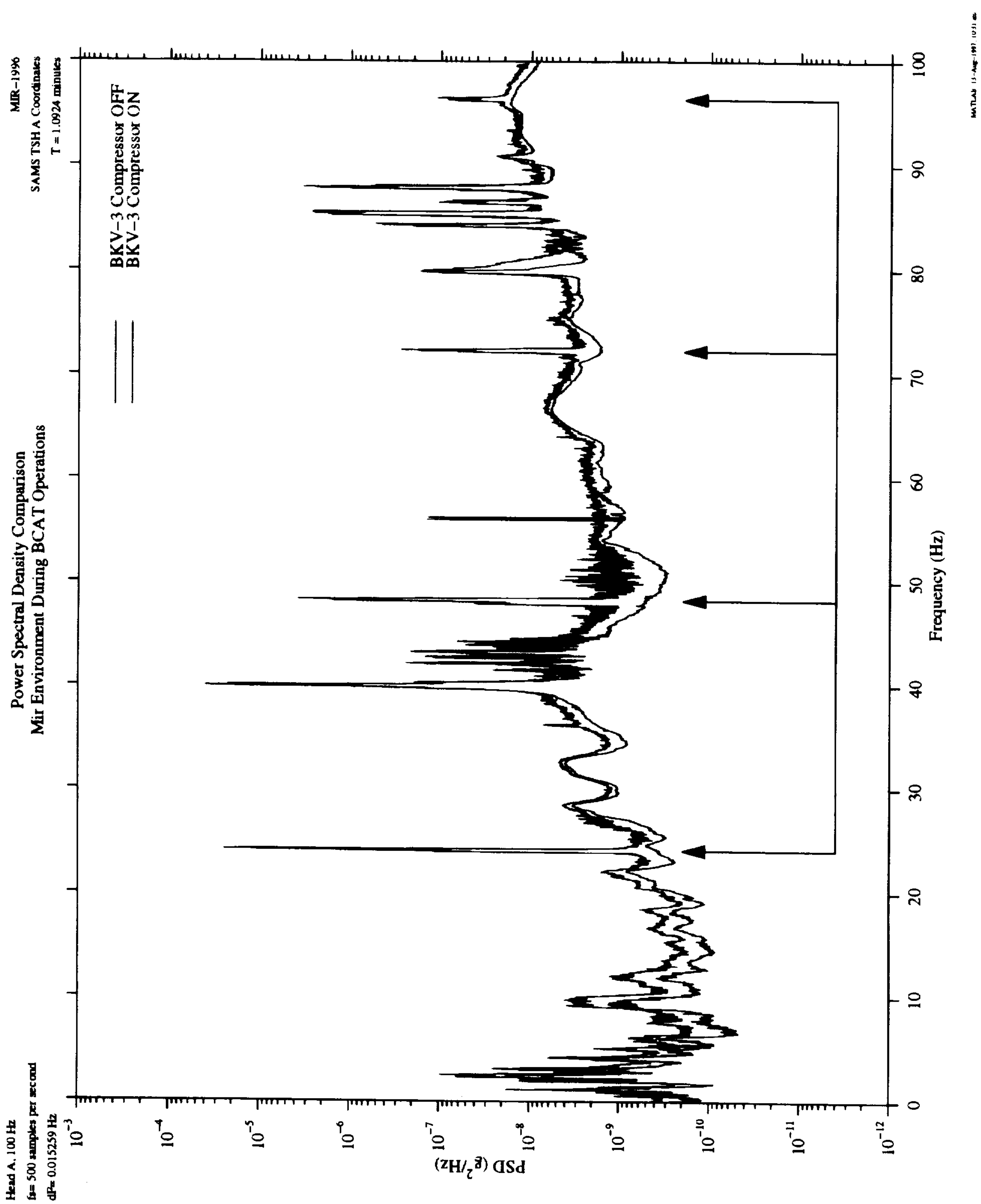


Figure 14. Comparison of power spectral densities for periods during BCAT operations when the BKV-3 compressor was ON versus OFF.

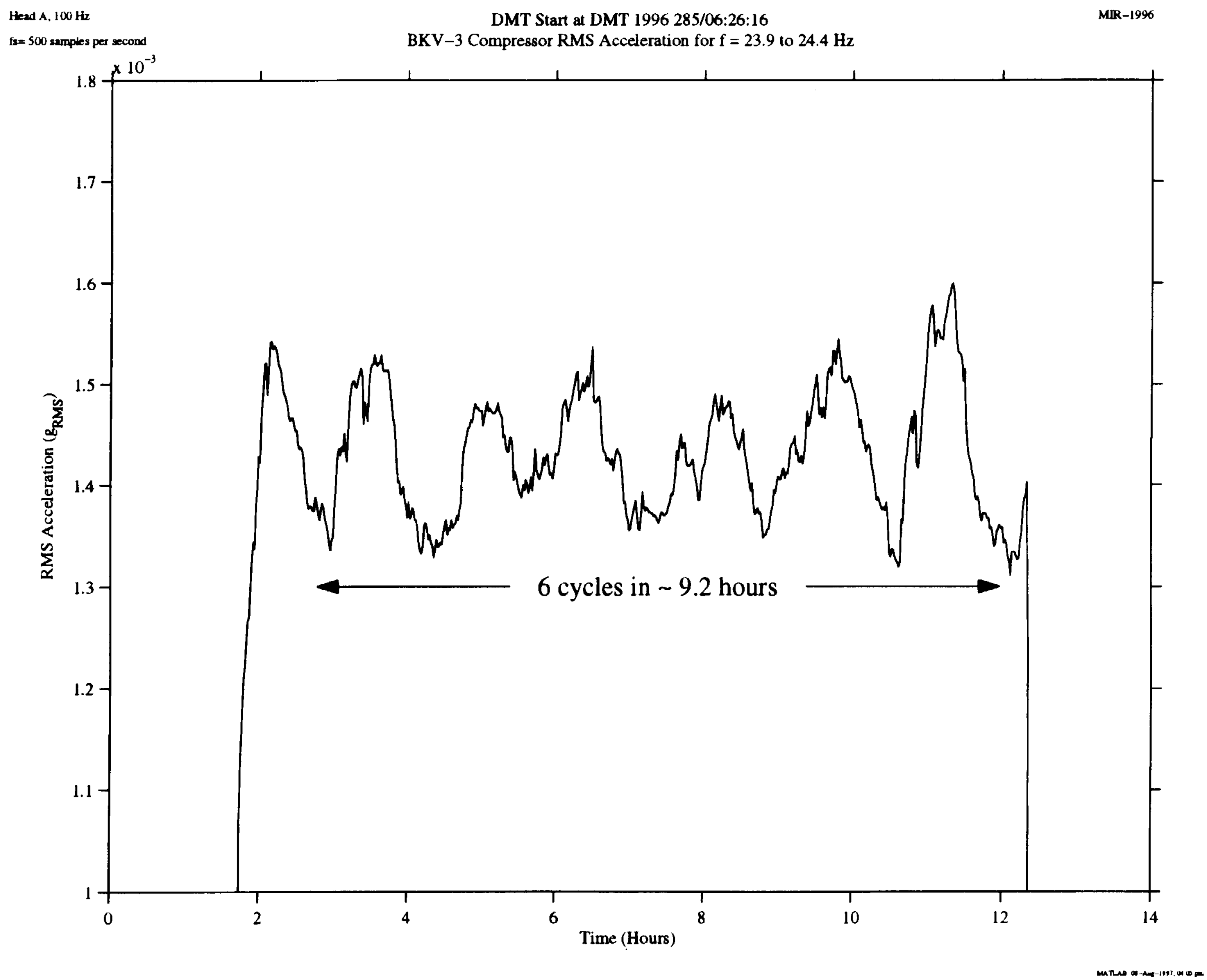


Figure 15. RMS acceleration for BKV-3 compressor fundamental.

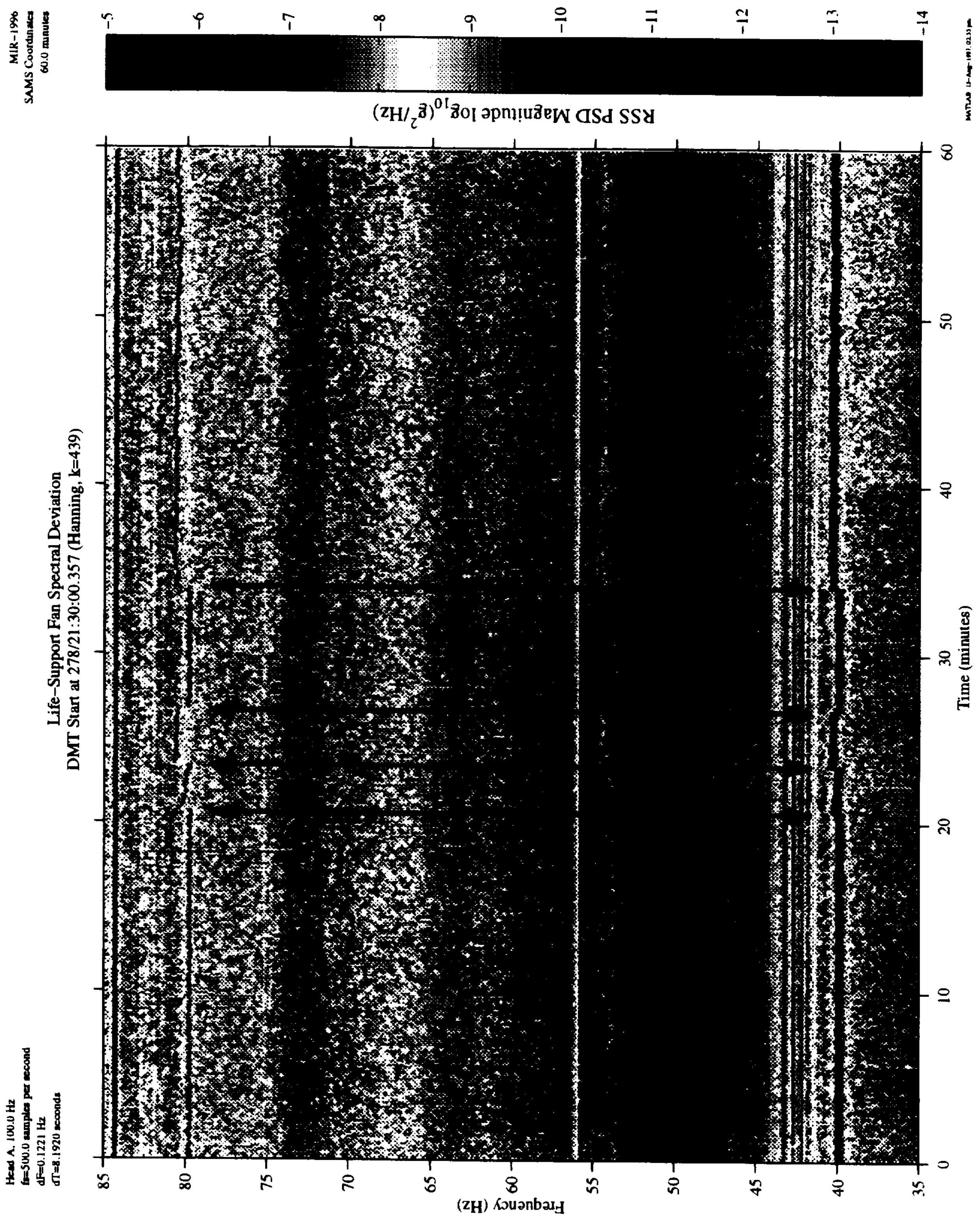


Figure 16. Spectral deviations of Life-support fan fundamental and second harmonic.

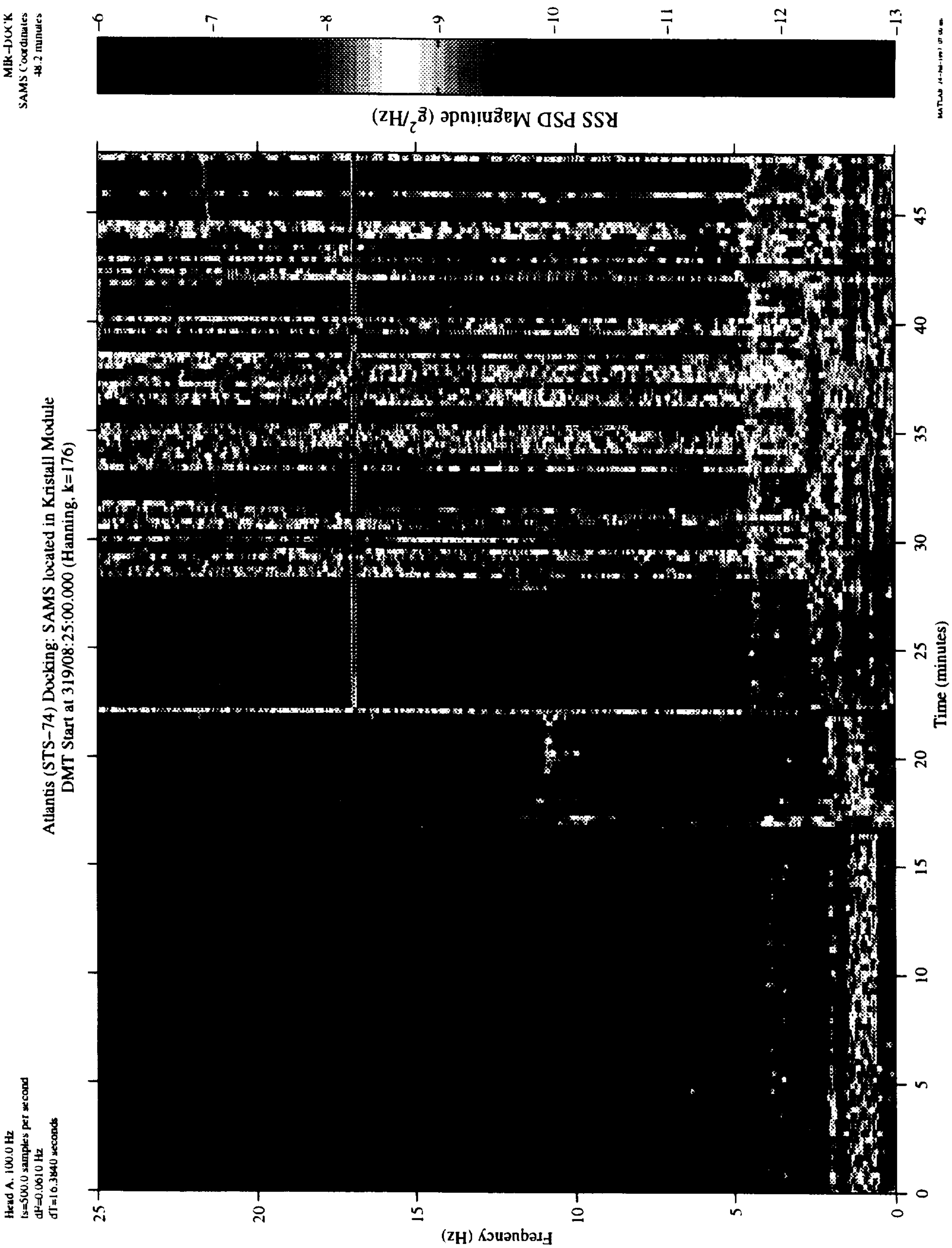


Figure 17. STS-74 Docking: SAMS TSH A (f_c=100 Hz) - Color spectrogram.

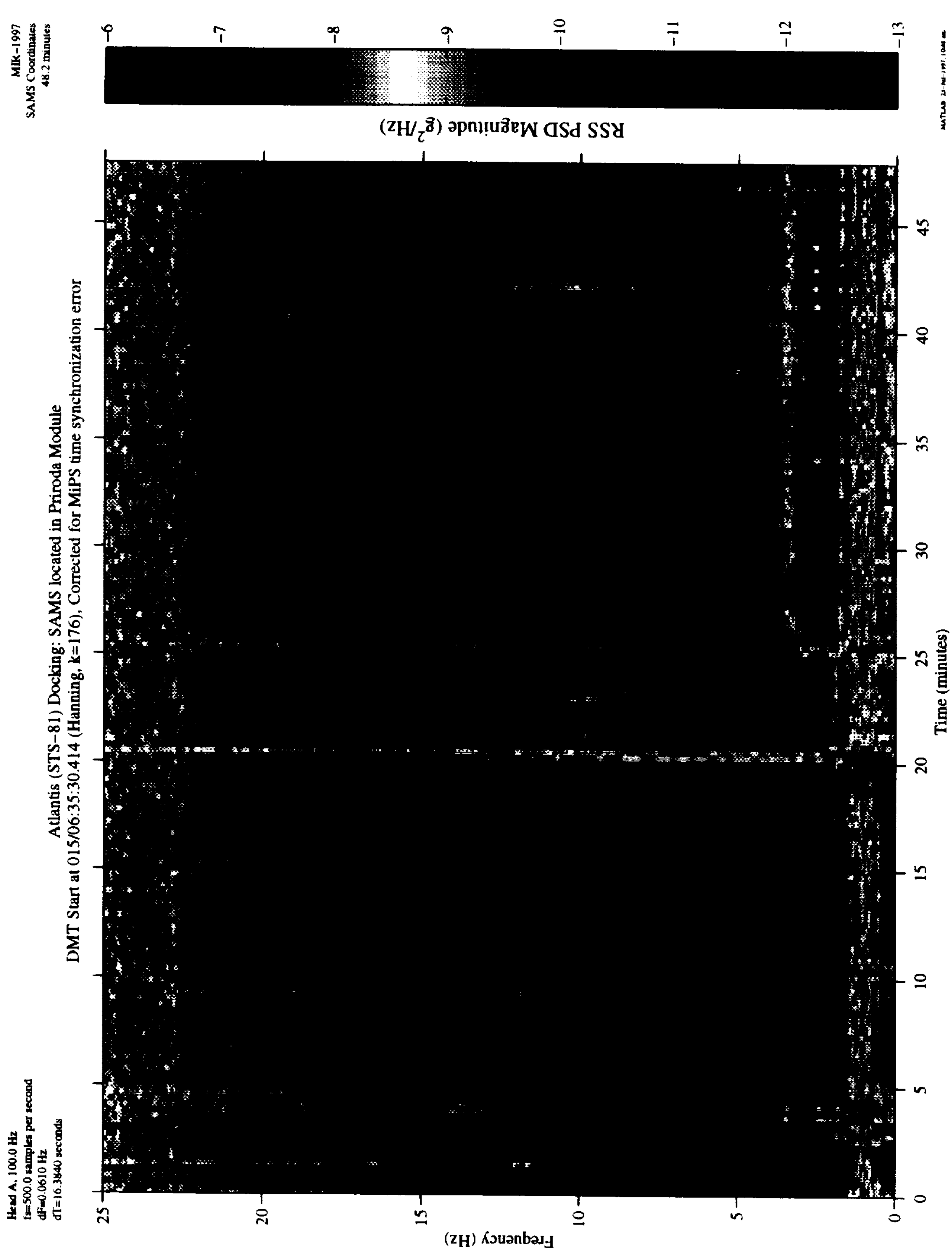


Figure 18. STS-81 Docking: SAMS TSH A (f_c=100 Hz) - Color spectrogram.

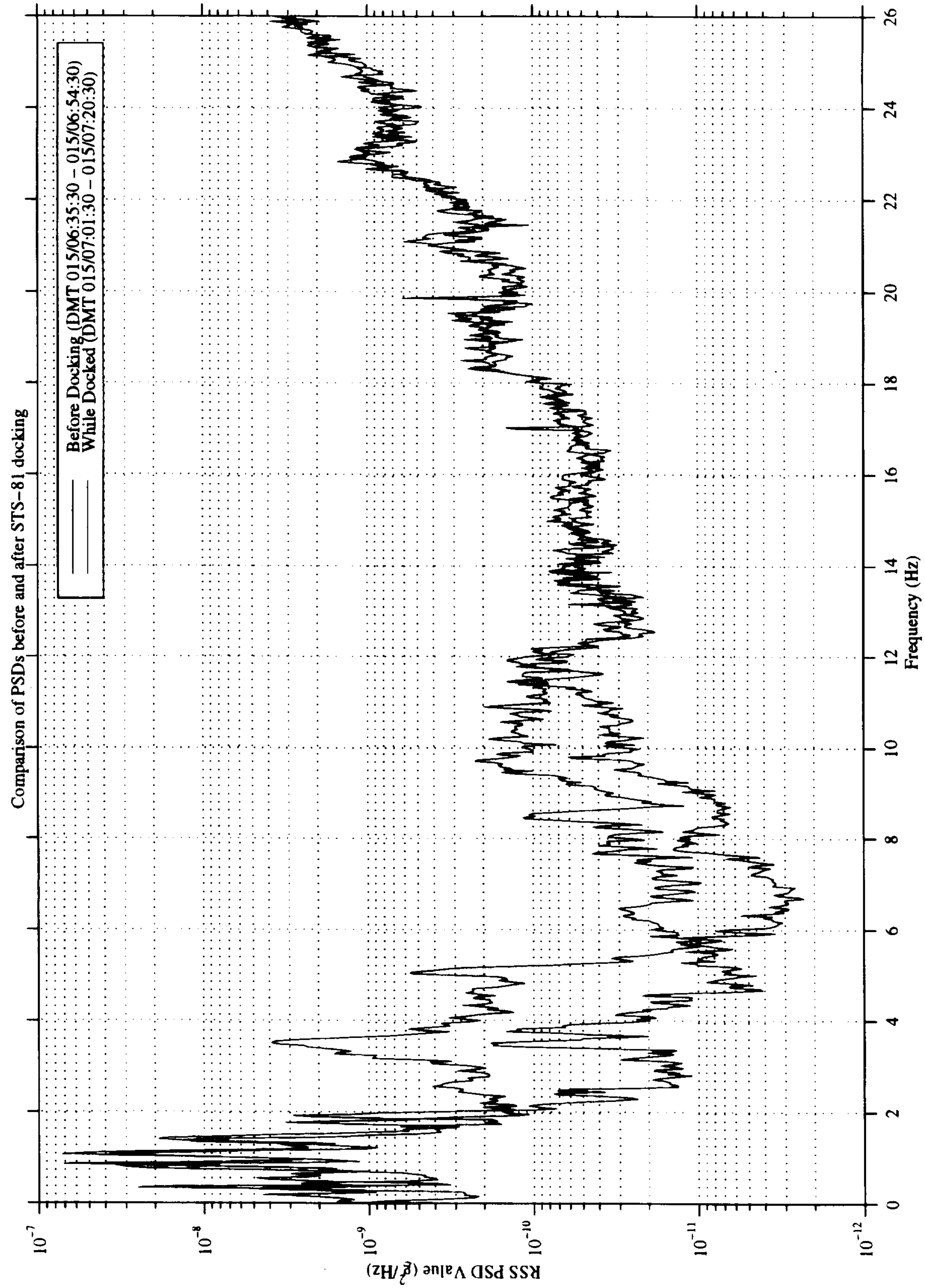


Figure 19. Comparison of PSDs before and after STS-81 Docking - TSH A (f_c=100 Hz).

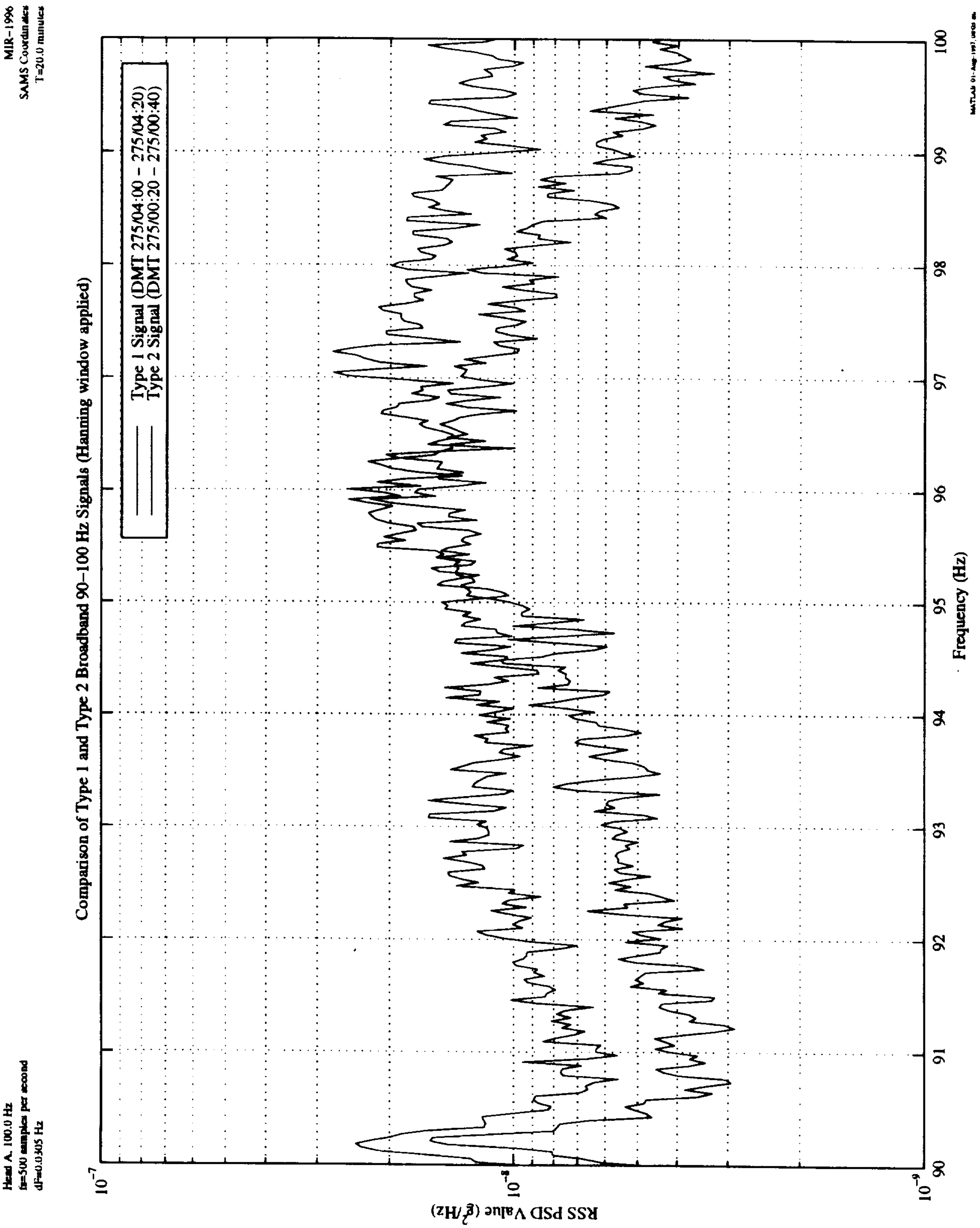


Figure 20. Comparison of two types of 90-100 Hz broadband disturbances, TSH A (f_c=100 Hz).

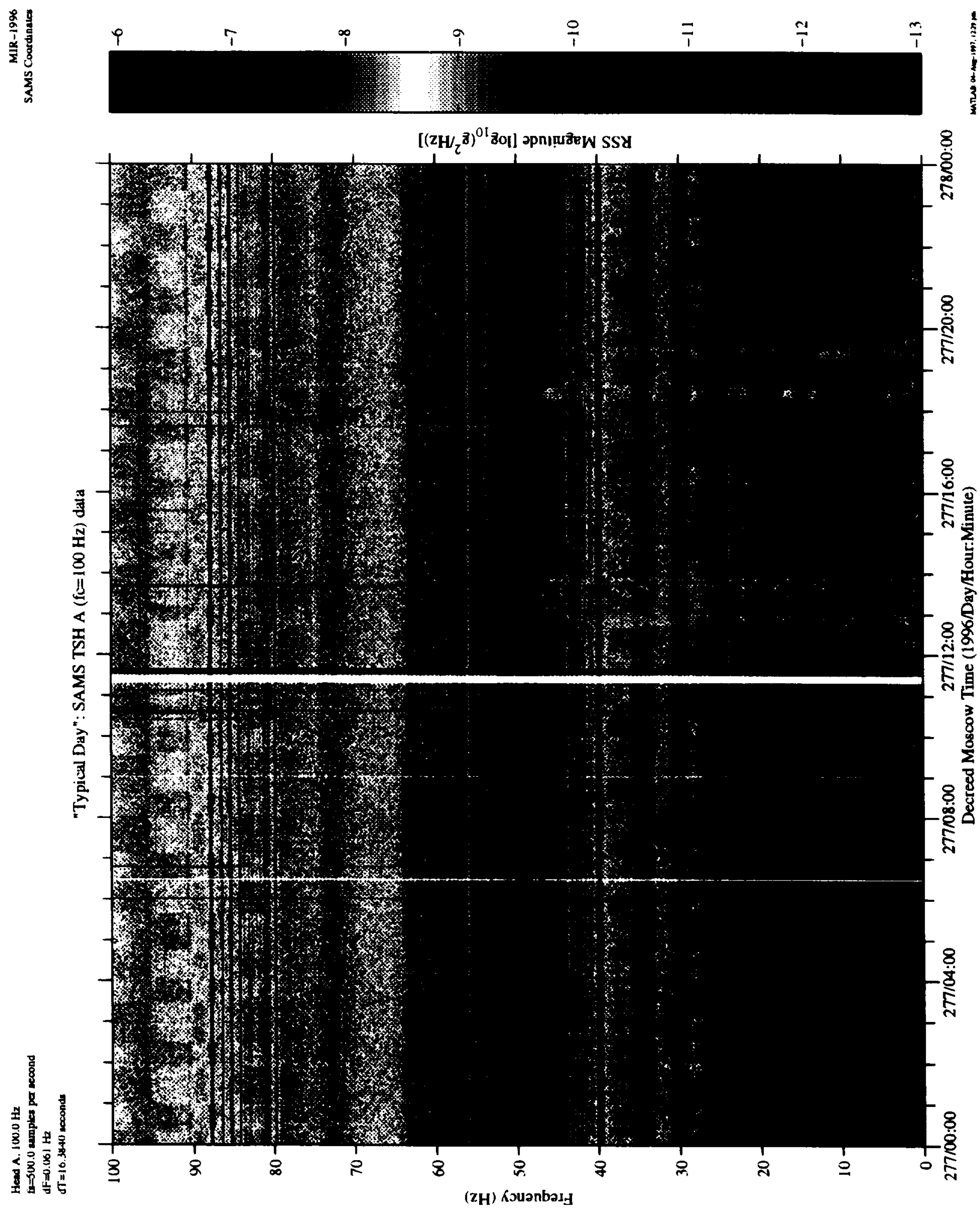


Figure 21. 24 Hour Period: SAMS TSH A (f_c=100 Hz) - Color spectrogram.

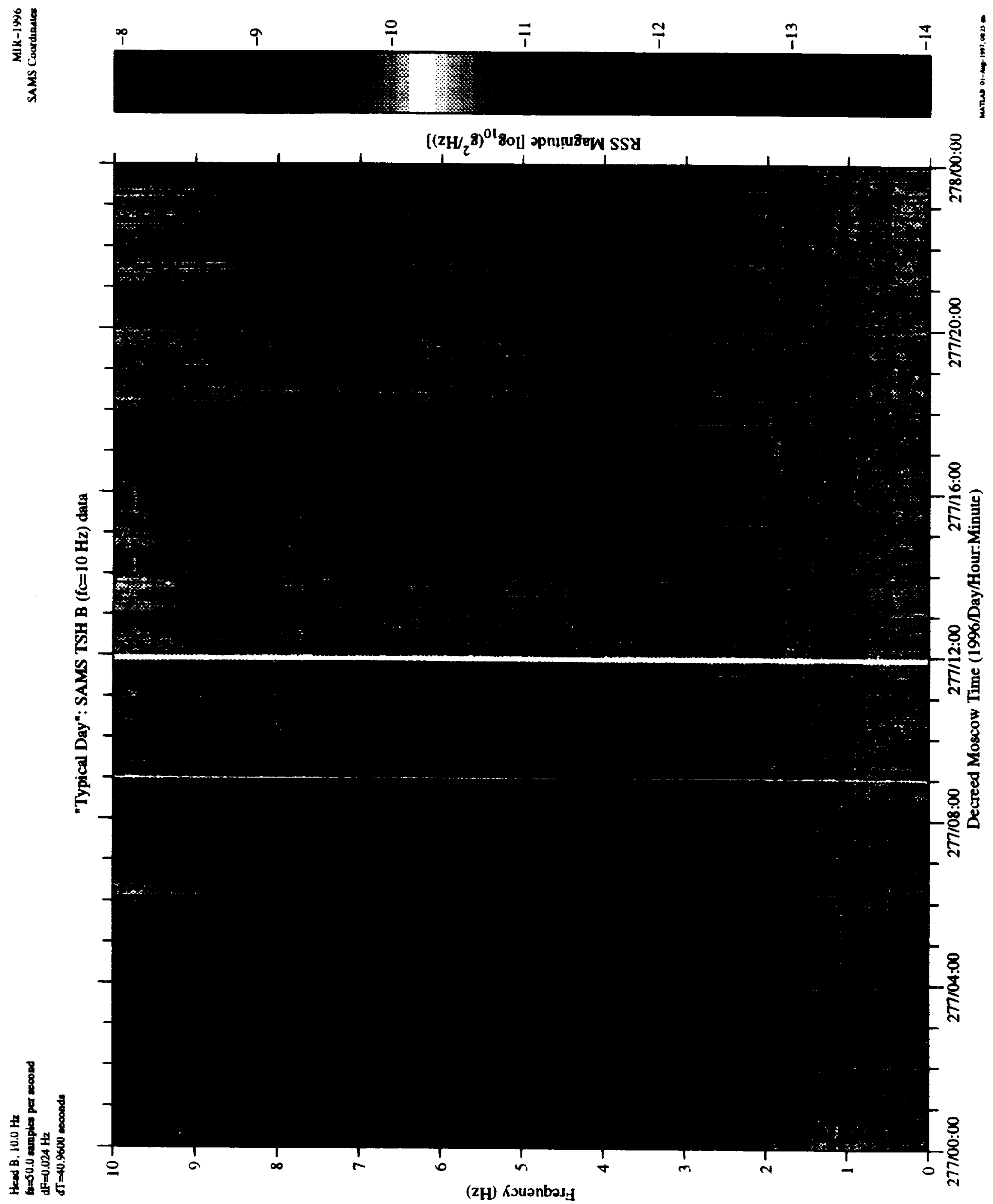


Figure 22. 24 Hour Period: SAMS TSH B (f_c=10 Hz) - Color spectrogram.

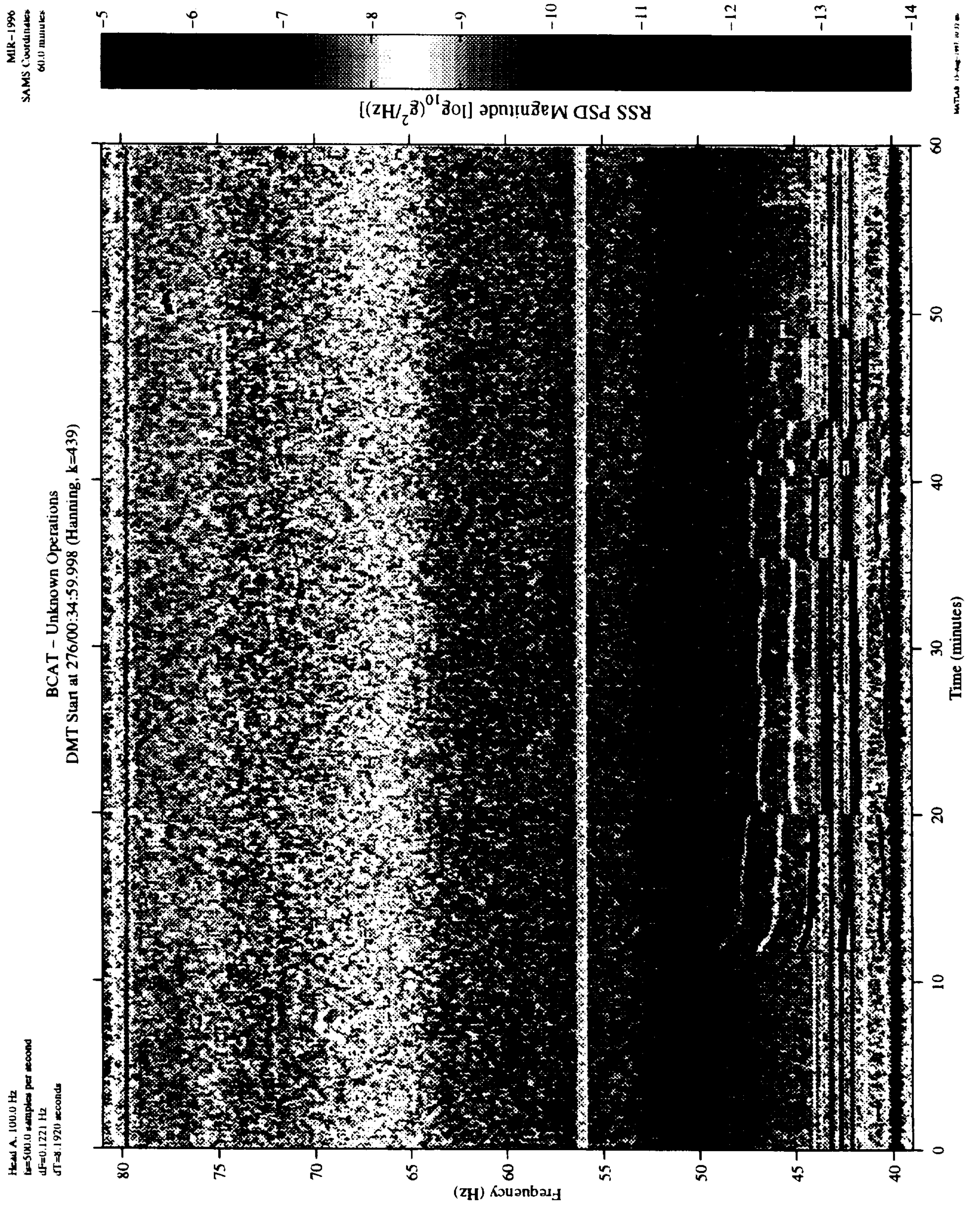


Figure 23. Spectrogram of unidentified disturbances during BCAT operations.

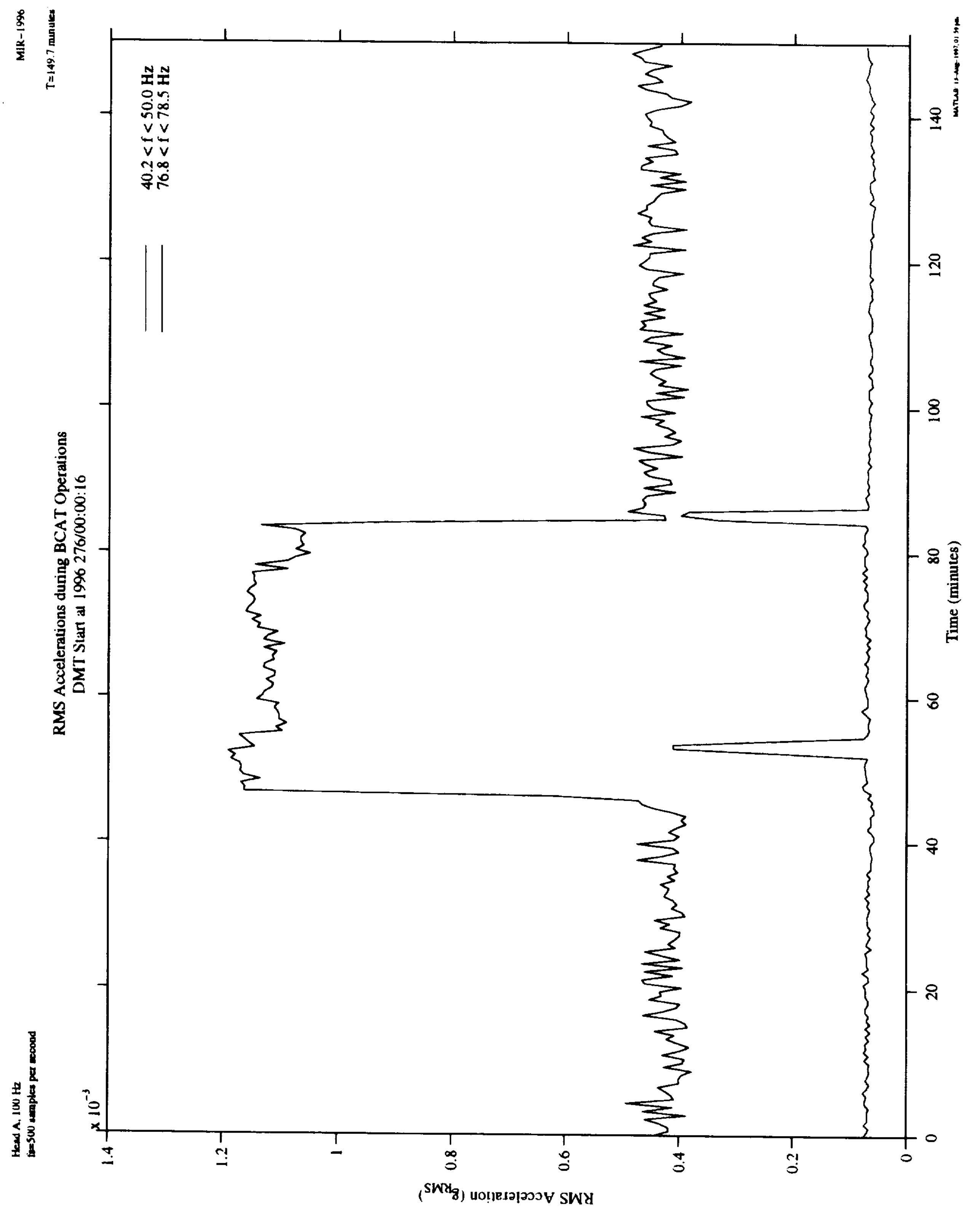
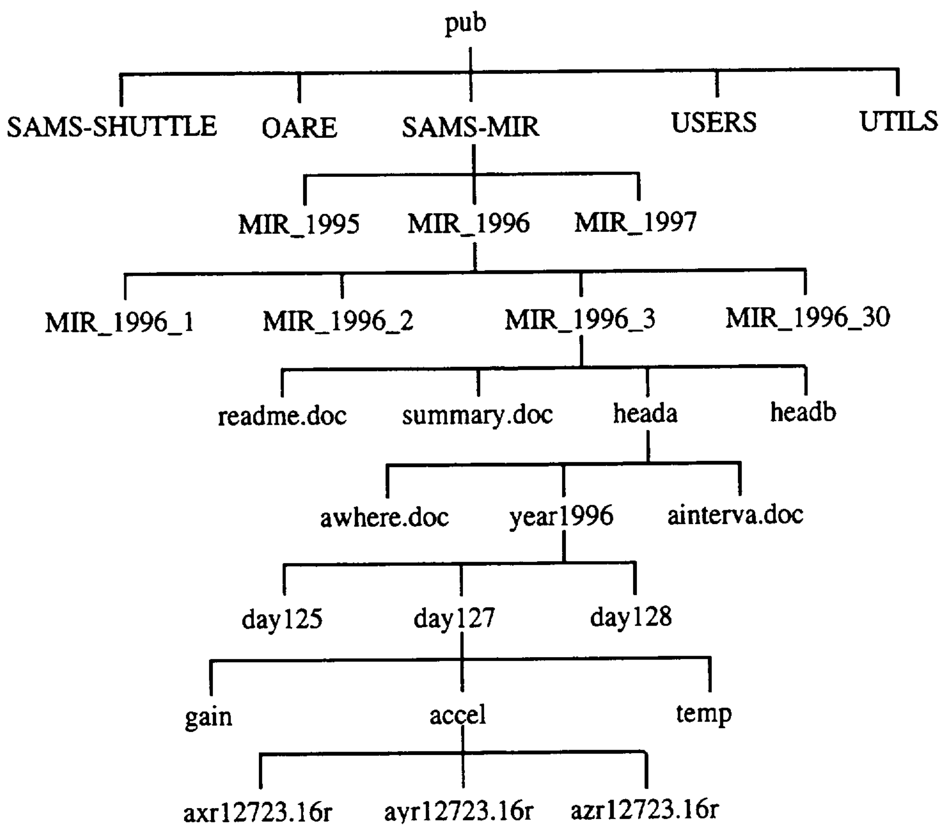


Figure 24. RMS accelerations for 40.2<f<50.0 Hz and 76.8<f<78.5 Hz showing start-up and stop of unidentified disturbances.

Appendix A: Accessing Acceleration Data via the Internet

SAMS data are available over the internet from the NASA LeRC file server "beech.lerc.nasa.gov". Previously, SAMS data were made available on CD-ROM, but distribution of data from current (and future) missions will be primarily through this internet file server.

SAMS data files are arranged in a standard tree-like structure. Data are first separated based upon mission. Then, data are further subdivided based upon some portion of the mission, head, year (if applicable), day, and finally type of data file (acceleration, temperature, or gain). Effective November 1, 1996, there has been a minor reorganization of the beech.lerc.nasa.gov file server. There are now two locations for SAMS data: a directory called SAMS-SHUTTLE and a directory called SAMS-MIR. Under the SAMS-SHUTTLE directory, the data are segregated by mission. Under the SAMS-MIR directory, the data are segregated by year. The following figure illustrates this structure.



The SAMS data files (located at the bottom of the tree structure) are named based upon the contents of the file. For example, a file named "axm00102.15r" would contain head A data for the x-axis for day 001, hour 02, file 1 of 5. The readme.doc files give a complete explanation of the file naming convention.

Data access tools for different computer platforms (MS-DOS, Macintosh, SunOS, and MS-Windows) are available in the /pub/UTILS directory.

The NASA LeRC beech file server can be accessed via anonymous File Transfer Protocol (ftp), as follows:

1) Open an ftp connection to "beech.lerc.nasa.gov"
2) Login as userid "anonymous"
3) Enter your e-mail address as the password
4) Change directory to pub
5) List the files and directories in the pub directory
6) Change directories to the area of interest
7) Change directories to the mission of interest
8) Enable binary file transfers
9) Use the data file structures (described above) to locate the desired files
10) Transfer the desired files

If you encounter difficulty in accessing the data using the file server, please send an electronic mail message to "pims@lerc.nasa.gov". Please describe the nature of the difficulty and also give a description of the hardware and software you are using to access the file server. If you are interested in requesting specific data analysis or information from the PIMS team, also send e-mail to pims@lerc.nasa.gov or call the PIMS Project Manager, Duc Truong at (216) 433-8394.

Appendix B: SAMS Time Histories and Color Spectrograms TSH A

The Principal Investigator Microgravity Services (PIMS) group has further processed SAMS data to produce the plots shown here. This appendix presents power spectral density versus frequency versus time (spectrogram) plots of SAMS TSH A (f_c=100 Hz) data.

Color spectrograms are used to show how the microgravity environment varies in intensity with respect to time and frequency. These spectrograms are provided as an overview of the frequency characteristics of the SAMS data. Each spectrogram is a composite of 6 hour's worth of data. The time resolution used to compute the spectrograms seen here is 16.384 seconds. This corresponds to a frequency resolution of 0.0610 Hz.

These data were collected at 500 samples per second, and a 100 Hz lowpass filter was applied to the data by the SAMS unit prior to digitization. Prior to plot production, the raw SAMS data were compensated for gain changes, and then de-meaned. De-meaning was accomplished by analyzing individual sections with a nominal length of 30 minutes. Since this de-meaning operation operates on time periods longer than the plot's time resolution, an artificial dc component may be seen in the extreme lower frequency regime of these spectrograms. Since these are data processing artifacts, the low frequency regime ($f<0.05$ Hz) should be ignored. Users who are interested in further details for either of these operations are encouraged to contact the PIMS group.

Power Spectral Density versus Frequency versus Time Calculations

In order to produce the spectrogram image, Power Spectral Densities were computed for successive time intervals (the length of the interval is equal to the time resolution). For the PSD computation, a Hanning window was applied. In order to combine all three axes into a single plot to show an overall level, a Vector-Magnitude (VM) operation was performed. Stated mathematically:

$$VM_k = \sqrt{PSD_{x_k}^2 + PSD_{y_k}^2 + PSD_{z_k}^2}\,.$$

By imaging the base 10 logarithm $(\log_{10})$ magnitude as a color and stacking successive PSDs from left to right, variations of acceleration magnitude and frequency are shown as a function of time. Colors are assigned to discrete magnitude ranges, so that there are 64 colors assigned to the entire range of magnitudes shown.

The colorbar limits are chosen in order to maximize the data value and visibility in a given set of spectrogram plots. Data which fall outside of these limits will be imaged as either the highest or lowest magnitude, depending on which side they have saturated. For this report, less than 1% of the total points lie below the lower limit, and less than 1% of the total points lie above the upper limit. If an area of interest seems to be saturated, care should be taken in that the actual values may lie above or below the color mapping shown on the plot.

Due to the nature of spectrograms, care should be taken to not merely read a color's numeric value as being the acceleration magnitude that is present at a given frequency. In order to get this type of information, the PSDs must be integrated between two frequencies. These frequencies (lower and upper) form the band of interest. The result of this integration is the g_{RMS} acceleration level in the $[f_{lower}, f_{upper}]$ band. The PIMS group is able to provide this type of analysis on a per-request basis.

Plot gaps (if any exist) are shown by either white or dark blue areas on the page. Care should be taken to not mistake a plot gap (represented by a blue vertical band) with a quiet period. If a plot gap exists for an entire plot (or series of successive plots), a comment is placed on the page to let the user know there is a gap in the data. These "No data are available" comments will not show exact times for which the data are not available, but will only indicate missing plots.

Contacting PIMS

To request additional analysis or information, users are encouraged to send an e-mail to pims@lerc.nasa.gov, or FAX a request to (216) 433-8660.

Appendix C: SAMS Time Histories and Color Spectrograms TSH B

The Principal Investigator Microgravity Services (PIMS) group has further processed SAMS data to produce the plots shown here. This appendix presents power spectral density versus frequency versus time (spectrogram) plots of SAMS TSH B (f_c=10 Hz) data.

Color spectrograms are used to show how the microgravity environment varies in intensity with respect to time and frequency. These spectrograms are provided as an overview of the frequency characteristics of the SAMS data. Each spectrogram is a composite of 6 hour's worth of data. The time resolution used to compute the spectrograms seen here is 40.960 seconds. This corresponds to a frequency resolution of 0.0244 Hz.

These data were collected at 50 samples per second, and a 10 Hz lowpass filter was applied to the data by the SAMS unit prior to digitization. Prior to plot production, the raw SAMS data were compensated for gain changes, and then de-meaned. De-meaning was accomplished by analyzing individual sections with a nominal length of 60 minutes. Since this de-meaning operation operates on time periods longer than the plot's time resolution, an artificial dc component may be seen in the extreme lower frequency regime of these spectrograms. Since these are data processing artifacts, the low frequency regime ($f<0.05$ Hz) should be ignored. Users who are interested in further details for either of these operations are encouraged to contact the PIMS group.

Power Spectral Density versus Frequency versus Time Calculations

In order to produce the spectrogram image, Power Spectral Densities were computed for successive time intervals (the length of the interval is equal to the time resolution). For the PSD computation, a Hanning window was applied. In order to combine all three axes into a single plot to show an overall level, a Vector-Magnitude (VM) operation was performed. Stated mathematically:

$$VM_k = \sqrt{PSD_{x_k}^2 + PSD_{y_k}^2 + PSD_{z_k}^2}\,.$$

By imaging the base 10 logarithm $(\log_{10})$ magnitude as a color and stacking successive PSDs from left to right, variations of acceleration magnitude and frequency are shown as a function of time. Colors are assigned to discrete magnitude ranges, so that there are 64 colors assigned to the entire range of magnitudes shown.

The colorbar limits are chosen in order to maximize the data value and visibility in a given set of spectrogram plots. Data which fall outside of these limits will be imaged as either the highest or lowest magnitude, depending on which side they have saturated. For this report, less than 1% of the total points lie below the lower limit, and less than 1% of the total points lie above the upper limit. If an area of interest seems to be saturated, care should be taken in that the actual values may lie above or below the color mapping shown on the plot.

Due to the nature of spectrograms, care should be taken to not merely read a color's numeric value as being the acceleration magnitude that is present at a given frequency. In order to get this type of information, the PSDs must be integrated between two frequencies. These frequencies (lower and upper) form the band of interest. The result of this integration is the g_{RMS} acceleration level in the $[f_{lower}, f_{upper}]$ band. The PIMS group is able to provide this type of analysis on a per-request basis.

Plot gaps (if any exist) are shown by either white or dark blue areas on the page. Care should be taken to not mistake a plot gap (represented by a blue vertical band) with a quiet period. If a plot gap exists for an entire plot (or series of successive plots), a comment is placed on the page to let the user know there is a gap in the data. These "No data are available" comments will not show exact times for which the data are not available, but will only indicate missing plots.

Contacting PIMS

To request additional analysis or information, users are encouraged to send an e-mail to pims@lerc.nasa.gov, or FAX a request to (216) 433-8660.

Appendix D: User Comment Sheet

We would like you to give us some feedback so that we may improve the Mission Summary Reports. Please answer the following questions and give us your comments.

1. Do the Mission Summary Reports fulfill your requirements for acceleration and mission information?
______Yes ______No. If not why not?

Comments:
____

____

2. Is there additional information which you feel should be included in the Mission Summary Reports?
______Yes ______No. If so what is it?

Comments:
____

____

3. Is there information in these reports which you feel is not necessary or useful?
______Yes ______No. If so, what is it?

Comments:
____

____

4. Do you have internet access via: (____)ftp (____)WWW (____)gopher (____)other? Have you already accessed SAMS data or information electronically?
______Yes ______No

Comments:
____

____

Completed by: Name:________________________ Telephone________________________

Address:________________________ Facsimile________________________

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Return this sheet to:
Duc Truong
NASA Lewis Research Center
21000 Brookpark Road MS 500-216
Cleveland, OH 44135

or
FAX to PIMS Project: 216-433-8660
e-mail to: pims@lerc.nasa.gov.

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13. ABSTRACT ***(Maximum 200 words)***

During NASA Increment 3 (September 1996 to January 1997), about 5 gigabytes of acceleration data were collected by the Space Acceleration Measurement System (SAMS) onboard the Russian Space Station, Mir. The data were recorded on 11 optical disks and were returned to Earth on STS-81. During this time, SAMS data were collected in the Priroda module to support the following experiments: the Mir Structural Dynamics Experiment (MiSDE) and Binary Colloidal Alloy Tests (BCAT). This report points out some of the salient features of the microgravity environment to which these experiments were exposed. Also documented are mission events of interest such as the docked phase of STS-81 operations, a Progress engine burn, attitude control thruster operation, and crew exercise. Also included are a description of the Mir module orientations, and the panel notations within the modules. This report presents an overview of the SAMS acceleration measurements recorded by 10 Hz and 100 Hz sensor heads. Variations in the acceleration environment caused by unique activities such as crew exercise and life-support fans are presented. The analyses included herein complement those presented in previous mission summary reports published by the Principal Investigator Microgravity Services (PIMS) group.

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