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Flight Test Measurements From The Tu-144LL Structure/Cabin Noise Follow-On Experiment

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February 2000

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Abstract

This follow-on flight experiment on the TU-144LL Supersonic Flying Laboratory, conducted during the period September 1998 to April 1999, was a continuation of Structure/Cabin Noise Experiment 2.1 previously conducted during the initial phase of the program. Data was obtained over a wide range of altitudes and Mach numbers for the purpose of enlarging the data base used by models for the prediction of aircraft interior noise. Measured were: turbulent boundary layer pressure fluctuations on the fuselage in eleven instrumented window blanks distributed over the length of the fuselage; structural response on skin panels close to those window blanks using accelerometers; and flow direction over three windows using 'flow cones'. In addition to the previously used pressure transducers installed in seven window blanks on the right (starboard) side of the aircraft, four new window blanks on the left (port) side of the aircraft installed. These were arranged in two pairs, each pair bridged by a plate which created small sharp forward and aft facing steps. Three of the transducers on the right (starboard) side were additionally equipped with protractors to finely control their flushness with the exterior surface during flight. Flight test points were chosen to cover much of the TU-144's flight envelope, as well as to obtain as large a unit Reynolds number range as possible at various Mach numbers: takeoff, subsonic, transonic, and supersonic cruise conditions up to Mach 2. Data on engine runups and background noise were acquired on the ground. The data in the form of time histories of the acoustic signals, together with auxiliary data and basic MATLAB processing modules, are available on CD-R disks.

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1. Introduction

1.1. Tu-144 Program Overview

The Tu-144 modification and flight research program was initiated in September 1994 as part of the NASA High Speed Research (HSR) program. The overall objectives of the program were to modify and make flight worthy a Russian Tu-144 supersonic transport aircraft as a flight research test bed and conduct flight experiments to generate useful data for the HSR program [1]. The original program consisted of three phases:

Phase I: Aircraft Modification/Refurbishment

An out-of-service Tu-144 supersonic transport aircraft was completely refurbished and re-fitted with Kuznetsov NK-321 engines. This phase of the program culminated in the first flight of the modified and refurbished aircraft on 29 November 1996.

Phase II: Flight Test Planning and Preparations

Development of plans for six selected experiments and installation of instrumentation and data acquisition systems on the test aircraft for the experiments was conducted under this phase.

Phase III: Conduct of Flight Tests

This phase was to establish the airworthiness of the modified test aircraft over the entire flight envelope, acquire data for the flight experiments, reduce the data to engineering units and evaluate data quality. Nineteen flights were conducted over the period November 1996 to March 1998. References [1-7] summarize the six experiments. This phase ended in May 1998.

Phase IV: Follow-On Program

Following the successful completion of original three phases, a fourth follow-on phase was initiated. This phase consisted of seven experiments. Eight flights (20-27) were performed during the period September 1998 to April 1999. References [8-15] summarize the seven experiments. This phase ended in June 1999.

1.2. Structure/Cabin Noise Follow-On Experiment 2.1A

The data described in this report were collected as part of follow-on phase IV of the program. A companion report describes the data acquired during the phase III (experiment 2.1) program [16] and the reader is assumed to have some familiarity with it. Coordination of U.S. team activities was performed jointly by Robert G. Rackl and Stephen A. Rizzi. Coordination of Russian team activities was performed by Eduard V. Andrianov.

The objectives of the follow-on experiment were formulated in coordination with HSR Structural Acoustics ITD team members and Tupolev. These were:

- Enlarge the design database for supersonic passenger aircraft cabin noise prediction by acquiring additional data on fuselage turbulent boundary layer fluctuating pressure characteristics and the response of fuselage skin panels over a wide range of flight conditions.
- Obtain measurements of boundary layer pressure fluctuations at selected transducers to enable the investigation of the influence of transducer flushness with the surrounding exterior surface on measured signals.
- Measure surface flow direction at windows in order to estimate correction factors to measured cross-correlation functions from transducers not along the same streamline.

- Acquire pressure fluctuation data in front of and behind small steps in the fuselage exterior surface.

As done on previous occasions [16-18], turbulent boundary layer fluctuating pressure levels were measured using dynamic pressure transducers flush-mounted into metal blanks that replaced windows on the starboard and port sides of the aircraft. At selected adjacent locations on the fuselage, the structural response of the skin due to the turbulent boundary layer pressure fluctuation excitation was measured with accelerometers. The forward and aft facing steps were created by installing two plates (one in the front and one in the rear of the fuselage) which bridged instrumented blanks in adjacent windows. Two step sizes were flown: 7 mm and 4 mm.

Two on-ground measurements were performed as well:

- Engine runups with a stationary aircraft in order to assess the jet noise component by itself.
- Background levels with a quiet stationary aircraft.

Data was acquired on seven research flights of the Tu-144LL during the period September 1998 to April 1999. All flights were conducted out of Zhukovsky Air Base near Moscow, Russia. Instrumentation installation was performed jointly by U.S. team members and Tupolev personnel. Further, data acquisition required the presence of U.S. team members before and after most test flights. Besides the authors, Keith Harris and Donna Gallaher of the NASA LaRC also supported the installation and flight tests.

2. Instrumentation

2.1. Sub-Experiment 1: Database Enlargement

The objective of this sub-experiment was to enlarge the database previously developed under the phase III (experiment 2.1) program [16] by acquiring data at additional flight conditions and measuring fuselage skin vibrations at different locations. Interior noise measurements were not acquired in the follow-on program.

2.1.1. Window Blanks

The existing seven window blanks and two fuselage locations on the starboard side of the aircraft were utilized for additional flush turbulent boundary layer pressure fluctuation measurements. Locations for Kulite transducers N2.1, N5.1 and N6.1 were used to assess the effect of transducer flushness, as discussed in Section 2.2. Although pressure transducers were removed and reinstalled between the experiment 2.1 and 2.1A, the window blanks and Kulite insulating bosses were left in place. An exception to this was the location for Kulite S1 in the fuselage sidewall, which was repaired with a new insulating boss and mounting disk.

2.1.2. Dynamic Pressure Transducers

Following flight 23, 22 of the 25 previously used Kulite transducers (model XCS-190-15D) were installed in their former locations on the starboard side of the aircraft. Detailed flushness measurements were made at the locations shown in Figure 1 and are included in Table 1. These measurements show a comparable flushness with the installation in phase III. The other three transducers (N2.1, N5.1 and N6.1) were installed between flights 21 and 22 for the flushness sub-experiment.

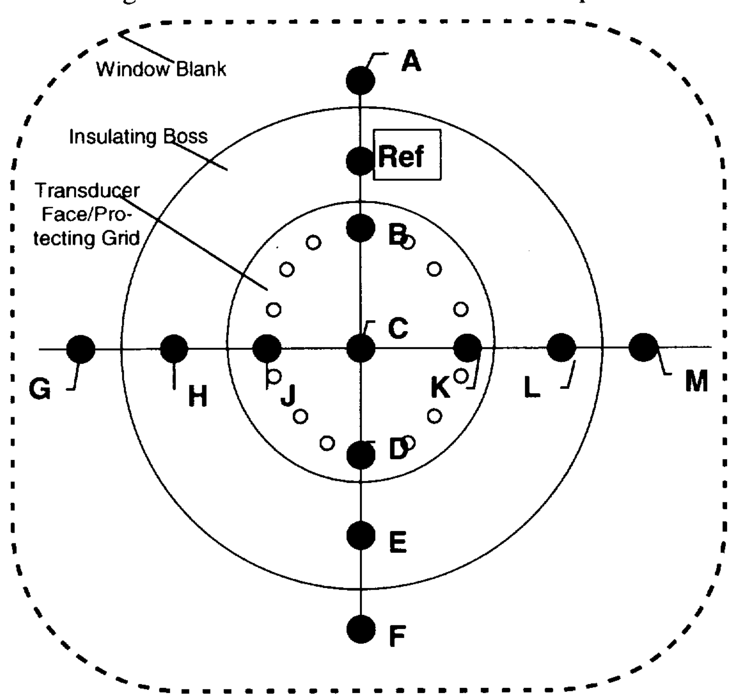


Figure 1: Pattern for Kulite transducer XCS-190-15D flushness measurements.

Table 1: Map of Kulite transducer flushness for sub-experiments 1 and 2.[1]

Id	A	B	C		D	E	F	G	H	J	K	L	M
N1.1	7	2	8	11	12	-6	-10	-8	-7	1	13	7	2
N1.2	-6	24	24	17	4	-4	-6	-19	-8	28	7	1	9
N1.3	-2	5	4	4	4	6	3	-12	4	7	1	-1	-3
N1.4	33	11	6	25	18	6	1	1	-6	27	16	-1	-13
N1.5	4	-9	-6	-3	17	-10	-16	12	-12	-16	9	-7	-16
N2.1	18	2	19	18	17	0	11	7	-1	1	29	-1	6
N3.1	13	22	41	43	32	8	0	17	16	38	0	2	7
S1	24	17	33	32	38	78	194	43	0	22	27	61	193
N4.1	15	14	4	5	-9	-6	-2	13	-4	1	4	-6	18
N4.2	-4	3	-2	-2	-8	-8	-1	2	-2	5	2	-7	4
N4.3	-4	2	0	0	2	-10	-19	0	-3	3	1	-5	-5
N4.4	-2	11	3	7	2	-8	-11	-13	-5	13	-3	-10	-2
N4.5	-4	12	0	1	-2	1	4	15	15	3	2	-9	-8
N4.6	-20	1	3	2	-1	-9	-12	-14	-2	3	-2	-19	-24
N4.7	-7	-7	3	2	17	9	-5	6	8	4	-2	4	-2
N4.8	-13	11	20	16	9	-15	-31	-16	-20	2	16	-14	-2
N4.9	-3	-1	1	0	-2	-5	-18	-19	-4	1	-6	6	11
S2	-45	-31	1	0	4	30	8	22	-4	-2	-7	-2	0
N5.1	24	4	13	13	12	0	14	24	-8	21	-10	-2	16
N6.1	18	-13	-16		-20	-13	-4	6	-7	-13	-19	-8	-7
N7.1	2	13	17	17	9	1	-3	6	-9	4	13	-2	-1
N7.2	0	3	3	3	-1	-1	-7	-6	-11	-6	5	1	-8
N7.3	5	0	8	7	9	0	-11	-14	-6	17	-1	-3	9
N7.4	5	1	11	12	4	2	21	8	-3	15	1	-7	8
N7.5	15	-2	7	6	0	-1	-2	3	-2	-2	1	1	13

[1] Measurements are in thousandths of a millimeter. Positive values indicate transducer is recessed, negative values indicate transducer protrudes. Point C was measured twice to provide an indication of measurement repeatability.

2.1.3. Accelerometers

The same six accelerometers as in experiment 2.1 were used. They were relocated into a cluster downstream of window blank 5 (on the starboard side of the aircraft) as shown in Figure 3 and Figure 4.

2.2. Sub-Experiment 2: Effect of Transducer Flushness

The objective of this sub-experiment was to obtain measurements of boundary layer pressure fluctuations at selected transducers to enable the investigation of the influence of transducer flushness with the surrounding exterior surface on measured signals.

2.2.1. Flushness Adjustment Mechanism

Between flights 21 and 22, three transducer locations (N2.1, N5.1 and N6.1) on the starboard side of the aircraft were outfitted by Tupolev with mechanisms to adjust the transducer flushness in flight. The mechanisms allow the transducers to protrude above or recess below the surrounding surface in a continuous fashion. Protractors mounted on the inside of the window blank were used to give the Tupolev operators a visual indication of the flushness setting and a locking nut was used to fix the position when adjustments were not being made. Figure 5 shows a photograph of the view from the inside, with protractor and transducer. A drawing of the mechanism is shown in Figure 6. The protractors had markings so that flushness could be varied in the range plus and minus 50 thousandths of a millimeter.

Measurements of transducer flushness in the flush condition are also provided in Table 1. An assessment of the repeatability of the adjustment mechanism was made by turning each transducer through the range of settings and making measurements at the center location C (see Figure 1). The results are shown in Table 2. Repeatability was found to be within about 10 thousandths of a millimeter.

Table 2: Repeatability of Kulite transducer flushness adjustment mechanism.[2]

Nominal Setting	N6.1	N5.1	N2.1
0	-1	0	0.5
-50	-52	-48	-44.5
-10	-5	-5	13.5
0	6	6	4.5
10	19	14	16.5
50	61	50	60.5
10	20	14	18.5
0	8	5	8.5
-10	-5	-3	-1.5
-50	-51	-45	-43.5

[2] Measurements are in thousandths of a millimeter. Positive values indicate transducer is recessed, negative values indicate transducer protrudes.

For each setting, the average measurements are provided in Table 3. Because it was difficult to adjust the settings to better than about ±0.01 mm, ±0.02 mm settings were substituted for the ±0.01mm settings following flight 23 (see Section 4). Repeatability measurements for this flushness setting were not made.

Table 3: Average Kulite transducer flushness settings.[2]

Nominal Setting	N6.1	N5.1	N2.1
-50	-51.5	-46.5	-44.0
-10	-5.0	-4.0	+6.0
0	4.33	3.67	4.5
10	19.5	14.0	17.5
50	61.0	50.0	60.5

2.3. *Sub-Experiment 3: Local Flow Direction*

The objective of this sub-experiment was to measure surface flow direction at windows in order to estimate correction factors to measured cross-correlation functions from transducers not along the same streamline.

Prior to flight 21, three windows on the port side were outfitted on their exterior with three flow cones each for measuring local flow direction. The windows selected were: 1) location #1 between frames 23-24, opposite window blank 1, 2) location #2 between frames 55-56, opposite window blank 2, and 3) location # 3 between frames 90-91, opposite and one frame forward of window blank 7. A schematic of the flow cone design, modeled after one provided by Jim Crowder of Boeing-Seattle, is shown in Figure 7. The flow cones were machined from Techtron PPS material, manufactured by the Polymer Corporation, and painted black to enhance contrast against a possibly snowy landscape outside. They were attached to steel mounting bases with a short length of Dacron fishing string threaded through the cone apex and attached to an eyelet on the base. The bases were affixed to the exterior of the windows using a high temperature RTV compound. A black reference line was drawn on the outside of each window along a line parallel to the fuselage centerline to assist in data analysis. This was performed using the upper and lower horizontal splices of the window belt section (measured on the exterior of the fuselage) as a reference. The measurements were consistent at the three window locations.

Throughout each flight, interior video cameras recorded the position of each flow cone on Hi-8 mm format video tape. SONY consumer video cameras (model CCD-TRV65) were used. The internal time of each camera was recorded continuously on tape. It was synchronized on the day of each flight to within one second of the on-board time.

2.4. *Sub-Experiment 4: Effect of Steps*

The objectives of this sub-experiment were to acquire pressure fluctuation data in front of and behind small steps in the fuselage exterior surface.

2.4.1. Window Blanks

In order to measure turbulent boundary layer pressure fluctuations in front of and behind surface steps, four new aluminum window blanks were installed on the port side of the aircraft. Each window blank was designed and fabricated by Tupolev based on the measurement locations specified by the U.S. team.

These were: window blank 8 between frames 29-30, window blank 9 between frames 31-32, window blank 10 between frames 81-82, and window blank 11 between frames 83-84. Figure 8 shows the location and identification of the new window blanks. The new window blanks included transducers for this experiment only, as described in Section 2.4.3. Some of the previous window blanks on the starboard side had transducers both for experiment 2.1/2.1A and for other experiments. The approximate distances of the window blank centers are given in Table 4.

Table 4: Approximate distances of new window blanks from aircraft nose (including nose boom).

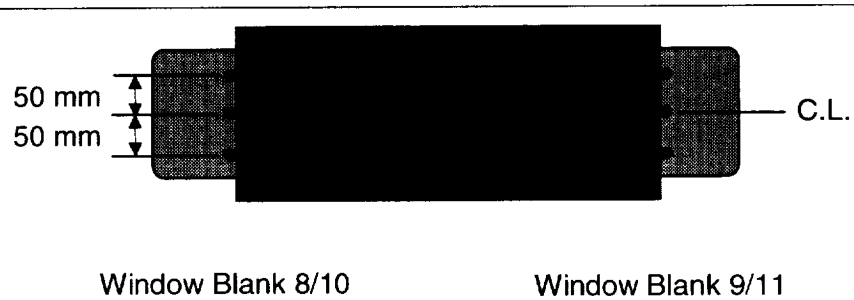
	Distance from Nose (including nose boom)	
	meters (±0.5)	feet(±1.5)
Nose (without nose boom)	0.9	3
Window Blank 8	21.7	71
Window Blank 9	22.6	74
Window Blank 10	44.9	147
Window Blank 11	45.8	150

2.4.2. Step Plates

Following flight 23, forward and aft facing steps were created by installing plates over the fuselage skin between and slightly overlapping adjacent windows, as sketched in Figure 8. More details are shown in Figure 9. The plate consists of two thinner plates riveted to each other. The one closer to the skin had a thickness of 4-mm, the outer layer was 3-mm thick. Flights 24, 25 and 26 were flown with a combined thickness and step height of 7-mm. The outer layer was then removed and flight 27 flown with the 4-mm step height.

Measurements of the 4-mm step height (as installed) were made following flight 27 at several locations. These are provided in Table 5. Measurements of the 7-mm step height were not obtained.

Table 5: Step plate thickness measurements of the 4-mm configuration.



	Step Height (mm)		
Window Blank	A	B	C
8	4.1	4.0	4.1
9	4.2	4.1	4.2
10	4.1	4.0	4.0
11	4.1	4.0	4.1

2.4.3. Dynamic Pressure Transducers

Following flight 23, 36 new, smaller pressure transducers were installed on the port side; 9 transducers in each of the four new window blanks. The layouts for these transducers on the window blanks are shown in Figure 10 and Figure 11. The transducers were manufactured by Kulite Semiconductor Products, Inc; all 36 were the same model, XCS-062-15D, with the following options:

- "B" screen (transducer face consists of a circular plate perforated with a circle of holes)
- 0.625-inch transducer length, 0.5-inch long reference tube
- 10 feet long 38 gage shielded cable
- External temperature compensation module 24-inches from transducer with compensation range of –65 to +250 °F
- Coated diaphragm
- Differential operational mode

A copy of the specification sheet is provided in Figure 22 of Appendix A. This transducer had nominally the same performance characteristics as the larger XCS-190-15D transducer used on the starboard side.

A mounting boss, made from the same material as the mounting boss for the starboard transducers and flow cones, provided electrical isolation of the transducer from the fuselage. A rough sketch is provided in Figure 12. The unthreaded transducers were glued to the inside of the mounting boss with Hysol epoxy. A fine metric thread, M3 x 0.35, was used to allow fine adjustments of the boss in the window blank. The threaded length of the blank was 8-mm, with the 0.1-inches closest to the external surface left unthreaded. The thin reference tube in the back of the transducer vented to the aircraft interior. Dummy bosses with solid centers were also fabricated to fill spare holes in the window blanks and to backfill the transducer locations following completion of the experiment.

Figure 13 shows an interior view of window blank 8 after complete installation. Figure 14 and Figure 15 show exterior views of window blanks 9 and 10 with the flush mounted Kulite pressure transducers. Figure 16 shows more details of some transducer faces.

As was the case for the starboard side transducers, great care was taken to install them flush with the surrounding surface by ensuring that the outer face (or protecting screen) of each transducer did not protrude past the surrounding surface, and that recess behind that surface was minimized. Red glyptol paint was used to hold the boss in place (at the inside surface) once the transducer was made flush with the outside surface. Detailed flushness measurements were made at the locations shown in Figure 2 and are included in Table 6. Due to the small size of the transducer, it was not possible to obtain measurements at more than one location on the transducer itself. A special study of transducer sensitivity to non-flush installation was not performed.

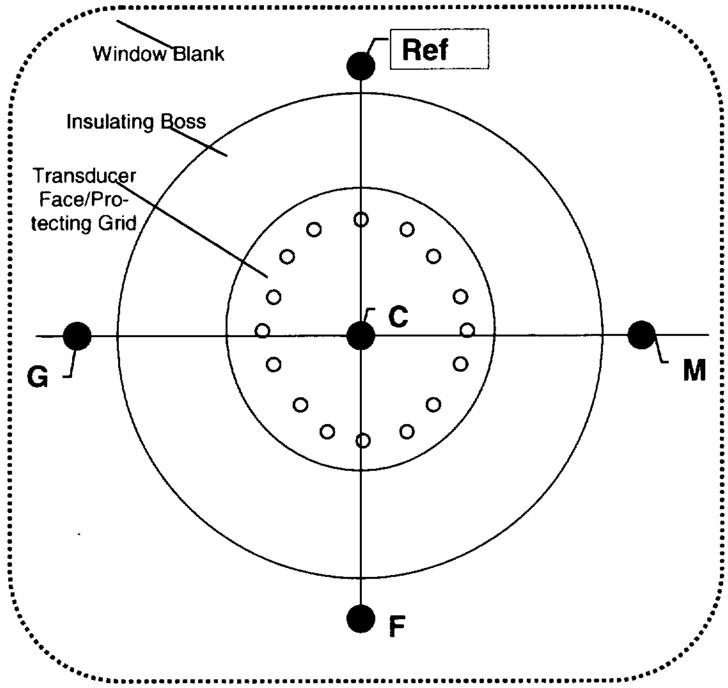


Figure 2: Pattern for Kulite transducer XCS-062-15D flushness measurements.

Table 6: Map of Kulite transducer flushness for sub-experiment 4.[1]

Id	C		F	G	M
N8.1	1	1	1	5	0
N8.2	-1	-1	-6	-7	-8
N8.3	3	3	-3	-3	-1
N8.4	2	2	-3	-8	9
N8.5	0	0	-2	-2	-1
N8.6	0	1	5	9	-6
N8.7	0	0	2	-7	3
N8.8	2	2	-1	-3	-7
N8.9	1	0	-1	-6	-5
N8.10	-8	-8	0	0	-4
N8.11	-1	-3	2	25	-20
N9.1	3	3	3	8	1
N9.2	2	2	0	0	-1
N9.3	-2	-2	1	1	3
N9.4	1	1	3	1	9
N9.5	-1	-1	3	-1	2

Id	C		F	G	M
N9.6	-1	-1	1	-2	1
N9.7	-1	-2	-3	1	-8
N9.8	-2	-2	3	4	3
N9.9	0	-1	-5	21	-22
N9.10	-11	-11	6	2	7
N9.11	-5	-8	-2	-4	-1
N9.12	-21	-20	4	-2	3
N10.1	2	2	0	-8	-12
N10.2	-3	-2	1	-3	-5
N10.3	-1	-1	-8	-7	-12
N10.4	-3	-2	-4	0	-5
N10.5	-3	-4	-3	-8	-3
N10.6	1	1	-1	-3	-5
N10.7	-1	-2	-2	-2	-3
N10.8	1	0	-5	-4	-2
N10.9	0	0	-2	0	-4
N10.10	-5	-5	4	-3	1
N10.11	-1	0	0	-1	-1
N11.1	2	2	0	-1	-3
N11.2	0	1	-14	-15	-14
N11.3	-5	-6	0	2	3
N11.4	-3	-4	-13	-9	-10
N11.5	0	-4	-3	2	-1
N11.6	-1	-11	-10	-5	-2
N11.7	0	-1	-5	-9	6
N11.8	-3	-5	-3	-18	7
N11.9	3	4	-2	1	-3
N11.10	-23	-24	-1	-7	3
N11.11	-24	-26	-11	-8	-9
N11.12	-16	-17	-5	-5	-7

Shaded cells indicate locations where dummy plugs were installed. Measurements made there are of the face of the dummy plug.

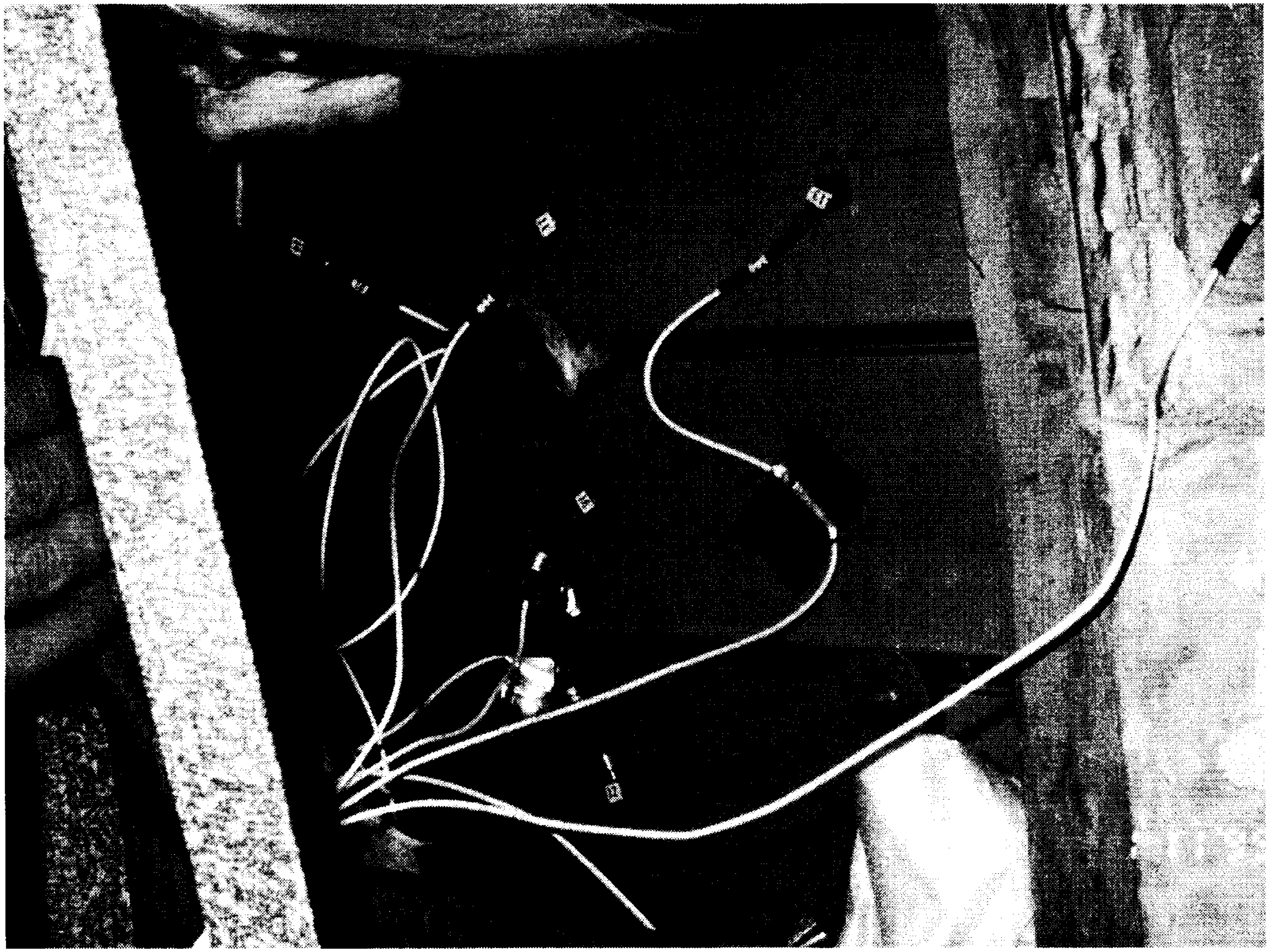


Figure 3: Photograph of accelerometer cluster on inside surface of exterior fuselage skin.

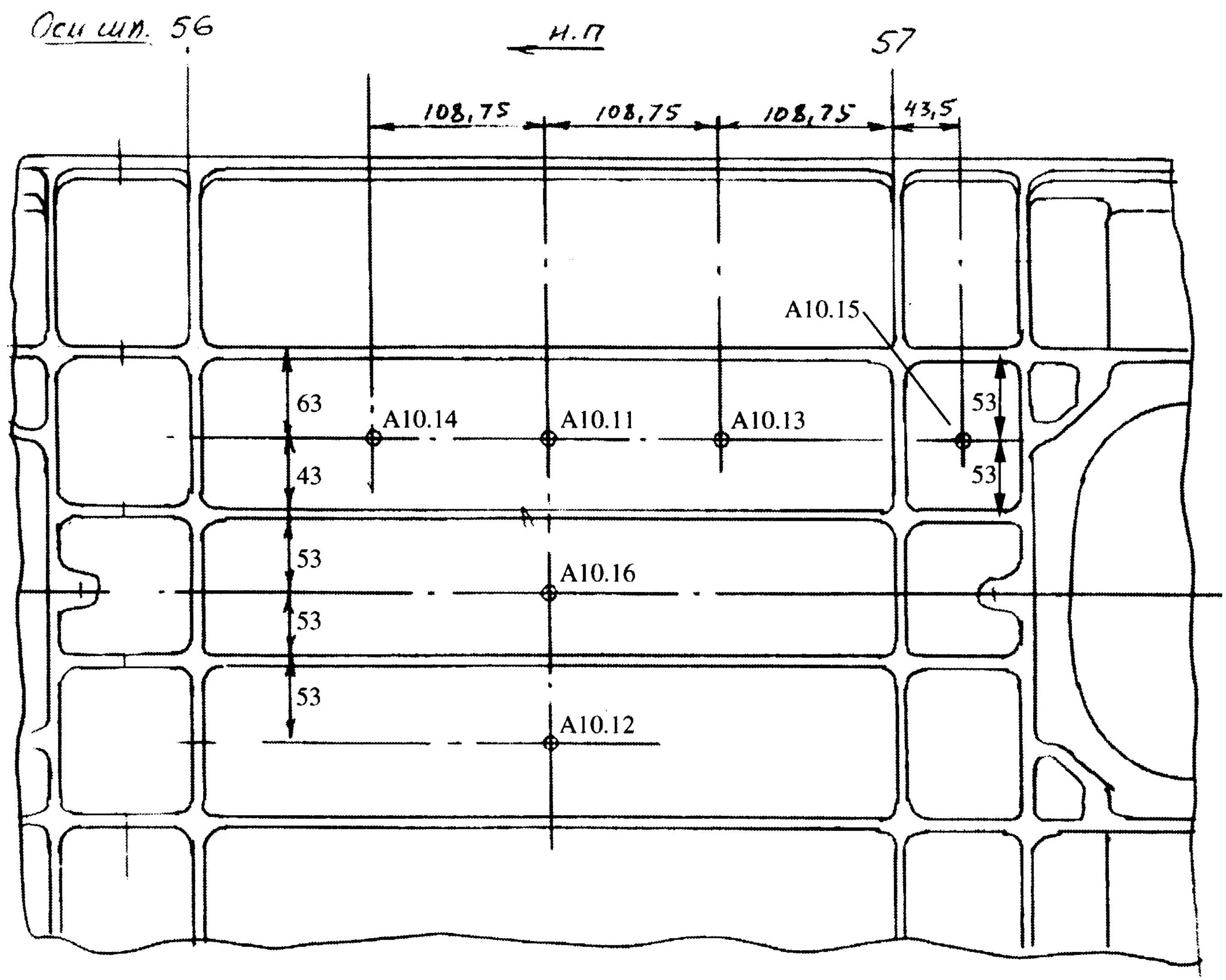


Figure 4: Drawing showing accelerometer locations (dimensions in mm).

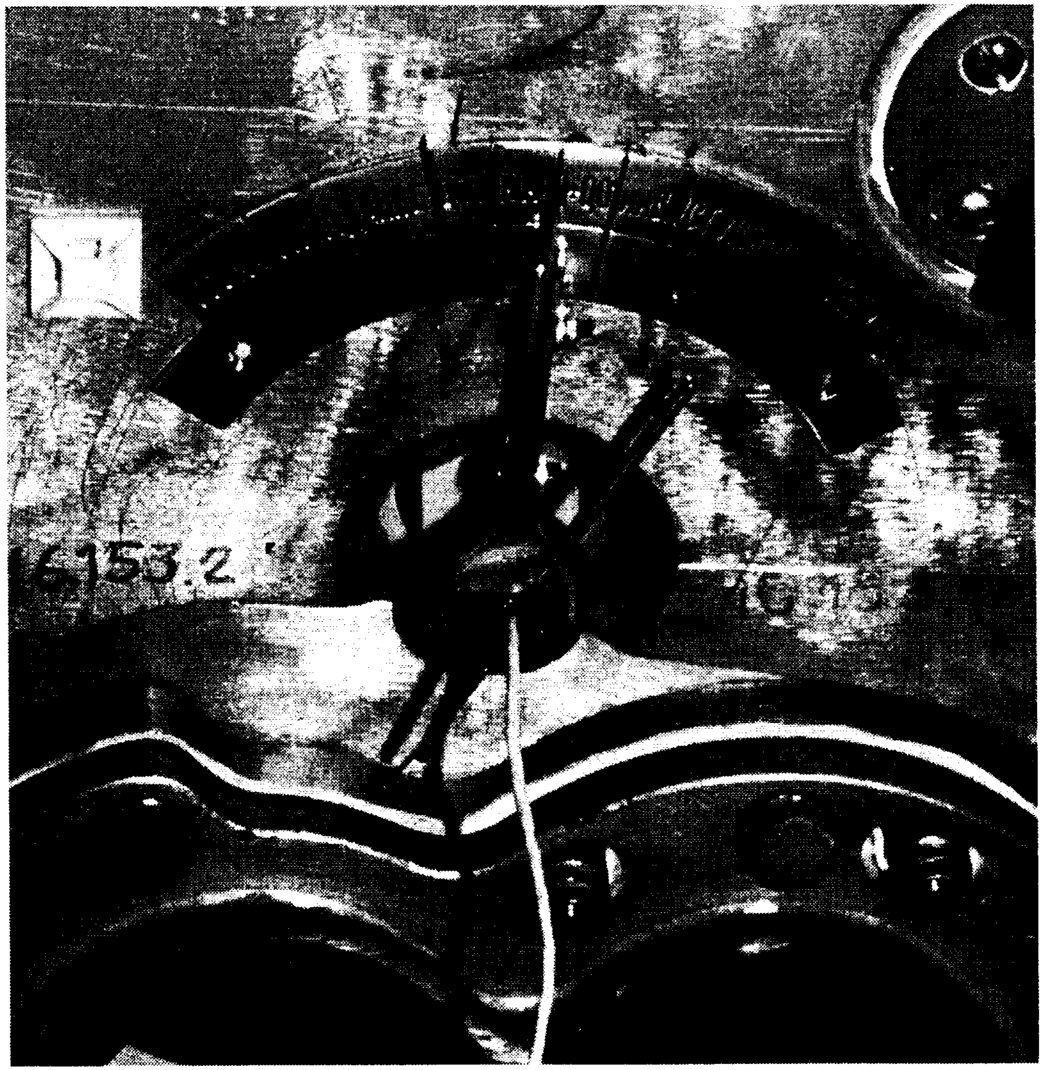


Figure 5: Photograph of Kulite flushness adjustment mechanism.

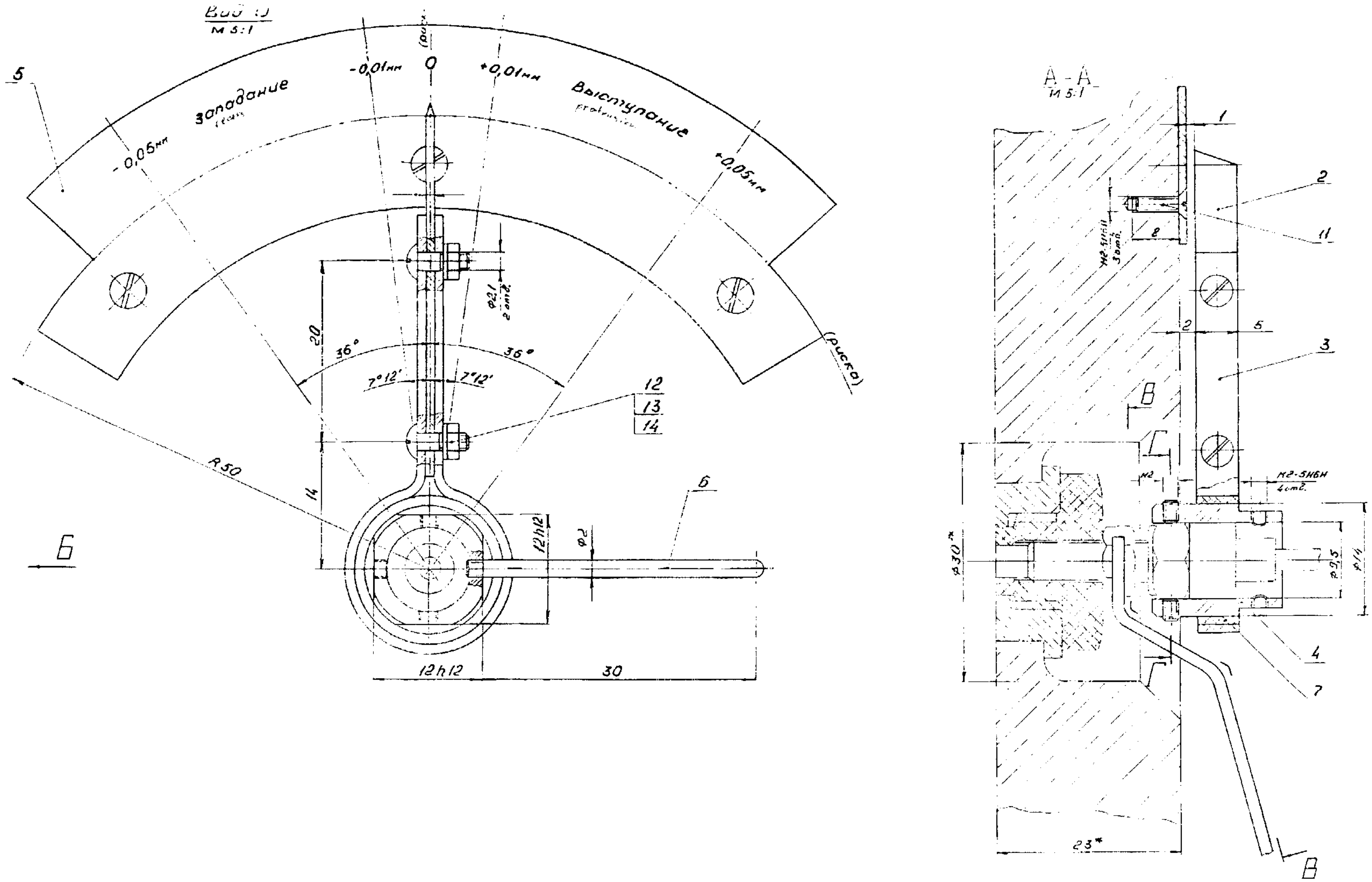


Figure 6: Schematic of Kulite flushness adjustment mechanism.

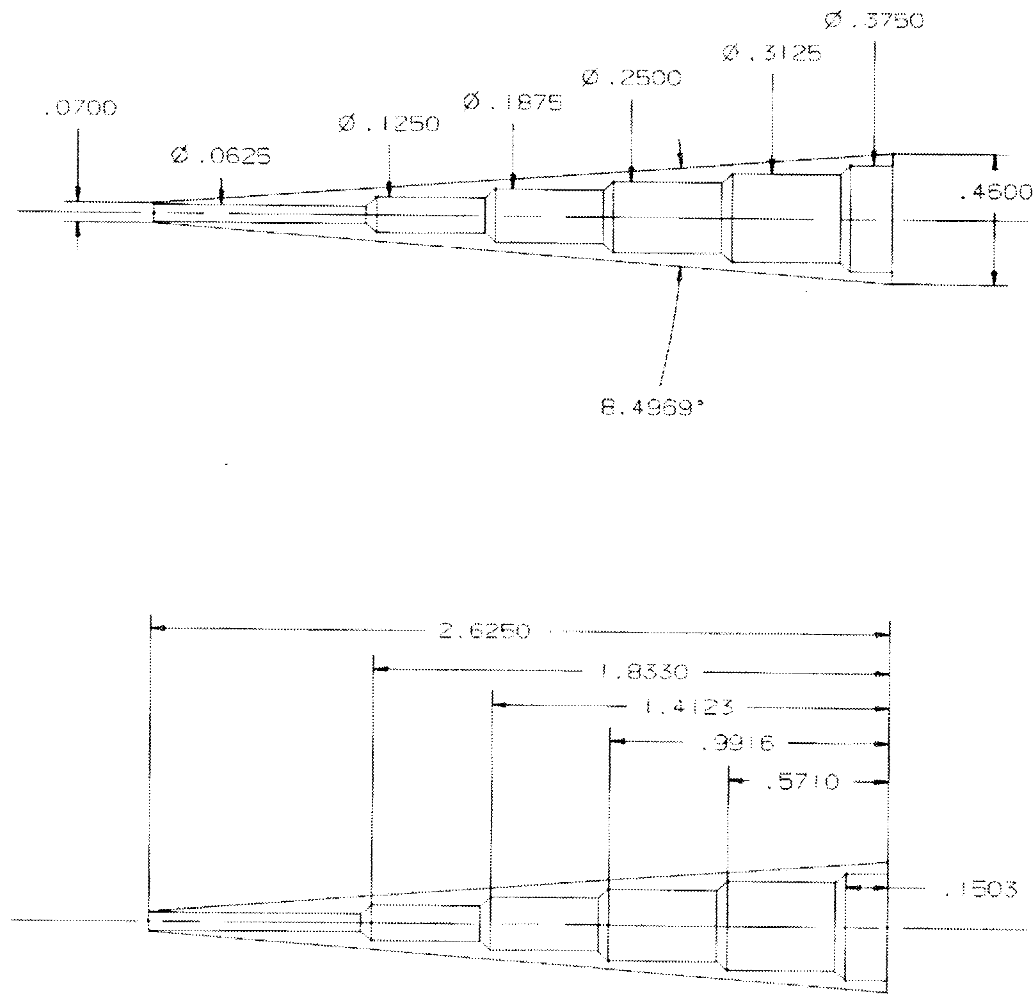


Figure 7: Schematic of flow cones (dimensions in inches).

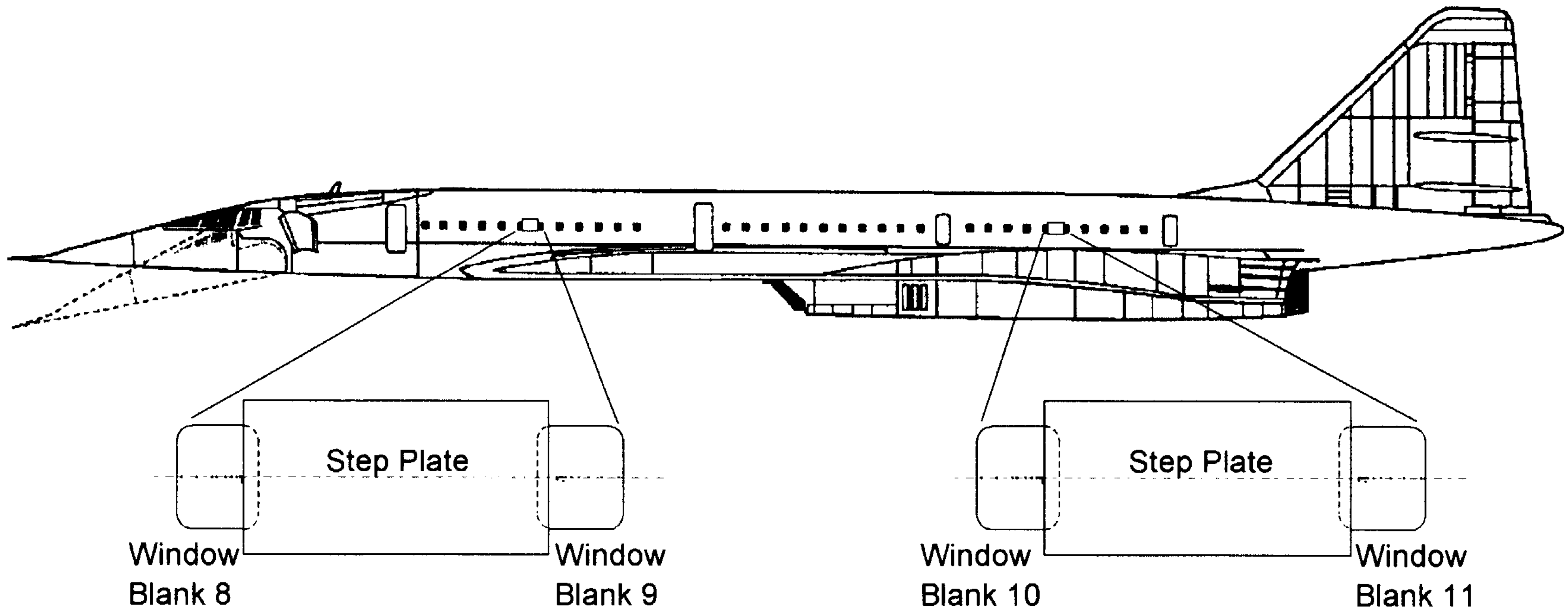
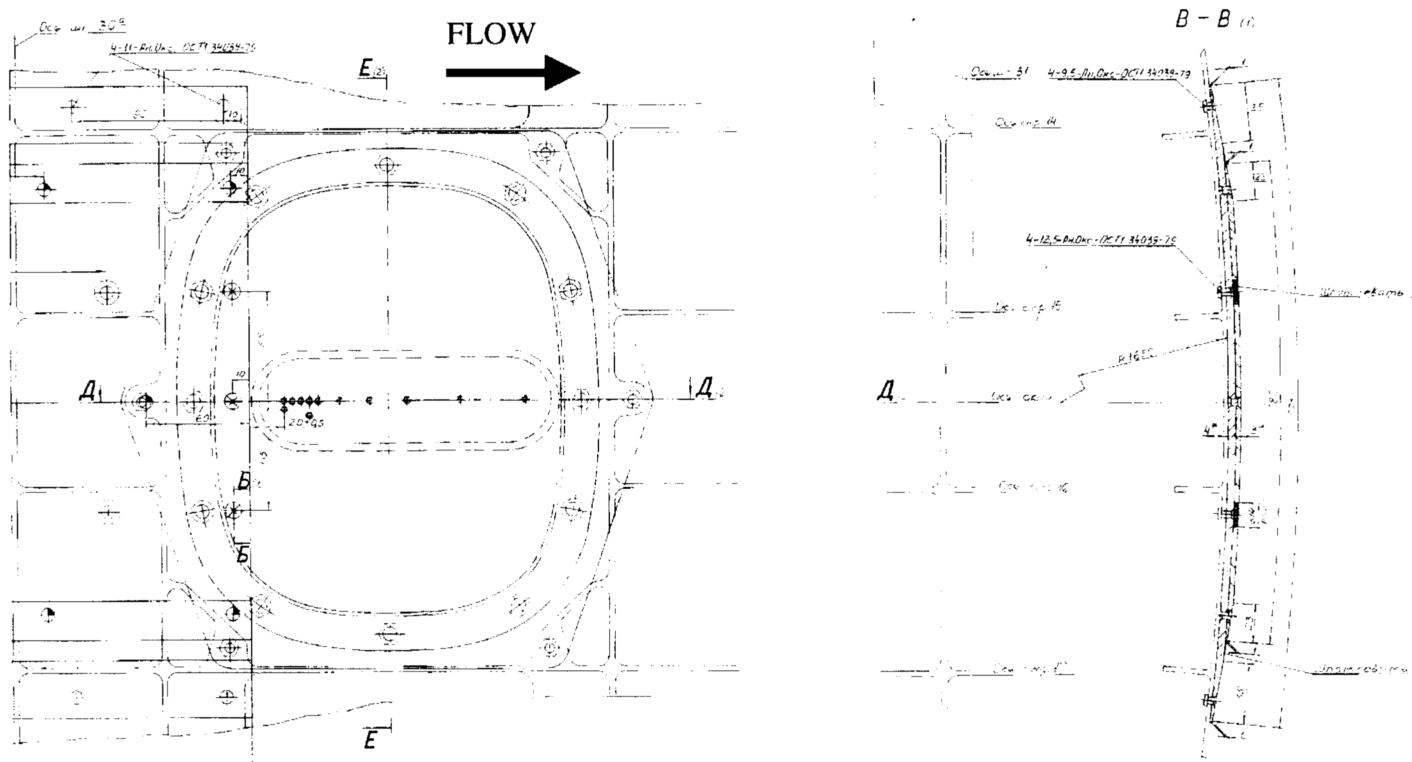


Figure 8: Location and identification of window blanks for sub-experiment 4.



Dimensions in mm.

Figure 9: Extract of Tupolev installation drawing of step plate; left portion shows the aft facing step.

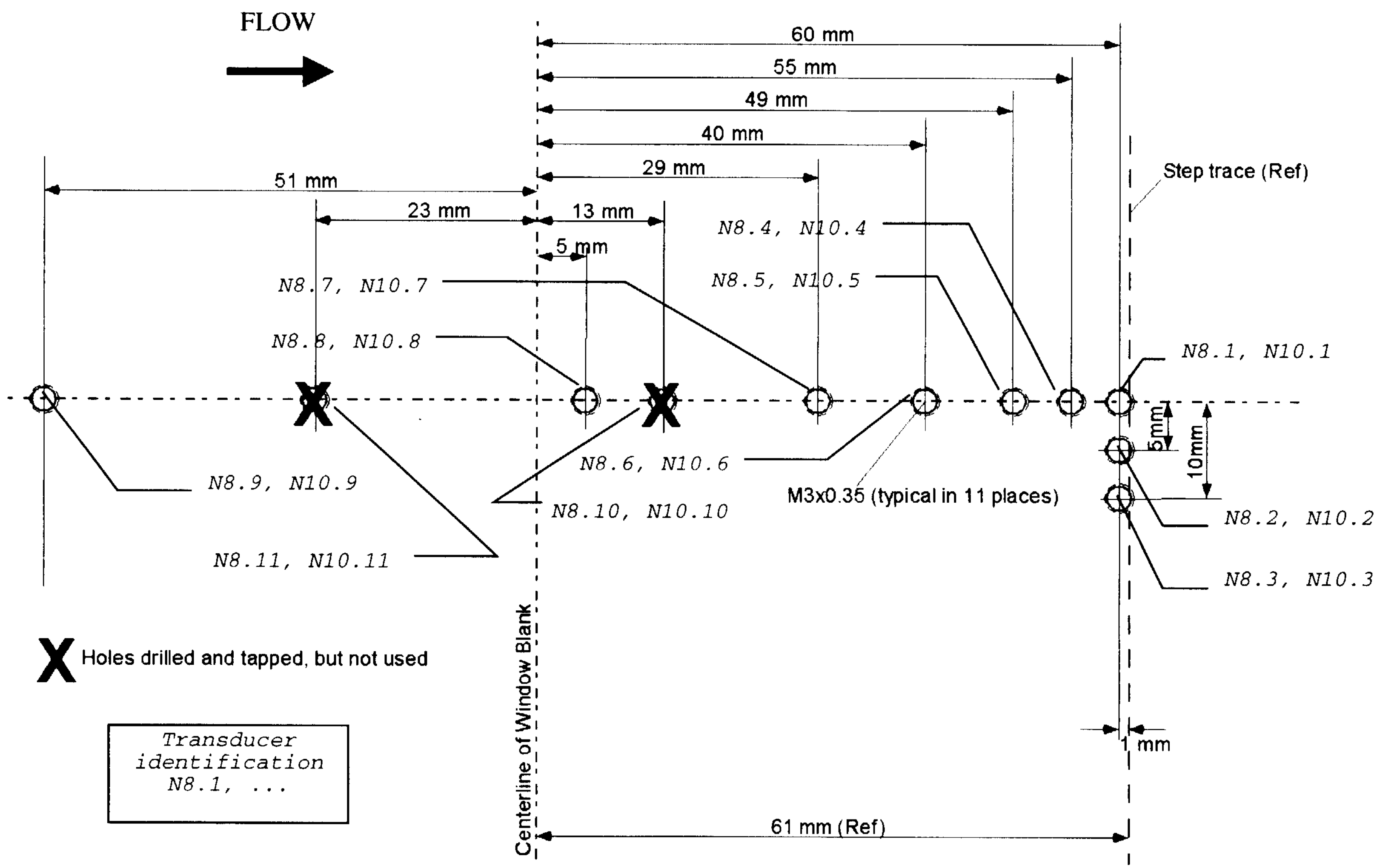


Figure 10: Hole pattern for transducers in front of forward facing steps on window blanks 8 and 10.

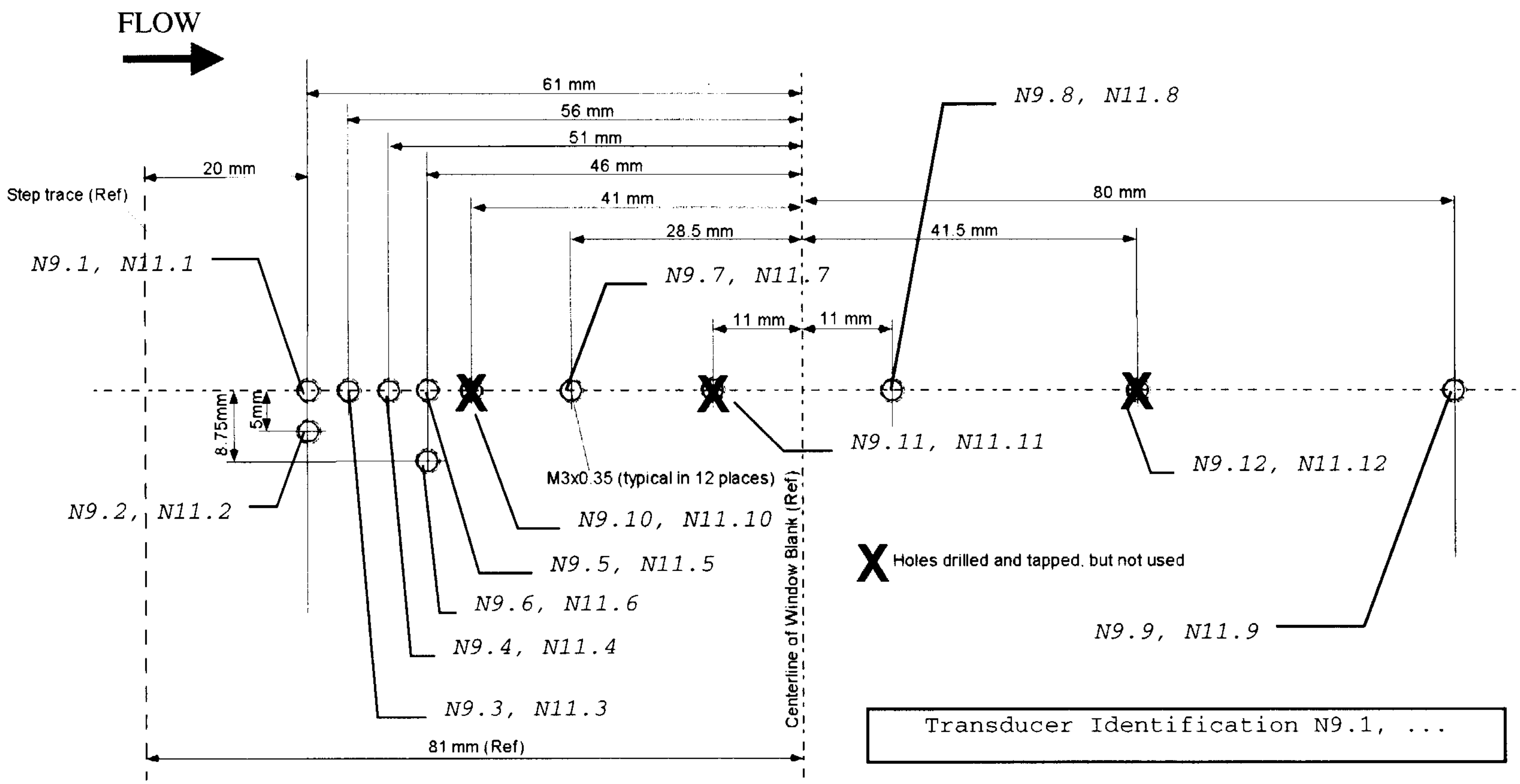


Figure 11: Hole pattern for transducers behind aft facing steps on window blanks 9 and 11.

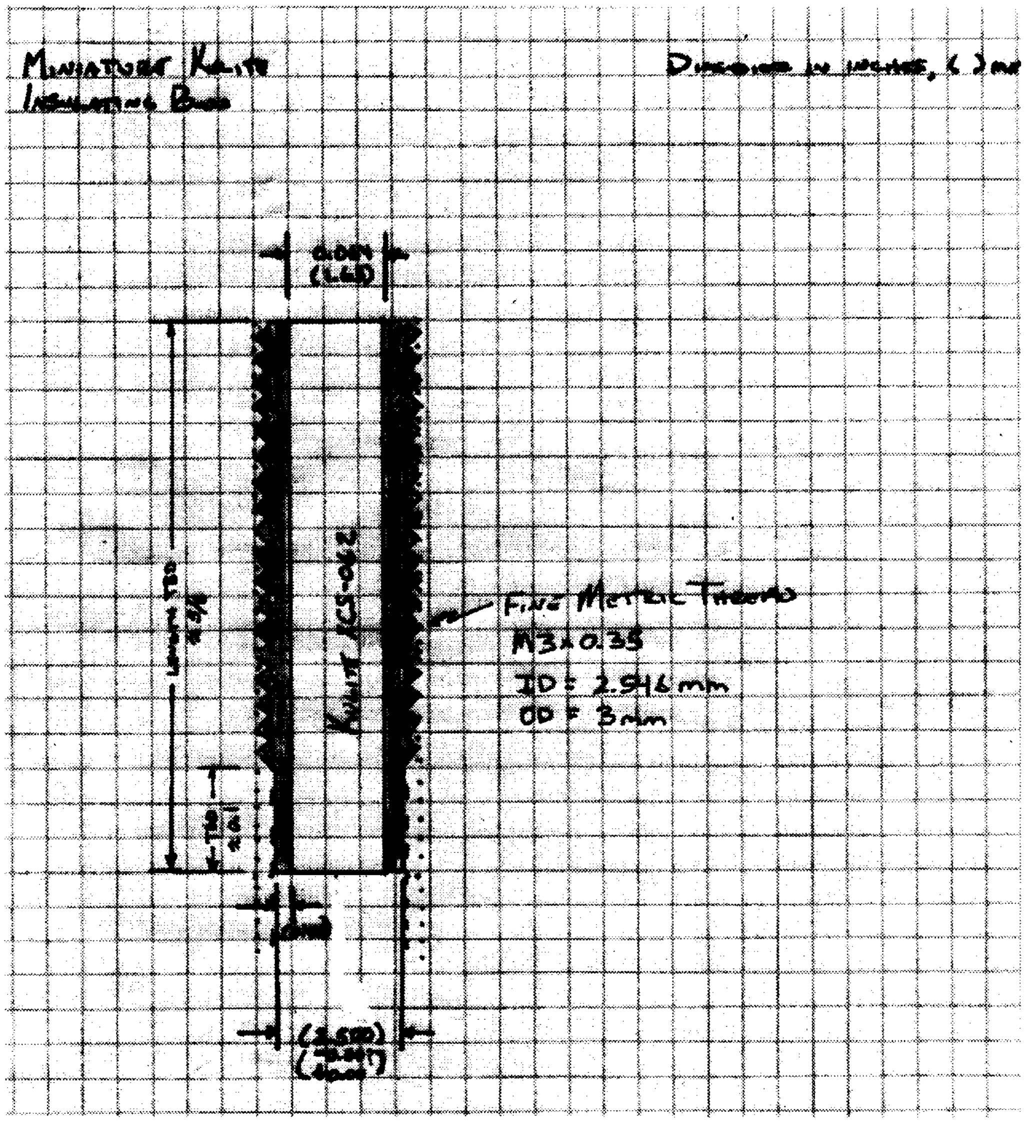


Figure 12: Sketch of Kulite transducer XCS-062 insulating/mounting boss.

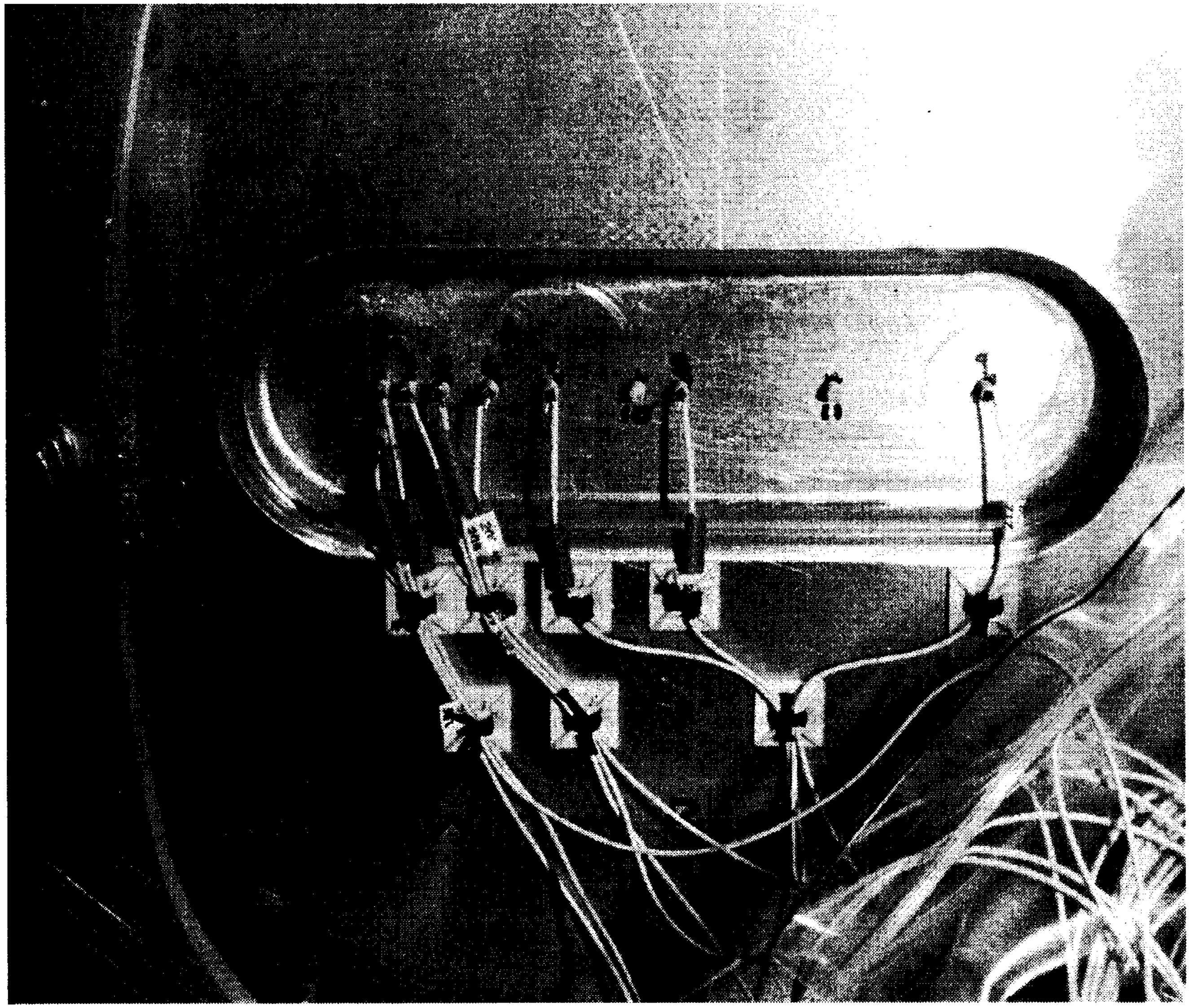


Figure 13: Photograph of interior of window blank 8 with Kulite miniature transducers installed.

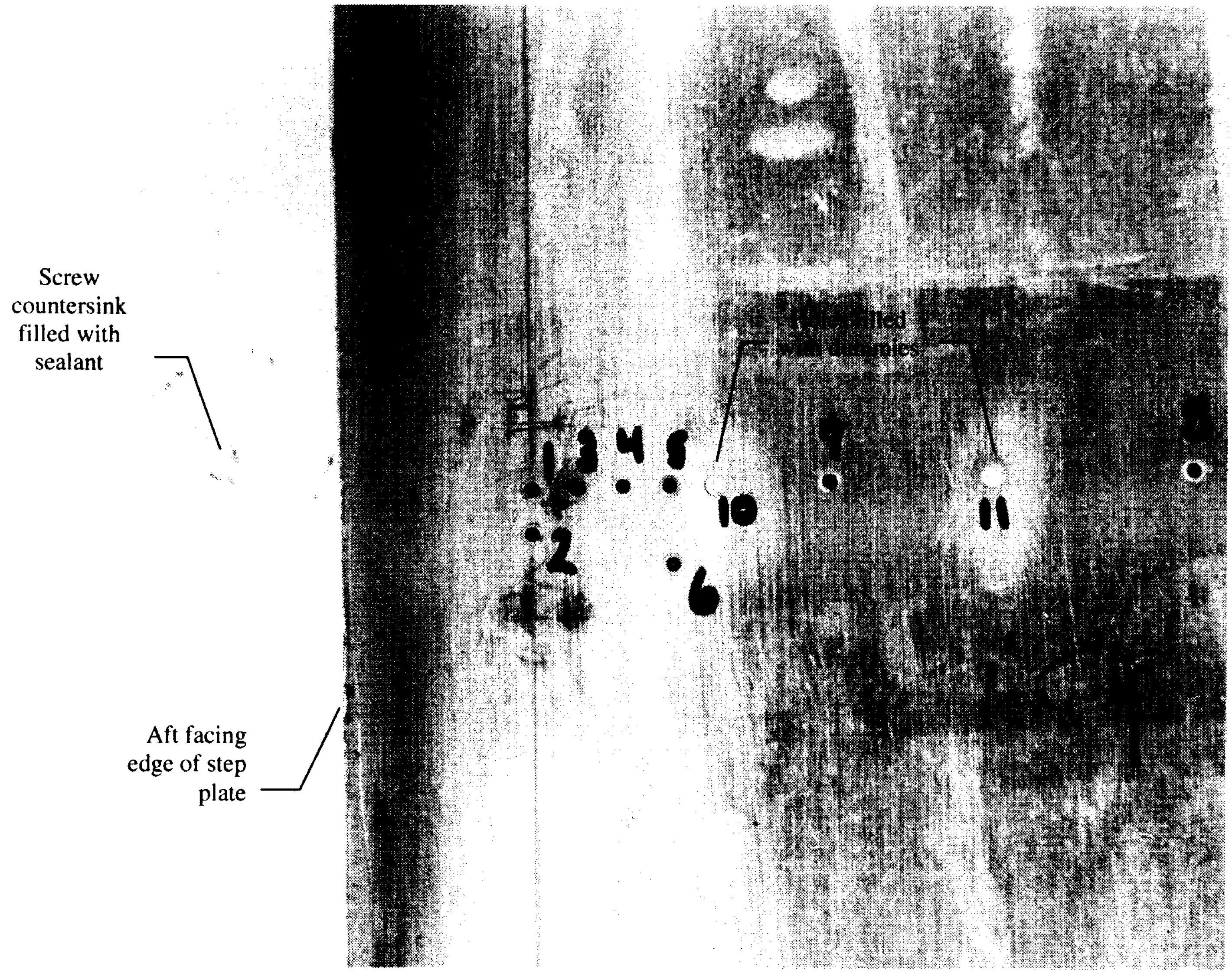


Figure 14: Photograph of exterior of window blank 9 with miniature Kulite transducers installed.

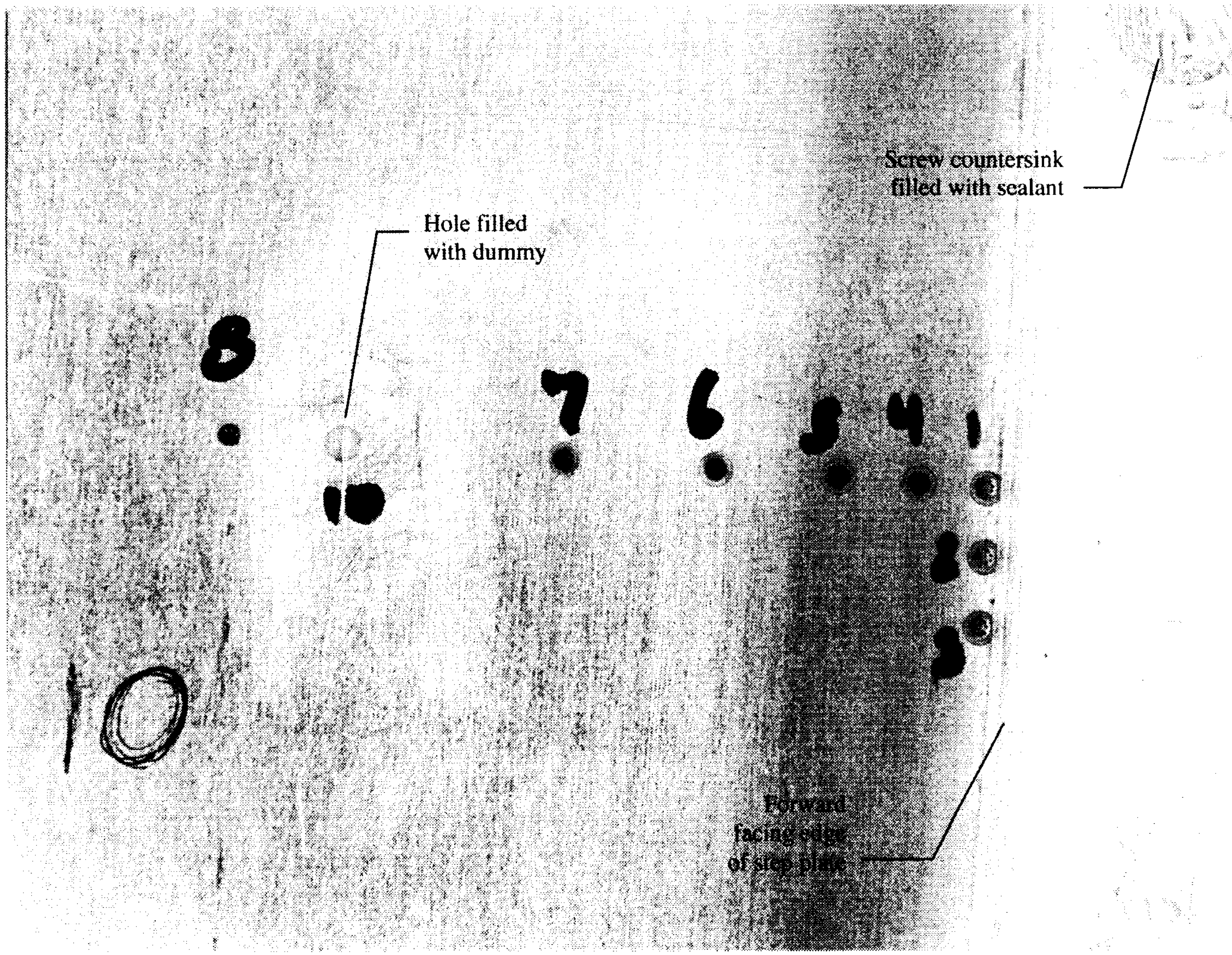


Figure 15: Photograph of exterior of window blank 10 with miniature Kulite transducers installed.

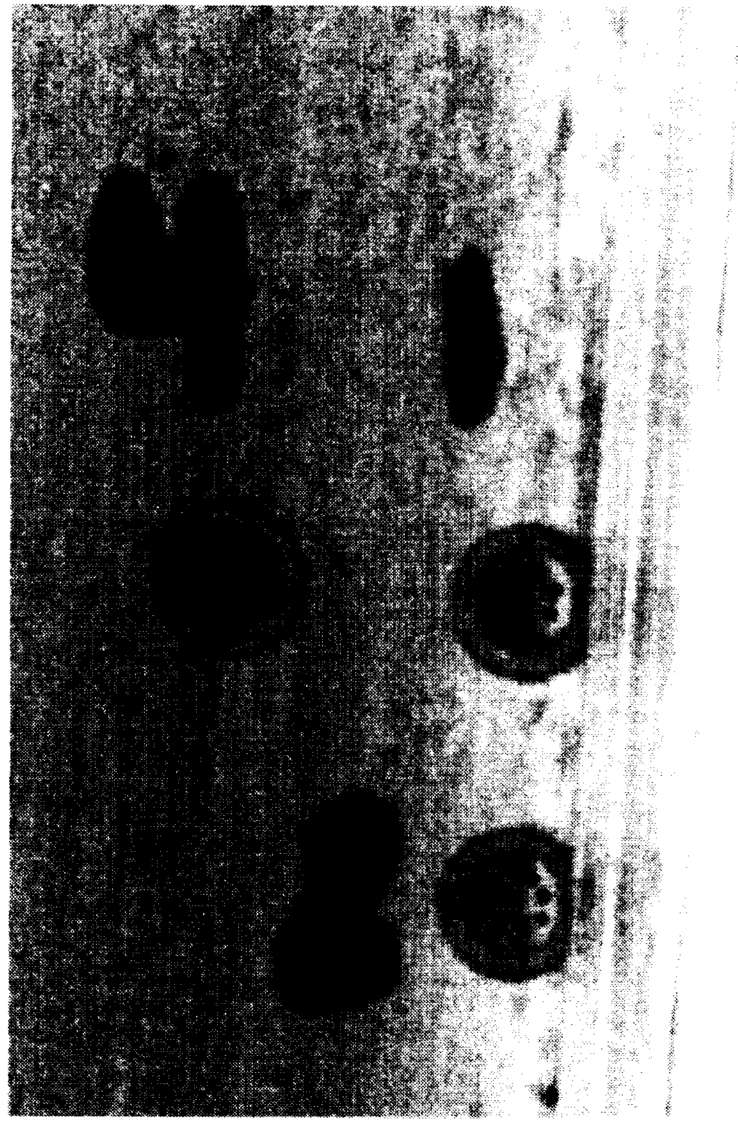


Figure 16: Blowup of transducers N10.1, N10.2, N10.4 outer face in front of forward facing step.

2.5. *Signal Conditioning*

2.5.1. *Kulite Signal Conditioning*

Signal conditioning for Kulite pressure transducers was provided by special instrumentation designed and fabricated at the NASA Langley Research Center (LaRC). The units were identical to the three existing ones used in experiment 2.1. Two additional 18-channel units were built for the new transducers on the port side. The units were mounted on the trim panels in the vicinity of the four new window blanks. The new units were programmed with a gain of 1100 instead of a gain of 500 used on the existing ones.

2.5.2. *Accelerometer Signal Conditioning*

Accelerometer signal conditioning was provided by the same Endevco amplifiers (model 2685M10B) used in experiment 2.1.

2.6. *Instrumentation Pallet*

The instrumentation pallet was modified slightly following flight 23 to accommodate a new multiplexer unit (see Section 2.6.1) needed for the higher channel count. Push button controls for the new multiplexer unit were added and internal wiring was changed to bypass the internal 12-channel multiplexer used for experiment 2.1.

2.6.1. *Multiplexer Unit*

Because 36 transducers were added for experiment 2.1A (but only 8 microphones removed) it became necessary to add to the system's multiplexing capabilities as the Metrum RSR-512 recorder was still limited to 32 input channels.

The multiplexer unit was designed and fabricated at NASA LaRC. It was an extension of the 12-channel multiplexer design used for experiment 2.1. All input signals, with the exception of IRIG-B, were routed through the multiplexer in one of three 32-channel input banks (a fourth input bank was not used). Channels which were recorded on more than one bank were split and connected to each bank input (see Table 7). The input banks were designated as 1, 2, 3 and 4. A push-button switch mounted on the multiplexer unit and a remote push-button switch mounted on the instrumentation pallet allowed the operator to choose which input bank to route to the 32-channel output.

Note: Since the new multiplexer was installed after flight 23, pressure data from flights 22 and 23 (only "flushness" Kulite transducers N2.1, N5.1 and N6.1) utilized the experiment 2.1 system with the old channel lineup. To avoid confusion, these transducers were assigned to the same channel numbers in the new lineup.

2.6.2. *Recording Requirements*

The recording requirements were the same as for experiment 2.1, see [16].

2.6.3. *Channel Switching Requirements*

The total channel count was 68. It consisted of 25 Kulite Model XCS-190-15D fluctuating pressure transducers and 6 accelerometers on the starboard side of the aircraft, 36 Kulite Model XCS-062-15D fluctuating pressure transducers on the port side, and IRIG-B time code. The IRIG-B time code was used to synchronize the experiment 2.1A data with the Damien PCM system used to record other flight data

[8]. Because a 32-channel Metrum recorder was selected, some channels had to be switched in one of three banks as previously noted. The channels were grouped together according to Table 7. This configuration was chosen as it allowed all starboard transducers to be recorded simultaneously on bank 1, all port side transducers from window blank pair 8 and 9 to be recorded simultaneously on bank 2, and all port side transducers from window blanks 10 and 11 to be recorded simultaneously on bank 3. In addition, transducers along the starboard centerline were common across banks 1-3 to allow additional undisturbed turbulent boundary layer pressure fluctuation data to be collected while recording data from the "steps" sub-experiment. Because changing flushness settings in flight for transducers N2.1, N5.1 and N6.1 was time consuming, their inclusion in all three input banks also allowed a time savings by minimizing the time at condition for any one bank.

Table 7: Channel table.[3]

	Input			
Output	Bank 1	Bank 2	Bank 3	Bank 4
1	Kulite N1.1	Kulite N1.1	Kulite N1.1	Not Used
2	Kulite N2.1	Kulite N2.1	Kulite N2.1	Not Used
3	Kulite N3.1	Kulite N3.1	Kulite N3.1	Not Used
4	Kulite S1	Kulite S1	Kulite S1	Not Used
5	Kulite N4.1	Kulite N4.1	Kulite N4.1	Not Used
6	Kulite N4.2	Kulite N8.1	Kulite N10.1	Not Used
7	Kulite N4.3	Kulite N8.2	Kulite N10.2	Not Used
8	Kulite N4.4	Kulite N8.3	Kulite N10.3	Not Used
9	Kulite N4.5	Kulite N8.4	Kulite N10.4	Not Used
10	Kulite N4.6	Kulite N8.5	Kulite N10.5	Not Used
11	Kulite N4.7	Kulite N8.6	Kulite N10.6	Not Used
12	Kulite N4.8	Kulite N8.7	Kulite N10.7	Not Used
13	Kulite S2	Kulite S2	Kulite S2	Not Used
14	Kulite N5.1	Kulite N5.1	Kulite N5.1	Not Used
15	Kulite N6.1	Kulite N6.1	Kulite N6.1	Not Used
16	Kulite N7.1	Kulite N7.1	Kulite N7.1	Not Used
17	Accel 10.12	Accel 10.12	Accel 10.12	Not Used
18	Accel 10.13	Accel 10.13	Accel 10.13	Not Used
19	Accel 10.14	Accel 10.14	Accel 10.14	Not Used
20	Accel 10.15	Accel 10.15	Accel 10.15	Not Used
21	Accel 10.16	Kulite N8.8	Kulite N10.8	Not Used

[3] Shaded blocks indicate transducers that are always recorded regardless of multiplexer position.

	Input			
Output	Bank 1	Bank 2	Bank 3	Bank 4
22	Kulite N1.2	Kulite N8.9	Kulite N10.9	Not Used
23	Kulite N1.3	Kulite N9.1	Kulite N11.1	Not Used
24	Kulite N1.4	Kulite N9.2	Kulite N11.2	Not Used
25	Kulite N1.5	Kulite N9.3	Kulite N11.3	Not Used
26	Kulite N4.9	Kulite N9.4	Kulite N11.4	Not Used
27	Kulite N7.2	Kulite N9.5	Kulite N11.5	Not Used
28	Kulite N7.3	Kulite N9.6	Kulite N11.6	Not Used
29	Kulite N7.4	Kulite N9.7	Kulite N11.7	Not Used
30	Kulite N7.5	Kulite N9.8	Kulite N11.8	Not Used
31	IRIG-B	IRIG-B	IRIG-B	Not Used
32	Accel 10.11	Kulite N9.9	Kulite N11.9	Not Used

2.6.4. Filter Requirements

The filtering requirements were the same as for experiment 2.1, see [16].

2.6.5. Signal Monitoring

The signal monitoring requirements were the same as for experiment 2.1, see [16].

2.7. Installation and Checkout

Mechanical installation of the video camera mounts in the passenger cabin and flow cones on window exteriors was performed in September 1998 between flights 20 and 21. Mechanical installation of Kulite transducers and flushness adjustment mechanisms for three locations (N2.1, N5.1 and N6.1) was performed between flights 21 and 22, also in September 1998.

During the period 1 – 15 November 1998, modifications were made to the instrumentation pallet on the aircraft. Changes were made primarily to accommodate the new multiplexer and two additional Kulite signal conditioning units. A complete checkout of the instrumentation was performed on the aircraft, including injecting signals into all channels of the multiplexer and observing the output on the spectrum analyzer located in the instrumentation pallet. Kulite transducers on the starboard side of the aircraft were reinstalled.

Between 15 November 1998 and 11 January 1999, Tupolev relocated the accelerometers from the positions used in experiment 2.1 to the new locations. Tupolev also completed installation of the new window blanks (without step plates attached) and mechanical installation of the multiplexer unit.

During the period 11 – 22 January 1999, new transducers on the port side were installed in window blanks 8 – 11 and checked out.

Prior to flight 24, Tupolev installed the step plates on window blank pairs 8 – 9 and 10 – 11.

2.8. Transducer Calibrations

2.8.1. Accelerometer Calibrations

Because it was not possible to perform an in-situ calibration of the accelerometers, the factory calibrations were utilized. All calibration files, see Section 5.4, therefore indicate the same accelerometer calibrations for all flight and ground tests.

2.8.2. Kulite Calibrations

The process of performing Kulite calibrations was identical to that used for experiment 2.1. Both 150dB/250Hz and broadband noise sources were used for calibrations. The calibrations and their use are provided in Table 8. The 150dB/250Hz source was used for magnitude calibrations, which provide the sensitivities necessary to convert volts to engineering units for data analysis. The broadband noise source was used to provide data for possible, future phase calibrations. Calibration data is provided in the calibration data files, see Section 5.4.

Table 8: Kulite magnitude calibration look-up table.

<table>
<tr><th>Calibration Date</th><th>Kulite Transducers Calibrated</th><th>Level (dB)</th><th>Use</th></tr>
<tr><td>17-Sep-98</td><td>N2.1, N5.1, N6.1</td><td>150</td><td>Flights 22, 23</td></tr>
<tr><td>11-Nov-98</td><td>N1.1-1.5, N2.1, N3.1, N4.2-N4.9, S2, N5.1, N6.1, N7.1-N7.5</td><td>150</td><td rowspan="4">Flights 24-27, Ground engine runups, Background Noise</td></tr>
<tr><td>19-Jan-99</td><td>S1, N4.1</td><td>150</td></tr>
<tr><td>20-Jan-99</td><td>N8.1-N8.9, N9.1-N9.5, N9.7-N9.9, N10.1-N10.9, N11.1-N11.9</td><td>150</td></tr>
<tr><td>21-Jan-99</td><td>N9.6</td><td>150</td></tr>
<tr><td>21-Apr-99</td><td>N10.5-N10.9, N11.1-N11.9</td><td>150</td><td>Post test in-situ calibration</td></tr>
<tr><td>Nov-99</td><td>All</td><td>(*)</td><td>Post test lab calibration</td></tr>
</table>

(*) Post test lab calibration performed at static pressure (0 to ±12 psi and dynamic pressure 50-4000 Hz at 140 dB.

Kulite magnitude calibrations in the Tu-144LL were very consistent and close to calibrations performed in the laboratory. Therefore, while it would have been desirable to obtain additional calibrations between flights 21 and 27, it does not appear to have been absolutely essential. A complete post-flight calibration following flight 27 was not possible due to problems with the calibrator. A laboratory calibration of the transducers only (not through the system) was performed following return of the system to NASA LaRC. These are provided in the calibration files.

Data from the Kulite phase calibrations was acquired for each transducer at the same time as the magnitude calibration data indicated in Table 8 (except for the post test lab calibration). This data was reduced but not processed to obtain the phase corrections. Additionally, phase calibration data in the form of time histories is not included in the CD-R set described in Section 5.3.

3. Procedures

3.1. Flight Tests

Because interior noise microphones were not used, an abbreviated pre-flight task list was followed. This included powering up and warming up the instrumentation pallet, uncovering transducers and flow cones, installation of video cameras, and synchronization of the internal clocks on the Metrum and video cameras with the main data system. Post flight activities included powering down the instrumentation pallet, removing log sheets and tapes, and covering transducers and flow cones.

For flights 22, 23 and 24, pre- and post-flight activities were carried out by Tupolev personnel with the participation of one of the authors. For flights 25, 26, and 27, these procedures were carried out by Tupolev personnel.

An English language only version of the portion of the procedures for operating the new multiplexer unit are included in Appendix B.

3.2. Data Quality Assurance

Following flight 24, the HP-715i computer and a spare Metrum RS-512 tape recorder were deployed in the offices of Boeing Operations International Moscow to assess data quality. The data recorded during test flight 24 with pressure and vibration data was examined for quality by narrow band spectral analysis. Data quality was generally found to be very good with a few exceptions. Also, relevant data from the PCM data stream (see [8]) were inspected mainly to ensure that the desired flight conditions were reached and held constant during the data acquisition time interval. The following problem was found and corrected for flights 25-27:

- Transducers N10.1, N10.2, and N10.3 provided signals as if they were not stimulated at all. Investigation revealed that they were covered by a thin layer of sealant which was only visible with a strong magnifying glass; the sealant was easily removed. Those transducers are located immediately in front of the forward facing step over window blank 10; some sealant used during installation must have covered them inadvertently. This condition existed for the background noise and ground engine runup data as well.

3.3. Ground Measurements

3.3.1. Ground Runups

Ground engine run-up data with the aircraft stationary was obtained for the following conditions:

- All engines idling
- Three engines idling, one engine at full power without afterburner; cycled through all four engines.

3.3.2. Background Noise Data

Background noise data with no external stimulation were also acquired to determine the dynamic range of the flight and ground runup recordings.

4. Test Points

Flight test points were chosen to cover much of the TU-144's flight envelope, as well as to obtain as large a unit Reynolds number range as possible at various Mach numbers: takeoff, landing, subsonic, transonic and supersonic conditions up to Mach 2 (see Table 9). Continuous data was acquired at each test condition and designated with a unique run number. Figure 17 shows the test points in relation to the TU-144LL's flight envelope.

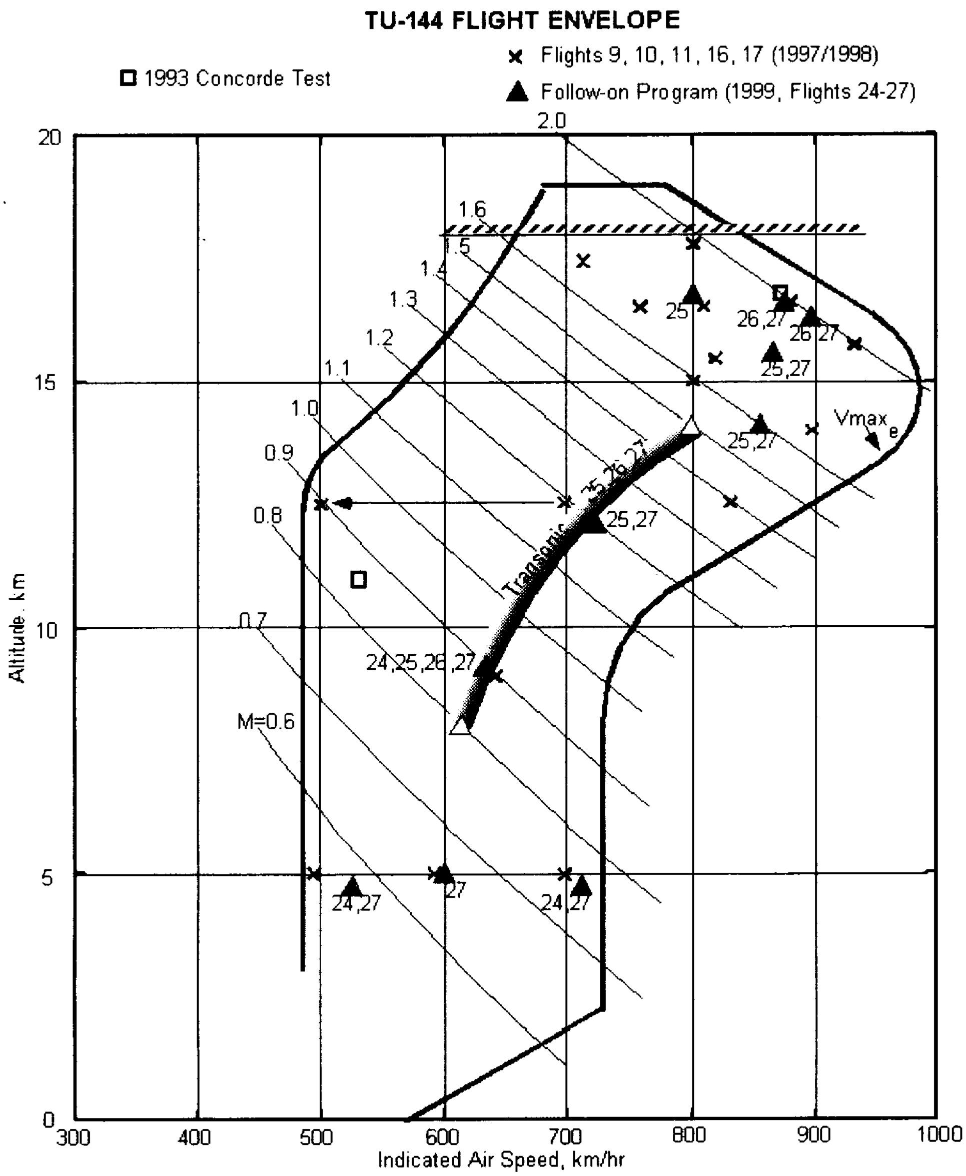


Figure 17: Tu-144 flight envelope and experiment 2.1/2.1A test points

Table 9: Table of test points.

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
	-	15-Sep-98	-	21					-		Video Only
FLIGHT 22											
	73				16.5	54.1	2	07:30:09	61.44		Flushness at -0.05mm
	74				16.7	54.6	2	07:33:00	60.67		Flushness at -0.01mm
	75	18-Sep-98	A	22	16.7	54.8	2	07:35:31	60.54	(*)	Flushness at 0.00mm
	76				16.7	54.8	2	07:37:49	61.31		Flushness at +0.01mm
	78				16.5	54.1	2	07:42:35	52.99		Flushness at +0.05mm
FLIGHT 23											
	80				16.5	54.1	2	07:23:35	61.06		Flushness at -0.05mm
	81				16.2	53.0	2	07:26:55	62.72		Flushness at -0.01mm
	82				16.2	53.2	2	07:28:50	60.80		Flushness at 0.00mm
	83				16.2	53.2	2	07:31:14	62.59		Flushness at +0.01mm
	84	24-Sep-98	A	23	16.6	54.3	2	07:33:24	59.90	(*)	Flushness at +0.05mm
	85				16.5	54.1	2	07:35:42	60.80		Flushness at +0.01mm
	86				16.5	54.1	2	07:37:38	60.16		Flushness at 0.00mm
	87				16.4	53.8	2	07:39:32	60.54		Flushness at -0.01mm
	89				13.5	44.3	1.6	07:41:29	50.83		Flushness at -0.05mm
PRE-FLIGHT 24											
	96		2		0.0	0.0	0	14:53:26	23.97		
	97	11-Mar-99	3	Pre-24	0.0	0.0	0	14:54:37	27.97	(!) (#)	Background Noise
	98		1		0.0	0.0	0	14:55:49	19.02		

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
PRE-FLIGHT 24											
	99		1		0.0	0.0	0	10:25:57	28.08		
	100		2		0.0	0.0	0	10:27:24	30.85		Background Noise Recording During Taxi with APU, no PCM
	101		3		0.0	0.0	0	10:30:34	30.11		
	102		1		0.0	0.0	0	11:17:19	30.24		
	103		2		0.0	0.0	0	11:18:17	31.50		All 4 engines at about 50%
	104		3		0.0	0.0	0	11:19:56	30.82		
	105	15-Mar-99	2	Pre-24	0.0	0.0	0	11:25:58	30.21	(!) (#)	Eng 1 & 2 idle, 3 & 4 max (no A/B)
	106		1		0.0	0.0	0	11:29:14	40.99		Eng 2 max (no A/B), all others idle
	107		1		0.0	0.0	0	11:31:44	31.39		Eng 1 max (no A/B), all others idle
	108		3		0.0	0.0	0	11:33:20	30.86		Eng 3 max (no A/B), all others idle
	109		3		0.0	0.0	0	11:35:31	30.32		Eng 4 max (no A/B), all others idle
FLIGHT 24											
Takeoff	110		3		0.5	1.6		10:53:32	60.13		
	111		2					11:04:17	40.05		Flushness at -0.05mm
	112	22-Mar-99	2	24				11:08:00	37.58	(!)	Flushness at -0.02mm
2.1A-7	113		1		9.0	29.5	0.9	11:12:05	61.39		Flushness at 0.00mm
	114		3					11:15:56	50.30		Flushness at +0.02mm
	115		3					11:18:31	46.98		Flushness at +0.05mm

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
2.1A-10	116	22-Mar-99	2	24	4.9	16.1	0.58	11:33:07	40.46	(!)	Flushness at -0.05mm
	117		2					11:34:58	57.12		Flushness at -0.02mm
	118		1					11:37:18	51.95		Flushness at 0.00mm
	119		3					11:39:29	51.60		Flushness at +0.02mm
	120		3					11:41:59	60.96		Flushness at +0.05mm
2.1A-8	121		2		4.9	16.1	0.75	11:56:00	60.99		Flushness at -0.05mm
	122		2					11:58:27	52.16		Flushness at -0.02mm
	123		1					12:00:35	58.98		Flushness at 0.00mm
	124		3					12:02:35	59.90		Flushness at +0.02mm
	125		3					12:04:44	62.82		Flushness at +0.05mm
2.1A-7	126		2		9.0	29.5	0.9	12:11:30	61.50		Flushness at -0.05mm
	127		2					12:14:11	54.19		Flushness at -0.02mm
	128		1					12:18:18	60.74		Flushness at 0.00mm
	129		3					12:21:23	60.74		Flushness at +0.02mm
	130		3					12:24:07	59.60		Flushness at +0.05mm
2.1A-10	131		2		4.9	16.1	0.58	12:36:51	52.06		Flushness at -0.05mm
	132		2					12:38:48	60.77		Flushness at -0.02mm
	133		1					12:41:12	58.48		Flushness at 0.00mm
	134		3					12:43:31	51.47		Flushness at +0.02mm
	135		3					12:45:48	60.74		Flushness at +0.05mm

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
FLIGHT 25											
Takeoff	136	30-Mar-99	2	25	0.5	1.6		13:14:34	43.63		
2.1A-11	137a		2		8.0	26.2	0.85	13:24:09	30.06		Transonic, unsteady. Run divided into 30-second segments.
	137k				↓	↓	0.90	13:29:00	30.05		
	137o						1.0 - 1.1	13:30:50	30.06		
	137p						1.1 - 1.2	13:31:20	30.06		
	137q						1.2 - 1.3	13:31:50	30.06		
	137r						1.3 - 1.4	13:32:20	30.06		
	137s				14.0	45.9	1.4 - 1.5	13:32:33	30.06	(^)	
2.1A-3 low	138		2		15.5	50.9	1.8	13:38:01	58.21		Flushness at -0.05mm
	139		2					13:40:18	44.85		Flushness at -0.02mm
	140		1					13:42:32	39.84		Flushness at 0.00mm
	141		3					13:44:38	33.74		Flushness at +0.02mm
	142		3					13:46:38	37.70		Flushness at +0.05mm
2.1A-3 hi	143		2		16.4	53.8	1.8	14:02:56	48.78		Flushness at -0.05mm
	144		2					14:05:17	31.04		Flushness at -0.02mm
	145		1					14:07:01	43.71		Flushness at 0.00mm
	146		3					14:08:49	44.43		Flushness at +0.02mm
	147		3					14:10:25	29.31		Flushness at +0.05mm
2.1A-4 hi	148		3		14.0	45.9	1.6	14:13:53	25.81		Flushness at 0.00mm
	149		2					14:15:05	22.42		
	150		1					14:16:04	40.03		

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
2.1A-6	151	30-Mar-99	3	25	12.0	39.4	1.2	14:24:20	19.42		Flushness at 0.00mm
	152		2					14:25:21	37.78		
	153		1					14:26:50	43.02		
2.1A-7	154		3		9.0	29.5	0.9	14:33:19	31.62		Flushness at 0.00mm
	155		2					14:34:38	37.23		
	156		1					14:35:58	29.17		
FLIGHT 26											
2.1A-7	157	2-Apr-99	1	26	9.0	29.5	0.9	09:25:28	62.40		Original run 157 bad. 2nd of 2 run 171s on original data sheet renamed to run 157. Flushness at 0.00mm.
2.1A-11	158a		3		8.0	26.2	0.82	08:23:37	27.28		Transonic, unsteady. Run divided into 30-second segments.
	158d				↓	↓	0.9	08:24:30	30.08		
	158g						1.0 - 1.1	08:26:00	30.03		
	158h						1.1 - 1.2	08:26:30	30.03		
	158i						1.2 - 1.3	08:27:00	30.03		
	158j						1.3 - 1.4	08:27:30	30.03		
	158k				14.0	45.9	1.4 - 1.5	08:27:51	29.31	(^)	
2.1A-1 low	159		2		16.0	52.5	2	08:33:31	61.12		Flushness at -0.05mm
	160		2					08:35:29	61.22		Flushness at -0.02mm
	161		1					08:37:23	61.66		Flushness at 0.00mm
	162		3					08:39:27	59.12		Flushness at +0.02mm
	163		3					08:41:32	50.91		Flushness at +0.05mm

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
2.1A-1 med	164	2-Apr-99	2	26	16.7	54.8	2	09:02:26	19.86		Flushness at -0.05mm
	165		2					09:03:36	22.42		Flushness at -0.02mm
	166		1					09:04:41	20.37		Flushness at 0.00mm
	167		3					09:05:45	32.91		Flushness at +0.02mm
	168		3					09:07:08	33.95		Flushness at +0.05mm
2.1A-11	169b		2		14.0	45.9	1.4 - 1.3	09:12:14	30.18		Transonic, unsteady. Runs divided into 30-second segments.
	169d						1.3 - 1.2	09:13:10	30.11		
	169h						1.2 - 1.1	09:15:00	30.11		
	169l				9.0	29.5	1.1 - 1.0	09:16:55	30.11		
2.1A-7	170		3		9.0	29.5	0.9	09:21:07	25.54		Flushness at 0.00mm
	171		2					09:23:48	41.87		
FLIGHT 27											
Takeoff	172	14-Apr-99	2	27	0.5	1.6		12:43:20	60.61		
2.1A-11	173a		2		8.0	26.2	0.8	12:51:35	30.02		Transonic, unsteady. Run divided into 30 and 40 second segments.
	173h						0.9	12:56:40	30.05		
	173k						1.0 - 1.1	12:58:10	40.03		
	173l						1.1 - 1.2	12:58:50	40.02		
	173m						1.2 - 1.3	12:59:30	40.03		
	173n				14.0	45.9	1.3 - 1.4	13:00:10	46.93		
2.1A-3 low	174		2		15.5	50.9	1.8	13:03:58	51.47		
	175		3					13:05:37	51.39		
	176		1					13:07:14	57.87		

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
2.1A-1 low	177	14-Apr-99	2	27	16.0	52.5	2	13:12:38	51.39		
	178		3					13:14:09	52.80		
	179		1					13:15:45	54.61		
2.1A-1 med	180		2		16.8	55.1	2	13:20:40	53.18		
	181		3					13:22:17	54.35		
	182		1					13:23:52	67.14		
2.1A-4 hi	183		2		14.0	45.9	1.6	13:28:43	50.91		
	184		3					13:30:08	42.24		
	185		1					13:31:28	57.30		
2.1A-11	186a		3		14.0	45.9	1.55 - 1.48	13:44:10	30.06		Transonic, unsteady. Run divided into 30-second segments.
	186b				↓	↓	1.48 - 1.42	13:44:40	30.06		
	186c				↓	↓	1.42 - 1.36	13:45:10	30.06		
	186e				↓	↓	1.30 - 1.25	13:46:10	30.06		
	186f				12.0	39.4	1.25 - 1.20	13:46:21	30.06	(^)	
2.1A-6	187		2		12.0	39.4	1.2	13:48:33	51.74		
	188		3					13:49:59	53.47		
	189		1					13:51:26	63.26		

Test Point	Run No.	Date	Data Bank	Flight No.	Altitude (km)	Altitude (kft)	Mach No. or V_{ind}	Time (GMT)	Duration (s)	Notes	Comments
	190b				12.0	39.4	1.24 - 1.20	13:56:49	30.10		
	190d						1.13 - 1.05	13:57:40	30.10		
2.1A-11	190e		3				1.05 - 1.00	13:58:10	30.10		Transonic, unsteady. Run divided into 30-second segments.
	190f						1.00 - 0.95	13:58:40	30.10		
	190g				9.0	29.5	0.95	13:59:10	30.10		
	191	14-Apr-99	2	27				14:03:48	46.62		
2.1A-7	192		3		9.0	29.5	0.9	14:05:22	53.30		
	193		1					14:07:00	68.85		
	194		2					14:15:18	49.57		
2.1A-8	195		3		4.9	16.1	V=700	14:16:42	57.17		
	195		1					14:18:18	67.12		
	197		2					14:21:23	47.98		
2.1A-9	198		3		5.0	16.4	V=530	14:23:13	57.65		
	199		1					14:24:53	67.36		

Notes:

(*) Data set contains only Kulite transducers N2.1, N5.1 and N6.1

(!) Data set contains Kulite transducers N10.1 – N10.3 which are known to be bad

(#) The flight/condition number associated with these records is 24 since they were collected just prior to flight 24 (see Section 5.3).

(^) Data run overlaps previous run

5. The Data

5.1. Data Reduction Process

The data reduction process was identical to that used for experiment 2.1 (see [16]).

5.2. Sample Data

- Flow direction data - A sample captured video picture is shown in Figure 18.
- The effect of Kulite transducer flushness is shown in Figure 19 for Kulite transducer N5.1 at a Mach 2, 16 km flight condition.
- The effect of a forward facing step at window blank 8 is shown in Figure 20 for run 159.
- The effect of an aft facing step at window blank 9 is shown in Figure 21 for run 159.

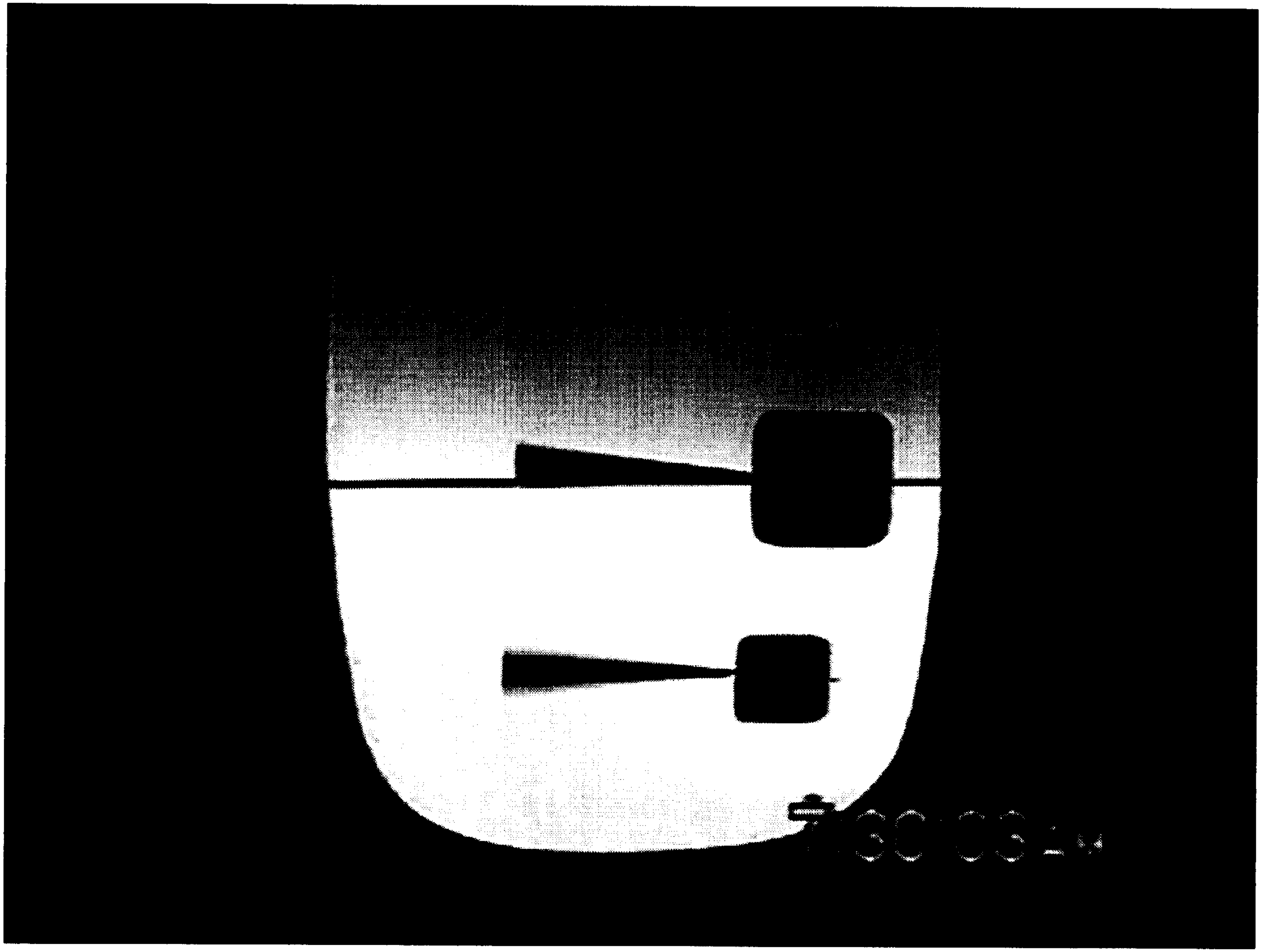


Figure 18: Sample video capture of flow cones on a window.

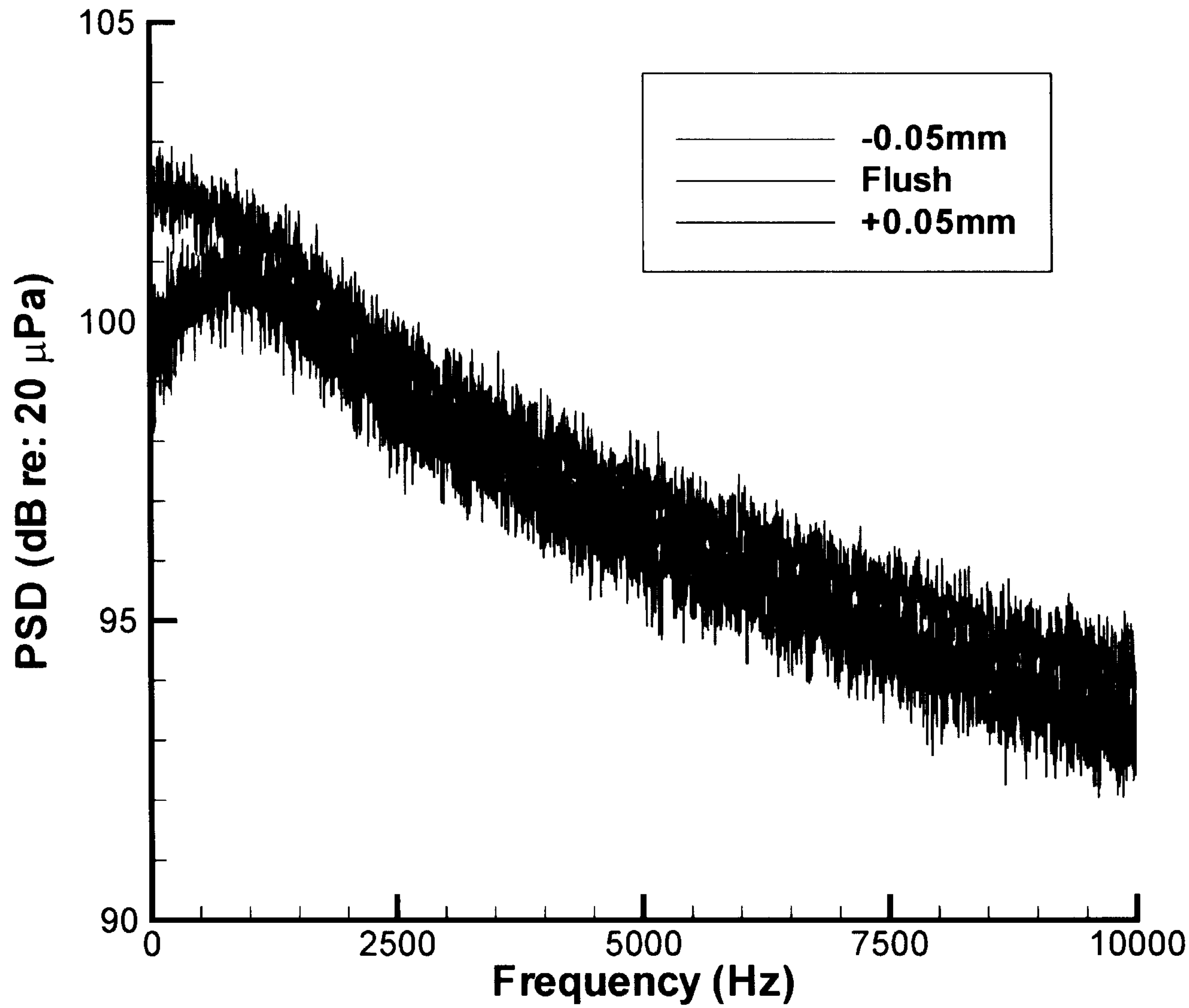


Figure 19: Effect of transducer flushness at N5.1 for a Mach 2, 16 km flight condition.

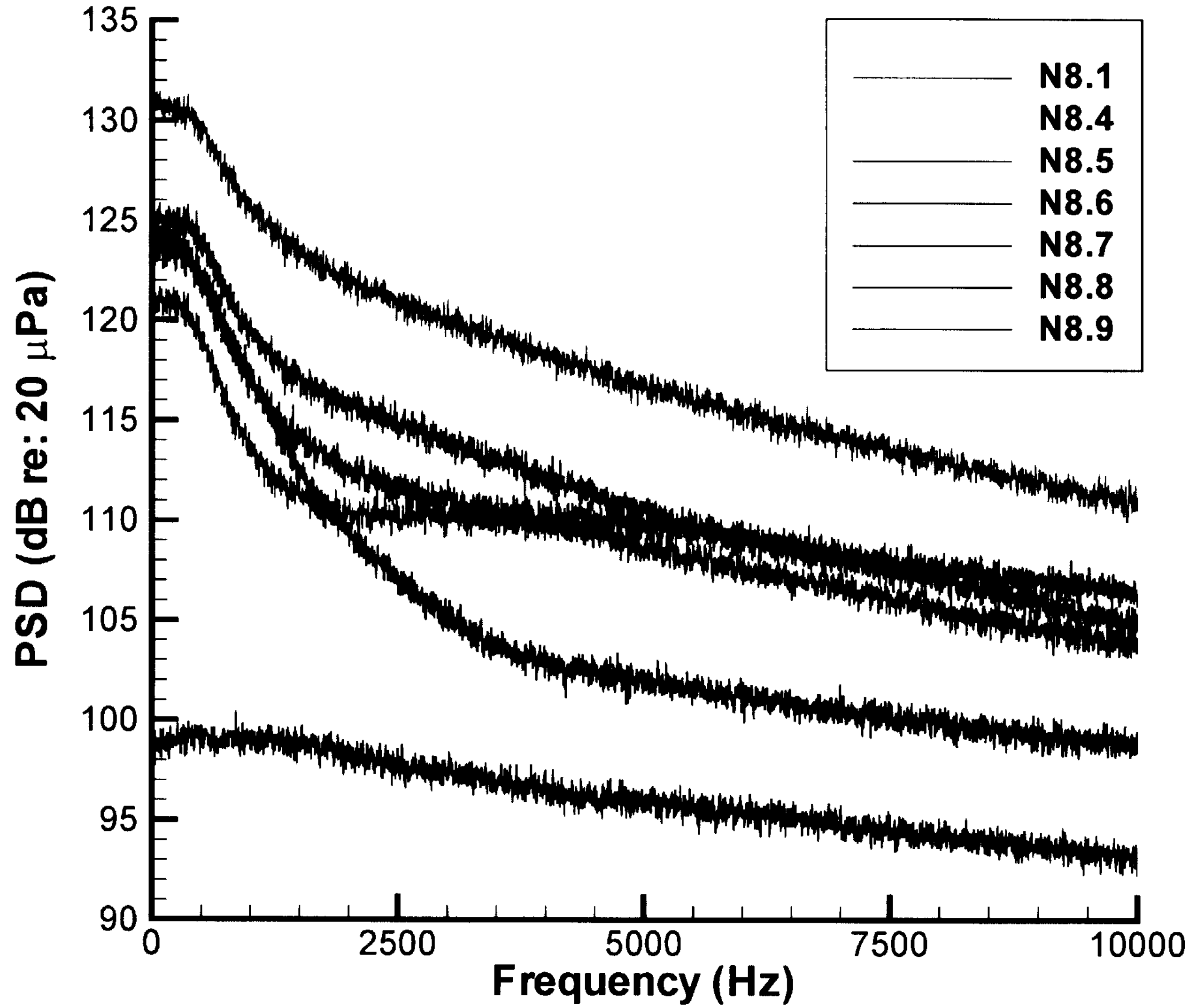


Figure 20: Effect of forward facing step at window blank 8 for run 159.

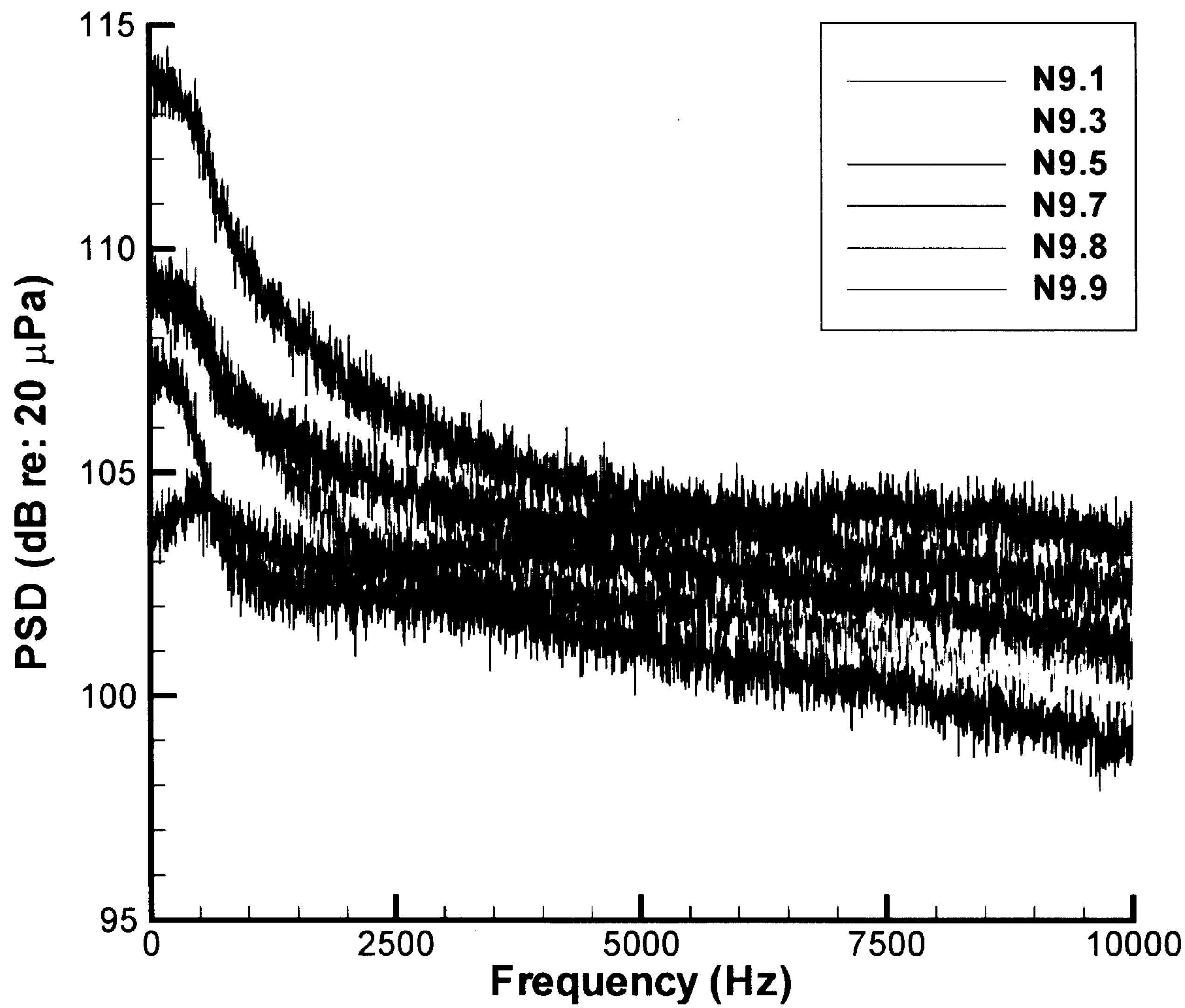


Figure 21: Effect of aft facing step at window blank 9 for run 159.

5.3. Time History Data File Format

Time history data files were written for each channel (except IRIG-B) for each run and each flight or ground test experiment. The data files all have the same format as used for experiment 2.1.

Previous experiment 2.1 data file names were written in the familiar DOS 8.3 format, i.e. an 8-character prefix and 3-character extension. Because the flight/condition numbers exceeded two digits, the old naming convention was not possible. The experiment 2.1A files were instead named according to the convention:

Txxyyyzz*s*.MAT

where

T = file type (f=flight, g=ground engine runup or background noise, c=calibration)
xx = flight or condition number, i.e. 27 for flight 27 or 24 for ground runup and background noise conditions.
yyy = run number from Table 9. Possible range is from 73-199 for experiment 2.1A.
zz = data channel as specified in Table 7.
s = optional field (a, b, c, ...) designating a data run that has been broken into smaller intervals.

For example, run 73 of flight 22, channel 15 would have the file name "f2207315.mat". Segment "b" of run 190, flight 27, channel 23 would have the file name "f2719023b.mat".

The file name extension used is MAT. Note that although this extension is also used to designate a MATLAB binary file format, the format used is as provided in Table 14 of reference [16]. Efforts to read the data into MATLAB as a MATLAB binary file format will fail.

Data files were archived in ISO 9660 format on CD-R as indicated in Table 10. The 26-volume set contains all data with the exception of Kulite calibration data. Time histories of the latter are used to compute scalar calibrations which are included in the calibration data files, see Section 5.4.

Table 10: Table of CD-R titles and contents.

CD-R Title	Size (MB)	Flight No.	Run No.
F22_V1	69	22	73-76,78
F23_V1	125	23	80-87,89
G_V4	380	24	96-101
G_V5	607	24	102-109
F24_V1	591	24	110-114
F24_V2	588	24	115-119
F24_V3	552	24	120-123
F24_V4	565	24	124-127
F24_V5	552	24	128-131
F24_V6	548	24	132-135
F25_V1	522	25	136,138-141

CD-R Title	Size (MB)	Flight No.	Run No.
F25_V2	588	25	137,142
F25_V3	582	25	143-149
F25_V4	565	25	150-156
F26_V1	636	26	158-159
F26_V2	599	26	160-164
F26_V3	567	26	157,165-168,170-171
F26_V4	286	26	169
F27_V1	524	27	172, 174-176
F27_V2	538	27	173
F27_V3	631	27	177-181
F27_V4	638	27	182-185, 187
F27_V5	483	27	186, 188
F27_V6	617	27	189-191
F27_V7	542	27	192-195
F27_V8	569	27	196-199

5.4. Calibration Data File Format

For each flight or ground engine runup/background noise test, a calibration data file was written into a computer file in a MATLAB data structure. The format of the calibration data files is identical to that used for experiment 2.1.

5.5. Auxiliary Data File Format

For each run, auxiliary data from the NASA DFRC FDAS system was collected into a computer file in MATLAB data structure. The format of the auxiliary data files is identical to that used for experiment 2.1.

Plots of the flight data parameters on a 10-second interval are provided for each flight in Appendix C.

5.6. Data Availability

The complete time history data set is archived on a 26 volume CD-R compilation. Data processing scripts for use with MATLAB, calibration data files and auxiliary data files are on floppy disk. Time histories of the calibration file records are not available.

Requests for data should be submitted in writing to the following address:

Dr. Stephen A. Rizzi
NASA Langley Research Center
Mail Stop 463
Hampton, VA 23681-2199
Email: s.a.rizzi@larc.nasa.gov

A determination of data availability will be made on a case-by-case basis.

6. References

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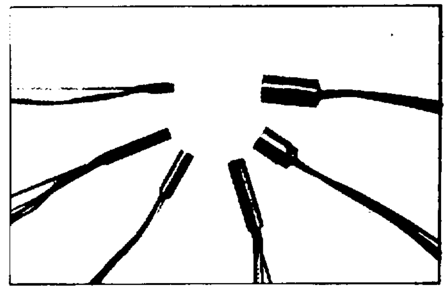
Appendix A Transducer Specification Sheets

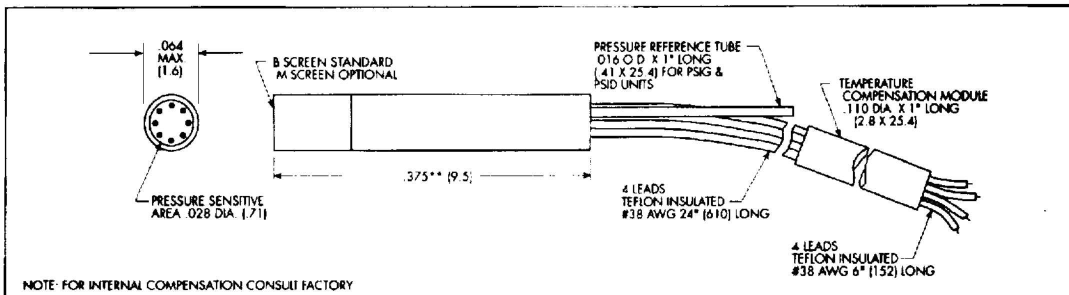
HIGH SENSITIVITY ULTRAMINIATURE

HIGH SENSITIVITY ULTRAMINIATURE IS® PRESSURE TRANSDUCERS

XCS-062 SERIES HIGH IMPEDANCE
XCW-062 SERIES LOW IMPEDANCE

- High Sensitivity
- Superior Signal To Noise Ratio
- Static And Dynamic Capability
- Wide Dynamic Range





	XCS		XCW	
INPUT Pressure Range	0.35 5	1.0 * BAR 15 * PSI	0.35 5	1.0 * BAR 15 * PSI
Operational Mode	Absolute, Gage, Sealed Gage, Differential			
Over Pressure	2 Times Rated Pressure With No Change In Calibration			
Burst Pressure	3 Times Rated Pressure			
Pressure Media	All Nonconductive, Noncorrosive Liquids or Gases			
Rated Electrical Excitation	15 VDC/AC			
Maximum Electrical Excitation	20 VDC/AC			
Input Impedance	1000 Ohms (Min.)		800 Ohms (Min.)	
OUTPUT Output Impedance	1000 Ohms (Nom.)		1000 Ohms (Nom.)	
Full Scale Output (FSO)	125 mV (Nom.) 50 mV (Nom.) for SG	200 mV (Nom.) 100 mV (Nom.) for SG	100 mV (Nom.) 50 mV (Nom.) for SG	200 mV (Nom.) 100 mV (Nom.) for SG
Residual Unbalance	± 3% FSO			
Combined Non-Linearity and Hysteresis	0.25% FS BFSL (Typ.) ***			
Hysteresis	0.1% (Typ.)			
Repeatability	0.1% (Typ.)			
Resolution	Infinite			
Natural Frequency (KHz) (Typ.)	150	225	150	225
Acceleration Sensitivity % FS/g Perpendicular Transverse	.002 .0005	.0005 .00005	.002 .0005	.0005 .00005
Insulation Resistance	100 Megohm Min. at 50 VDC			
ENVIRONMENTAL Operating Temperature Range	−65°F to 250°F (−55°C to 120°C) Temperatures to 400°F (204°C) Available on Special Order			
Compensated Temperature Range	80°F to 180°F (25°C to 80°C) Any 100°F Range Within The Operating Range on Request			
Thermal Zero Shift	± 1% FS/100°F (Typ.)***			
Thermal Sensitivity Shift	± 1%/100°F (Typ.)***			
Steady Acceleration	10,000g. (Max.)			
Linear Vibration	10-2,000 Hz Sine, 100g. Max.			
PHYSICAL Electrical Connection	4 Leads 38 AWG 30" Long			
Weight	.2 Gram (Nom.) Excluding Module and Leads			
Sensing Principle	Fully Active Four Arm Wheatstone Bridge Dielectrically Isolated Silicon on Silicon			

** Higher pressure ranges available upon request*
*** Shorter or longer lengths available on request*
**** For improved accuracy consult factory*

KULITE SEMICONDUCTOR PRODUCTS, INC. • One Willow Tree Road • Leonia, New Jersey 07605 • Tel: 201 461-0900 • Cable: Kultung • Telex: 685 3296 • Fax: 201 461-0990

Figure 22: Kulite transducer XCS-062-15D specification sheet

Appendix B Abbreviated Flight Operational Procedures

	3.2		Flight Measurements
		√	**Description**
	3.2.1		Perform the following steps (3.2.2 through 3.2.10) for each flight condition.
	3.2.2		If *READY* message still appears in upper right corner of *METRUM* screen, proceed to next step. Otherwise, press *SPEED* button in *TRANSPORT* section and then *ENABLE REC-READY* softkey. Wait until a *READY* message appears in upper right corner of screen before proceeding.
	3.2.3		Switch *DATA CHANNEL MULTIPLEXER SELECTOR* to desired position (1,2,3) as specified in flight plan (*BOX* 106). Engage one bank at a time by pushing the appropriate selector button and verify the bank has been engaged by observing the illuminated LED for that bank. Pushing two selector buttons at the same time could put the multiplexer in an unknown state.
	3.2.4		Record run number, test condition, *DATA CHANNEL MULTIPLEXER SELECTOR* position and starting block number on data sheet.
	3.2.5		When the desired stable test condition has been reached, perform the following procedures to autorange the input level on the *METRUM* :
	3.2.5.1		Press *BAR* button in *DISPLAY* section.
	3.2.5.2		Press *AUTORANGE SOFTKEYS* softkey (softkey should be lit after pressing).
	3.2.5.3		Press *ENABLE AUTORANGE* softkey and wait until *ENABLE AUTORANGE* softkey light turns itself off.

	3.2		Flight Measurements
		√	**Description**
	3.2.5.4		Press *AUTORANGE MODE* softkey (softkey should be lit after pressing).
	3.2.5.5		Press *INCR* button in *VALUE ENTRY* section to switch to *CONTINUOUS* autorange mode.
	3.2.5.6		Press *ENABLE AUTORANGE* softkey (softkey should be lit after pressing) and wait 10 seconds.
	3.2.5.7		Press *ENABLE AUTORANGE* softkey again to disable. Softkey should be unlit after pressing.
	3.2.5.8		Press *DECR* button in *VALUE ENTRY* section to switch to *BRIEF* autorange mode.
	3.2.5.9		Press *AUTORANGE SOFTKEYS* softkey to exit autorange function (softkey should be unlit after pressing).
	3.2.6		Press OVERRANGE CLEAR button in DISPLAY section. Press RECORD and hold. While holding RECORD, press PLAY, then release both buttons.
	3.2.7		Record mach number, altitude, cabin pressure, and cabin temperature on data sheet. Provide relevant voice annotation.
	3.2.8		Record data for one (1) minute (unless otherwise specified) after the light has become steady, then press *STOP*. Record end block number, condition of overrange indicator and any comments on data sheet.
	3.2.9		Repeat steps 3.2.2 through 3.2.8 for the next bank of data at the present test condition.
	3.2.10		Inform cockpit ready for next condition. Repeat steps 3.2.2 through 3.2.9 for next test condition.

	3.2		Flight Measurements
		√	**Description**
	3.2.11		Notes: 1) The record ready condition initiated in step 3.2.2 lasts for 30 minutes. The clock is reset to 30 minutes each time a recording is made. If the elapsed time since the last recording exceeds 25 minutes, a warning message will appear on the screen indicating *"Warning: Less than 5 minutes remaining for Record Ready."* This message will countdown each minute until the message *"Record Ready disabled, time expired"* appears and a *STOP* message appears in the upper right corner of the *METRUM* screen. As long as the *READY* message appears in the upper right corner of the *METRUM* screen (even after the first warning message appears), the clock may be manually reset to 30 minutes by pressing the *SPEED* button in the *TRANSPORT* section and then the *RESTART TIME REM.* softkey. If the time has expired and the *STOP* message appears, reinitiate the record ready condition following the procedure in step 3.2.2.

Appendix C Auxiliary Data

The following pages show plots of auxiliary data required for analyzing the main time history boundary layer and structural data. Note that there were several malfunctioning temperature sensors on flights 22 and 23 as shown in Figure 23 and Figure 24, respectively. Also, there are no run numbers indicated on these plots.

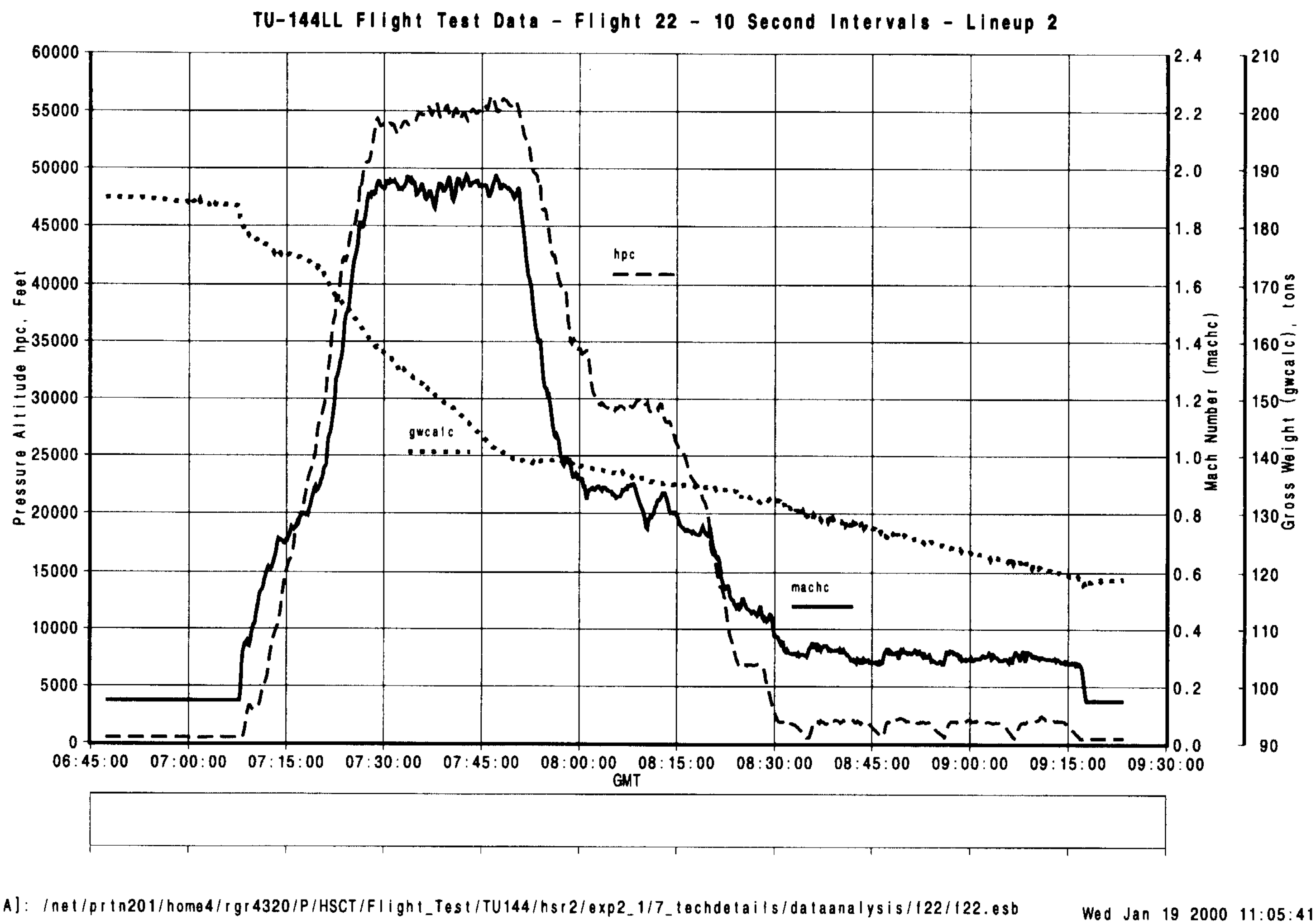


Figure 23: Flight 22 auxiliary data.

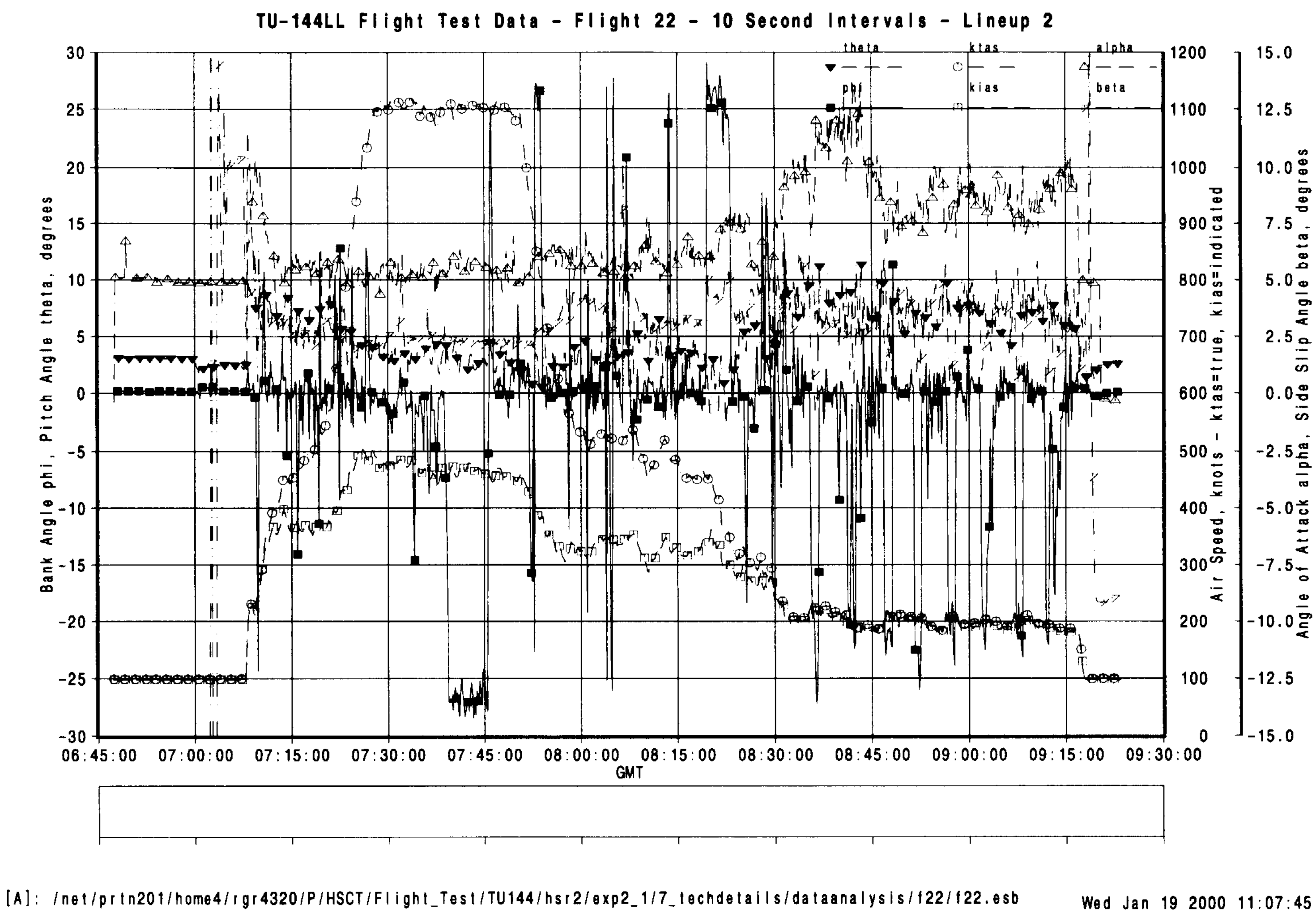


Figure 23 (continued)

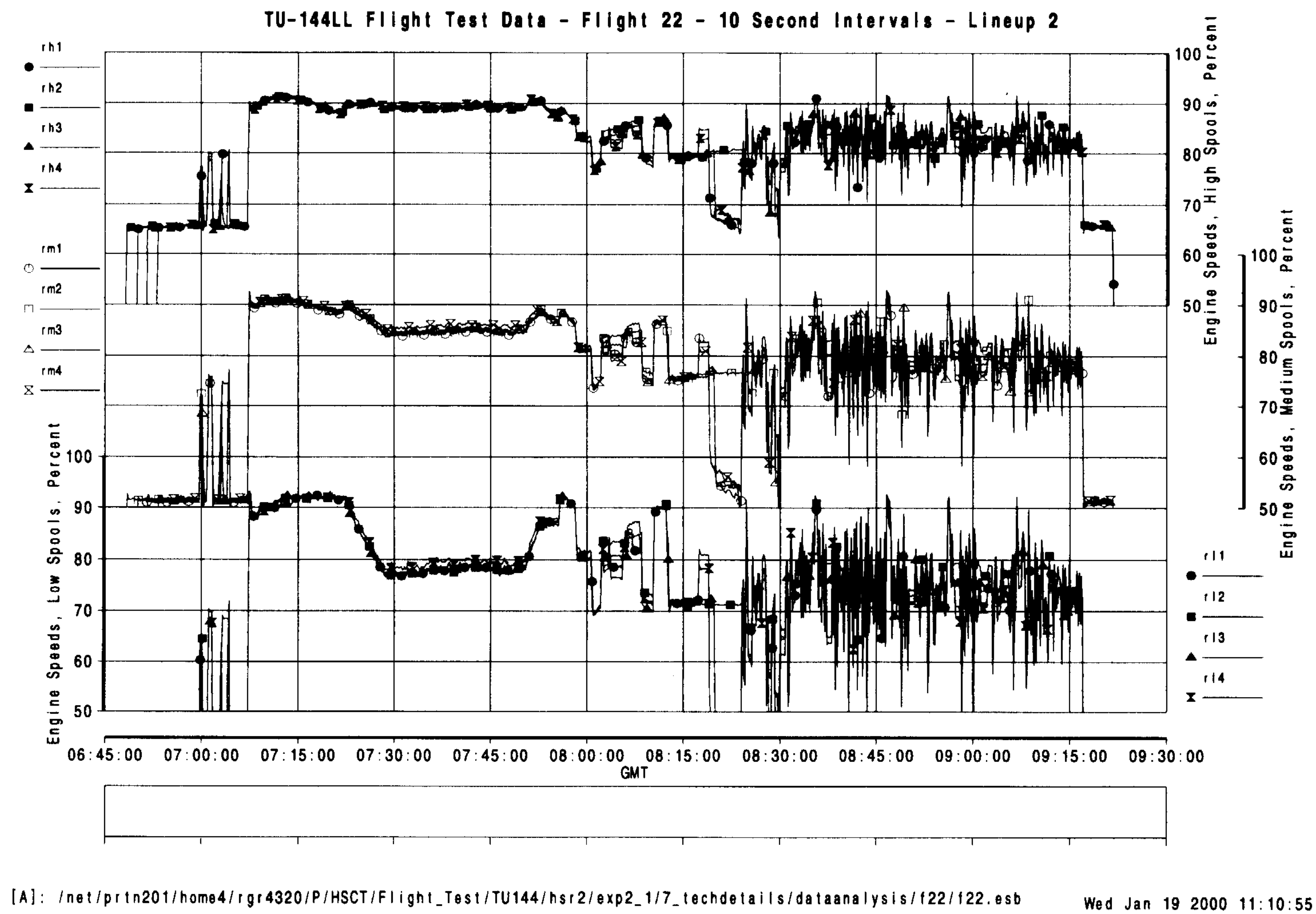


Figure 23 (continued)

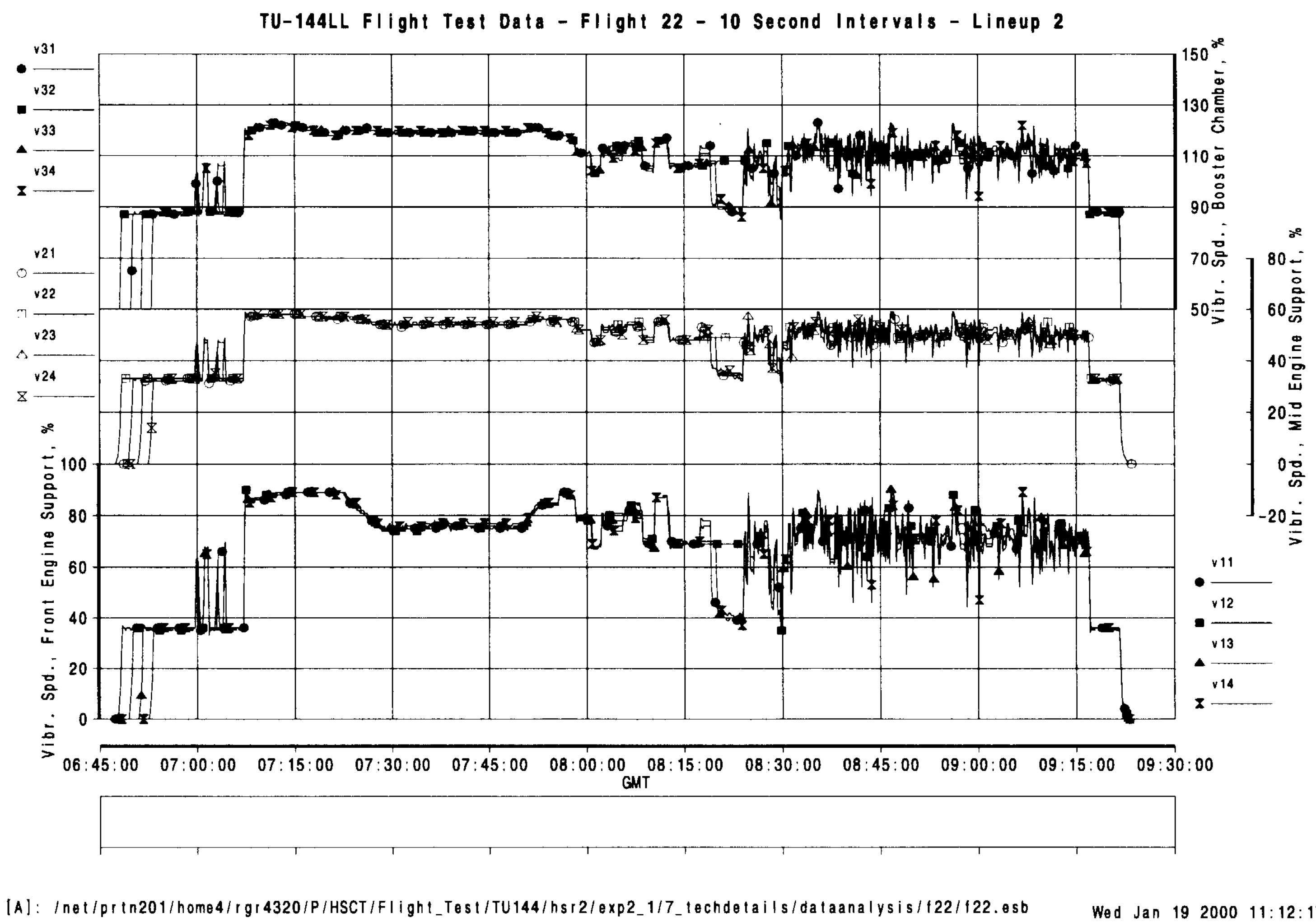


Figure 23 (continued)

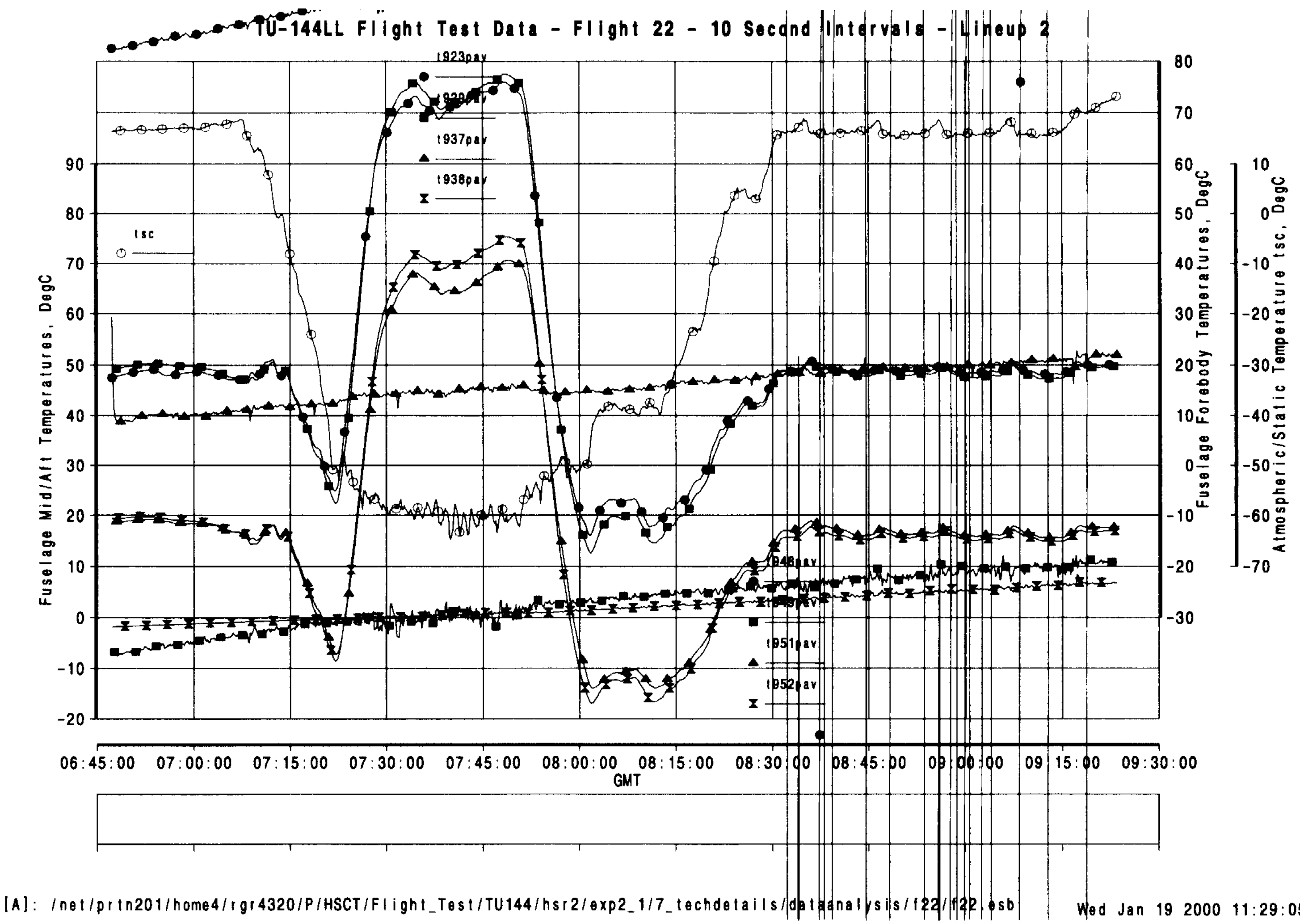


Figure 23 (continued)

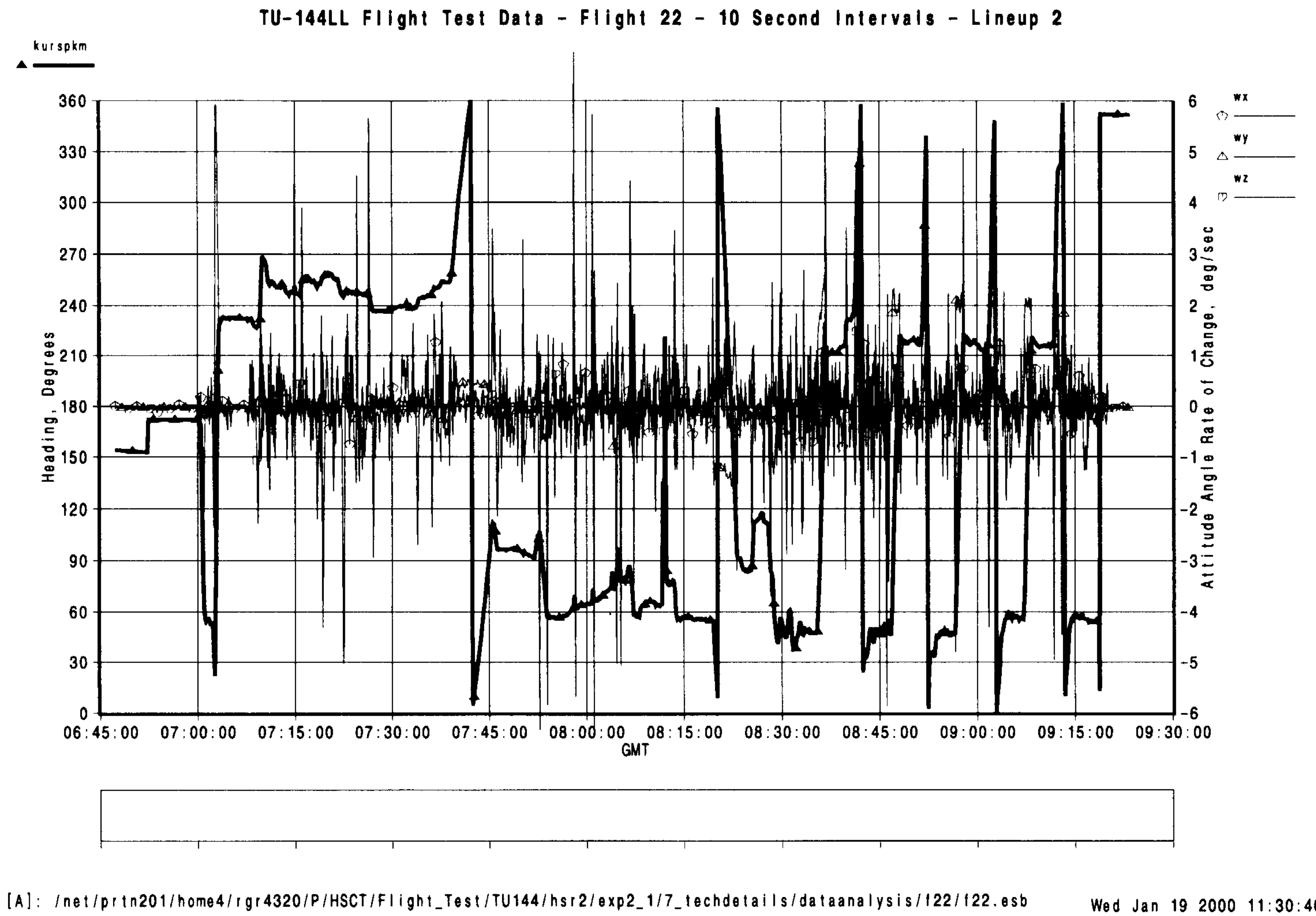


Figure 23 (continued)

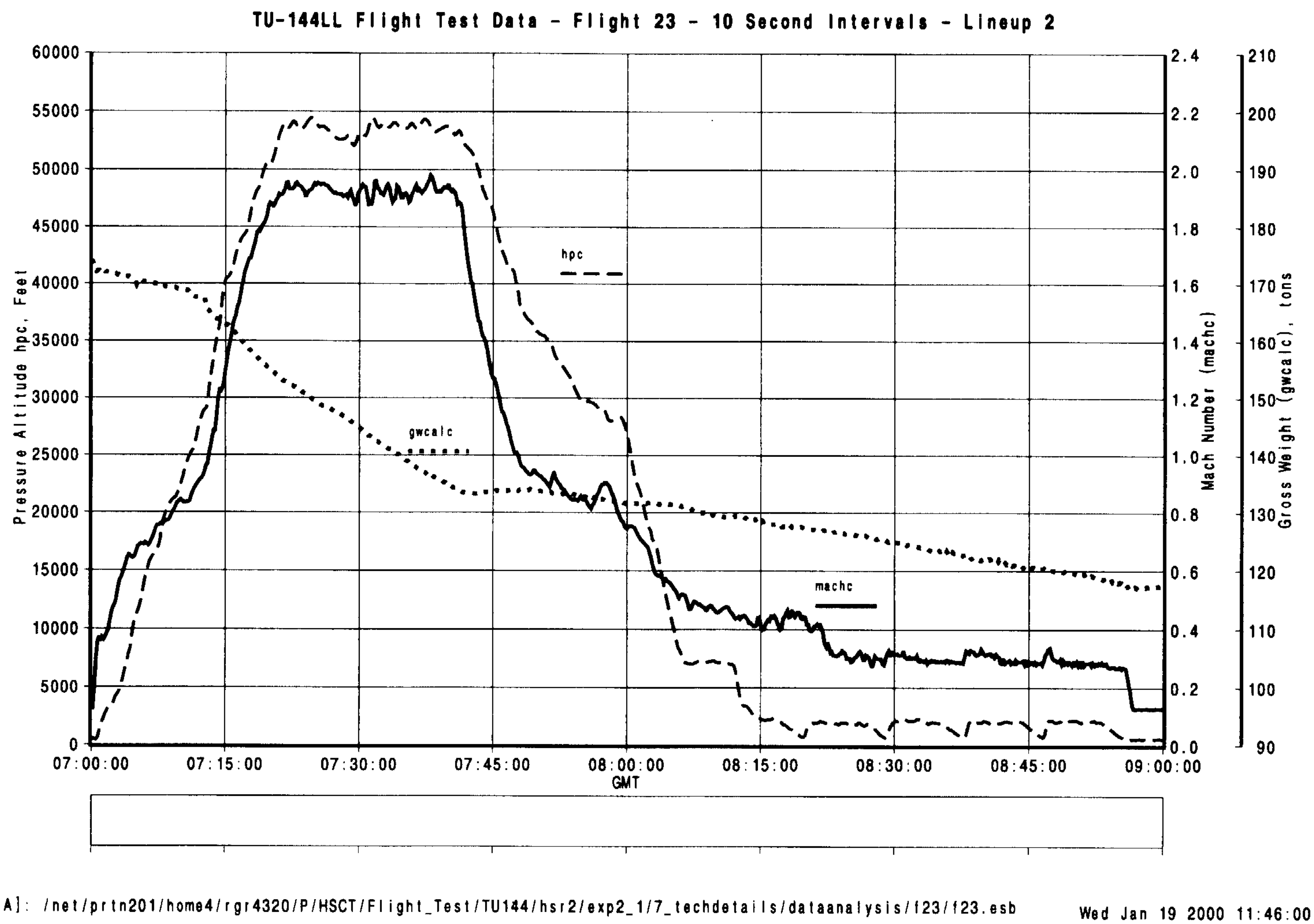


Figure 24: Flight 23 auxiliary data.

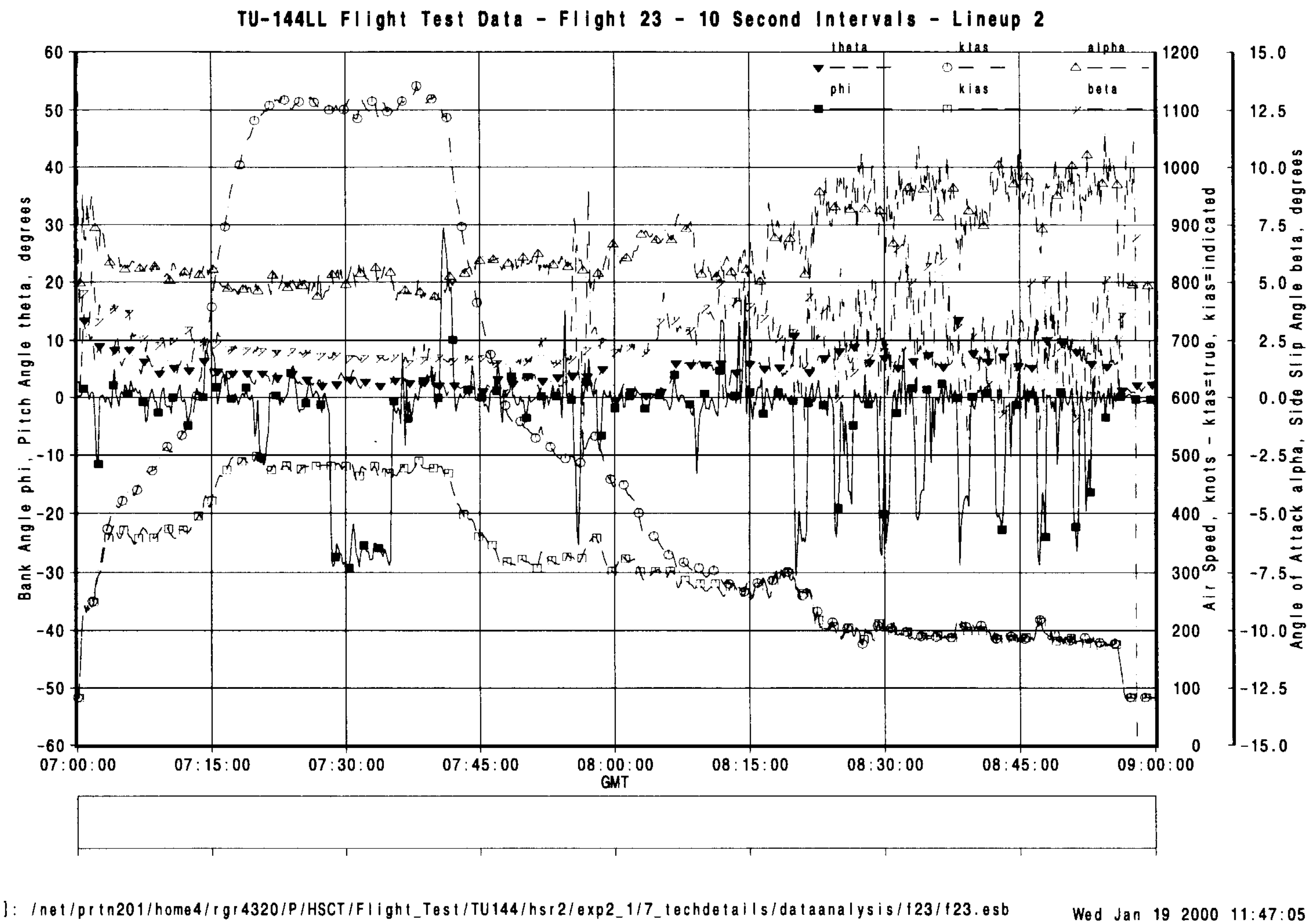


Figure 24 (continued)

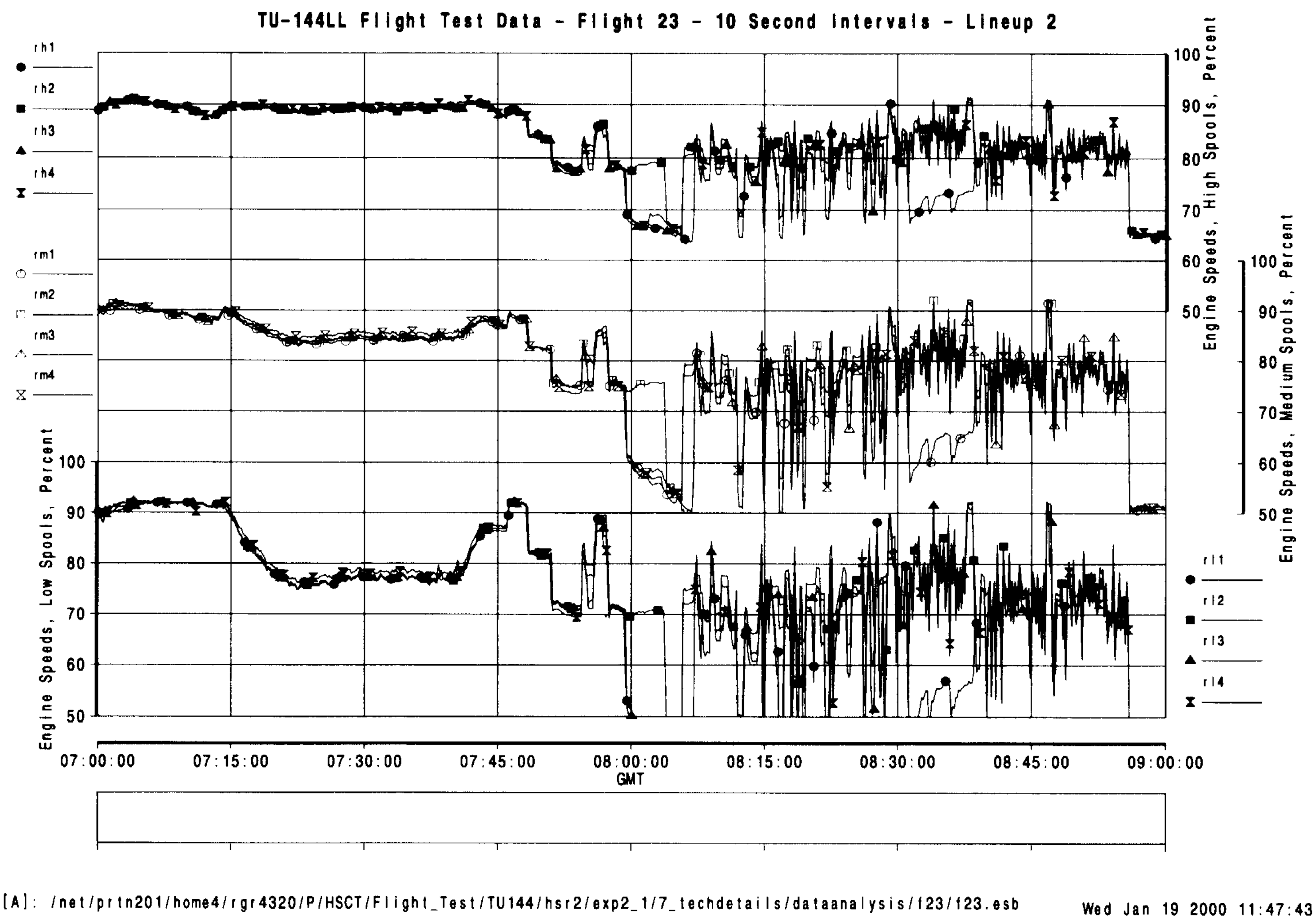
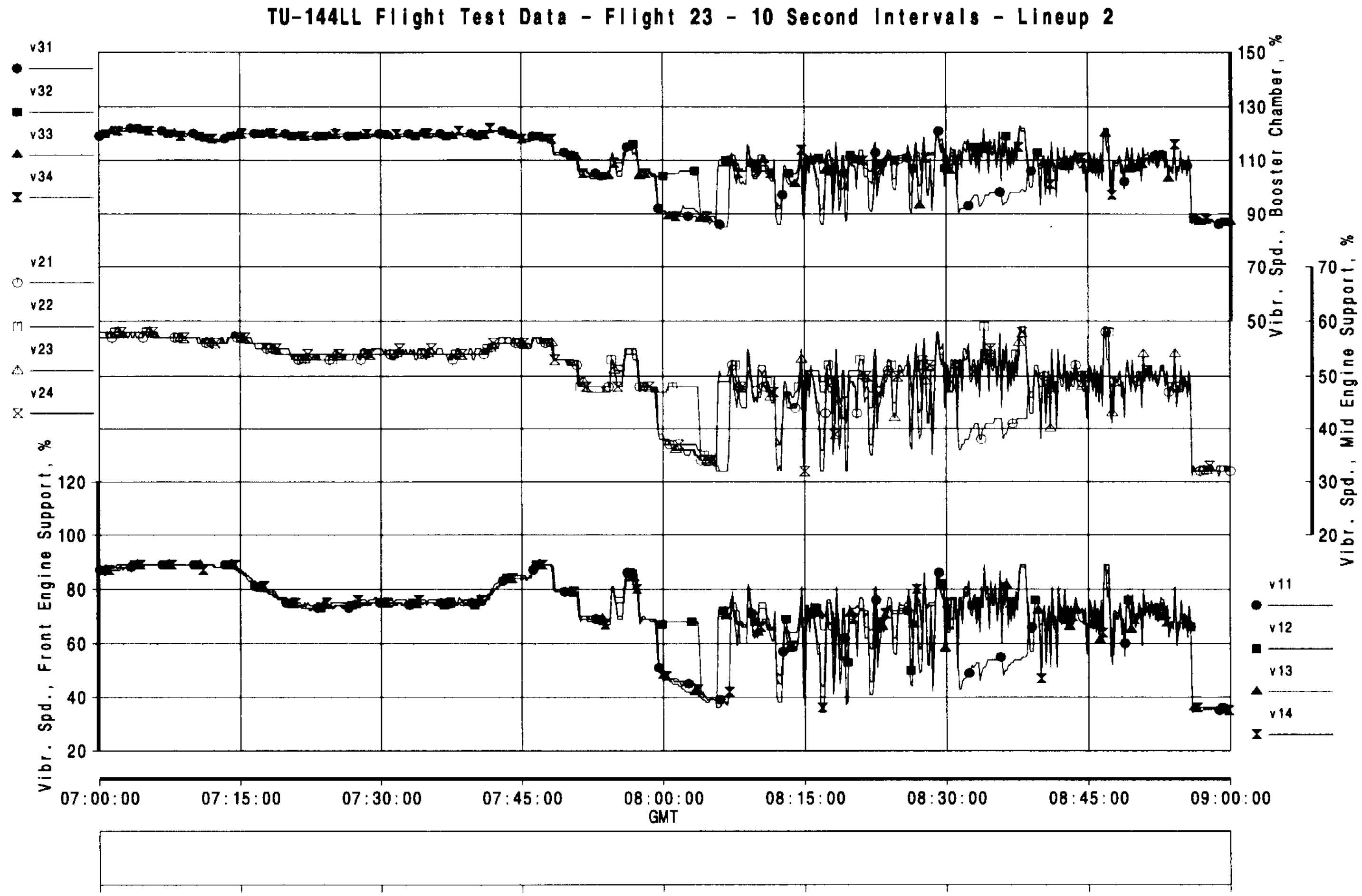


Figure 24 (continued)



[A]: /net/prtn201/home4/rgr4320/P/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/f23/f23.esb   Wed Jan 19 2000 11:48:19

Figure 24 (continued)

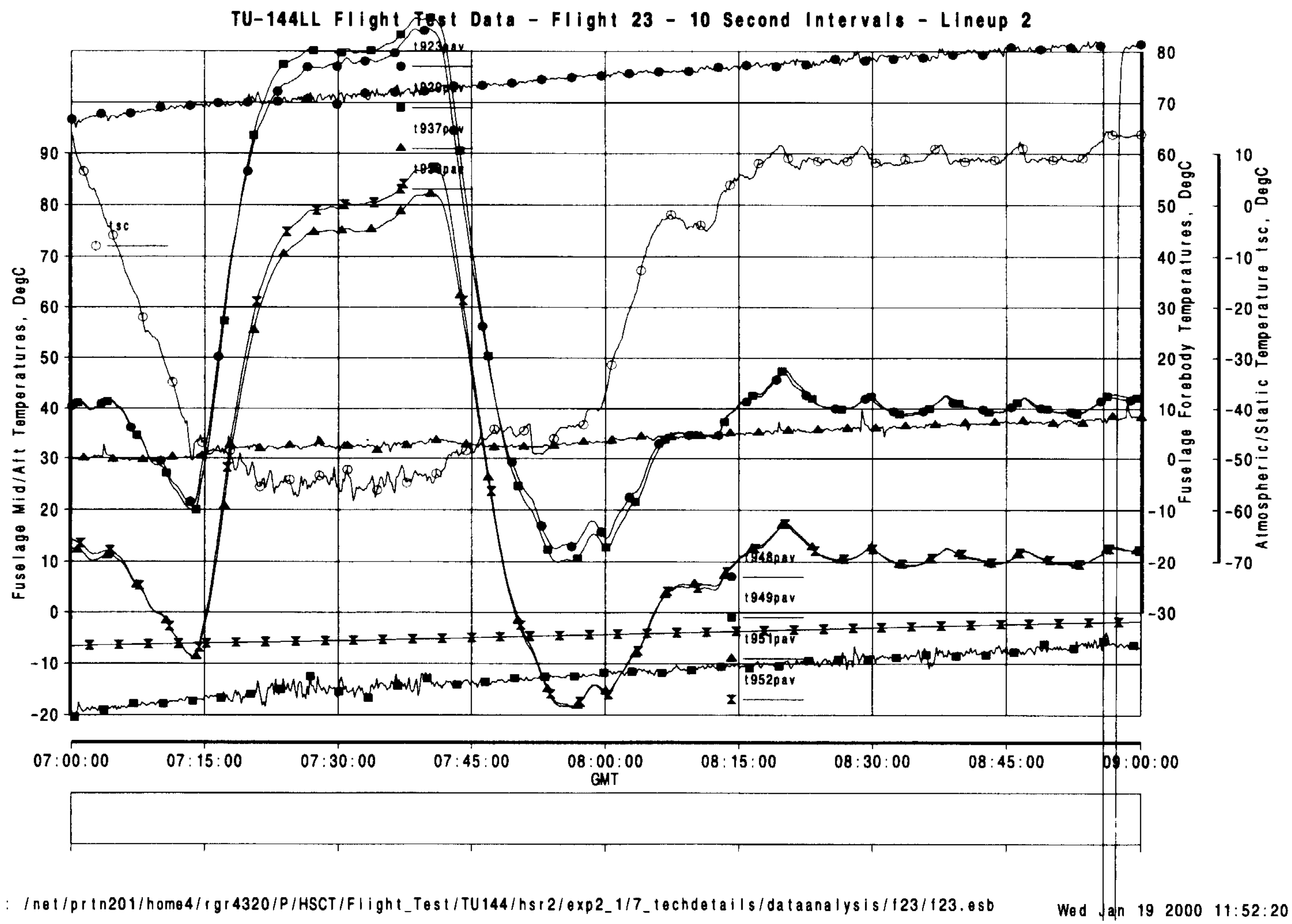
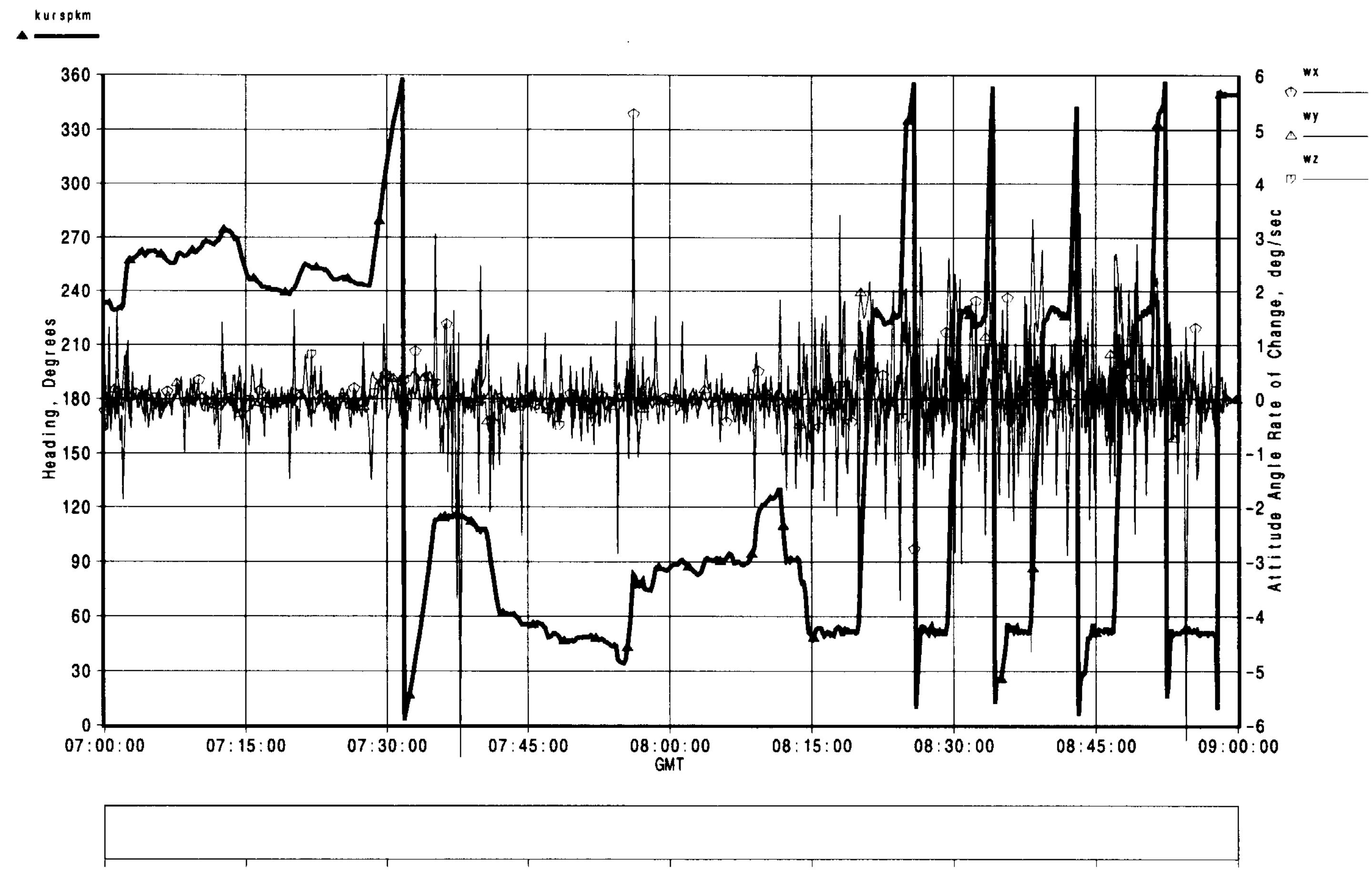


Figure 24 (continued)

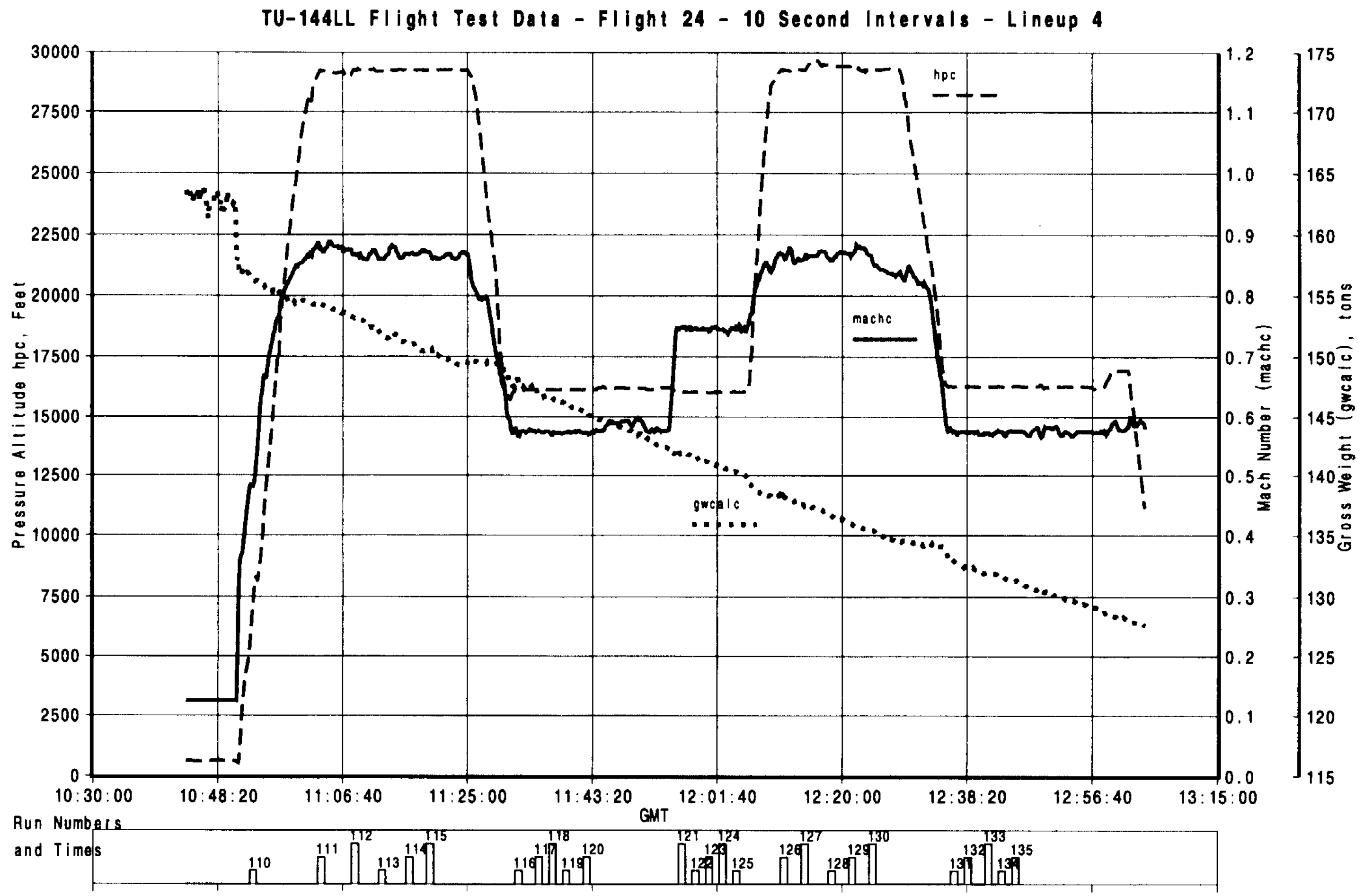
TU-144LL Flight Test Data - Flight 23 - 10 Second Intervals - Lineup 2



[A]: /net/prtn201/home4/rgr4320/P/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/f23/f23.esb

Wed Jan 19 2000 11:52:57

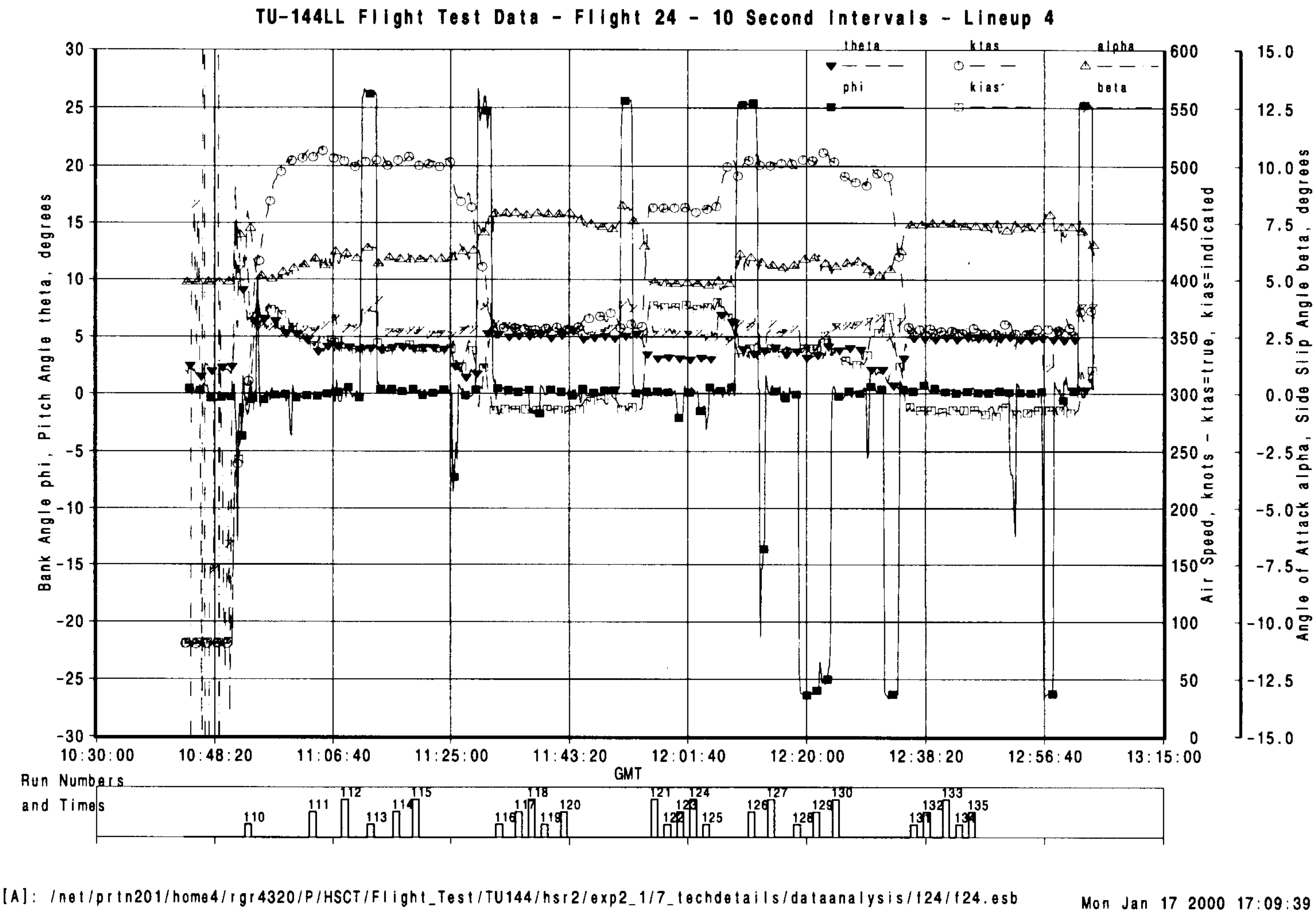
Figure 24 (continued)



[A]: /acct/rgr4320/Projects/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/f24/f24.esb

State File: /acct/rgr4320/Projects/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/f24/f24xt.peg   Fri Apr 23 1999 10:29:58

Figure 25: Flight 24 auxiliary data.



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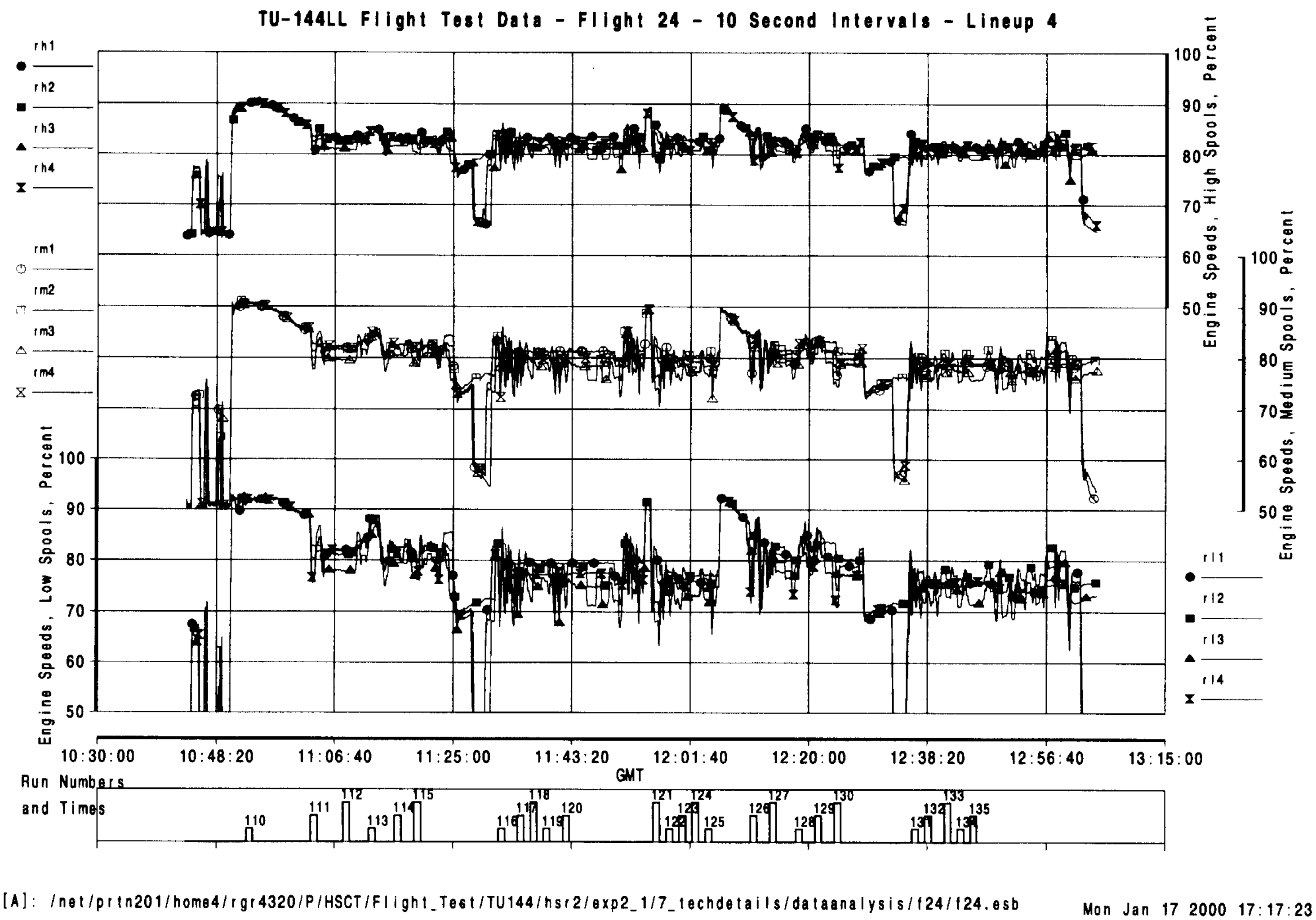


Figure 25 (continued)

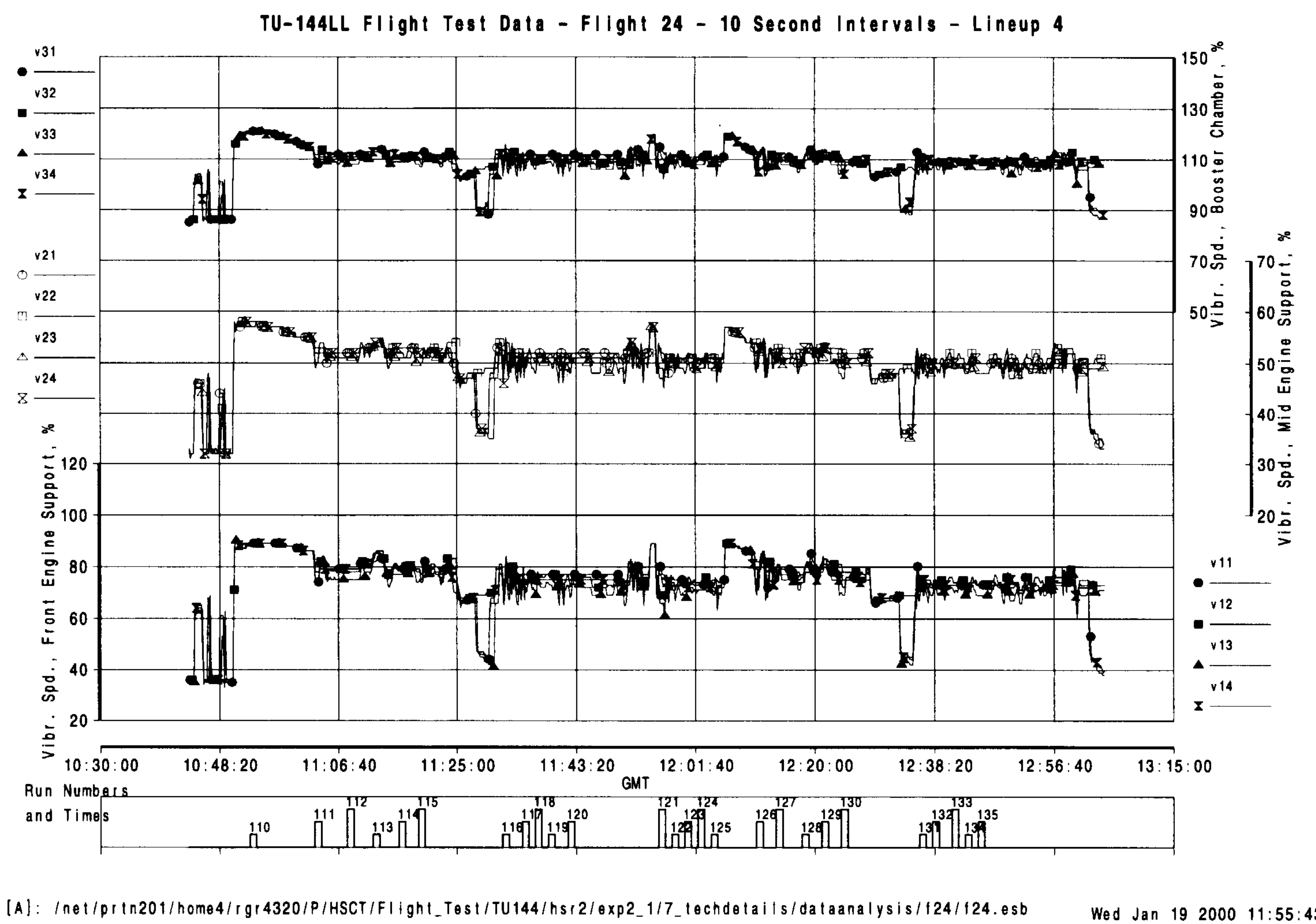


Figure 25 (continued)

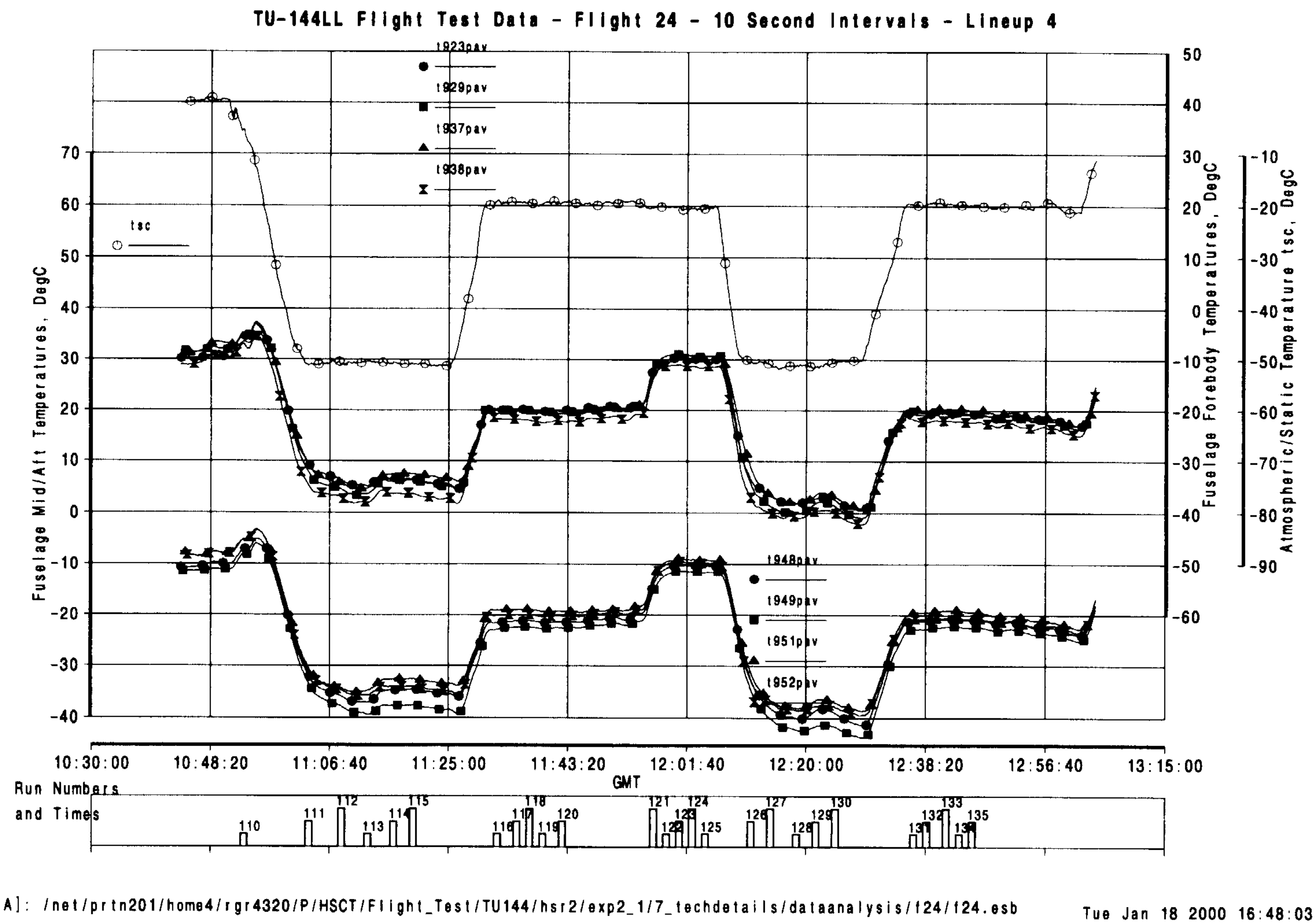


Figure 25 (continued)

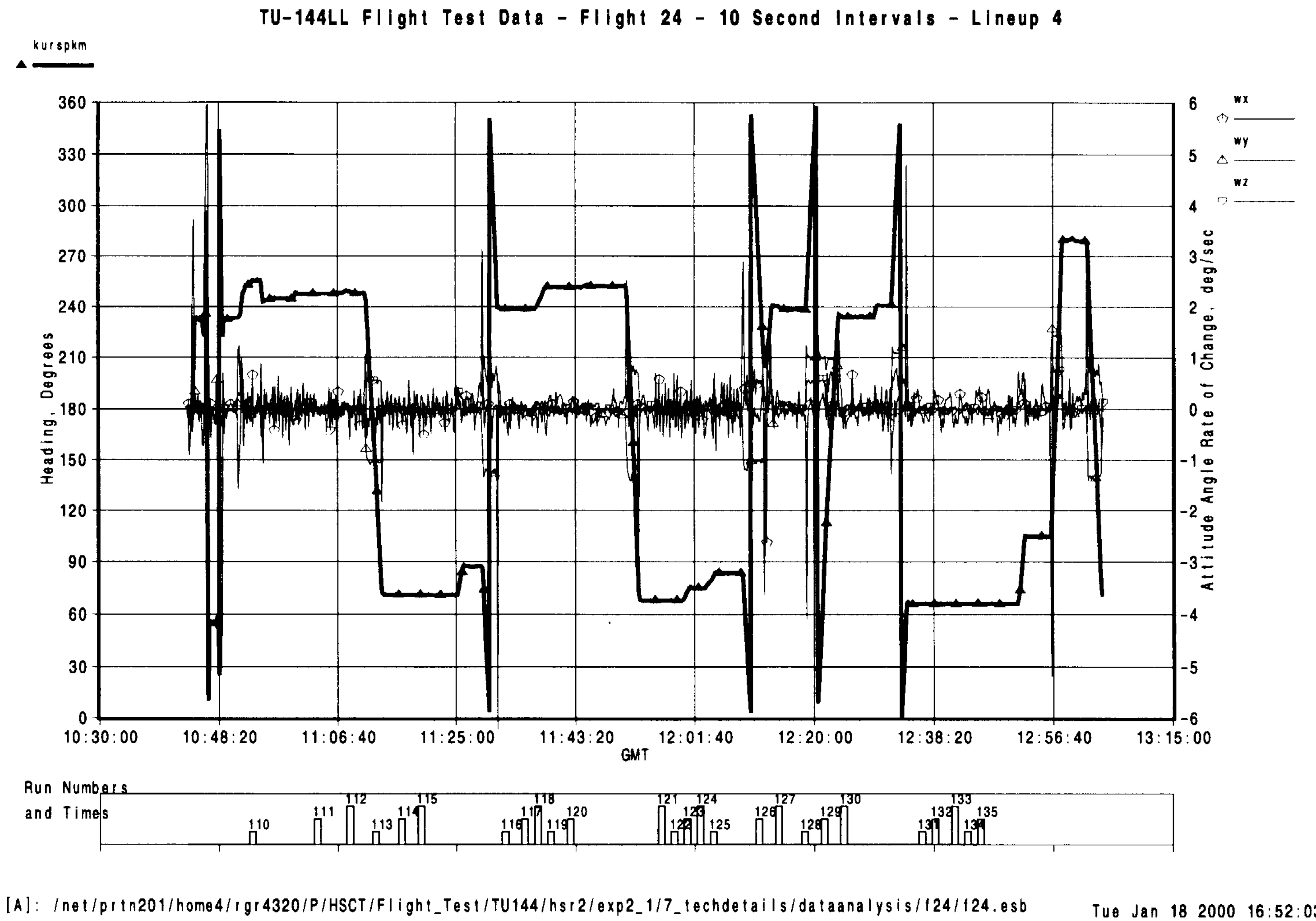


Figure 25 (continued)

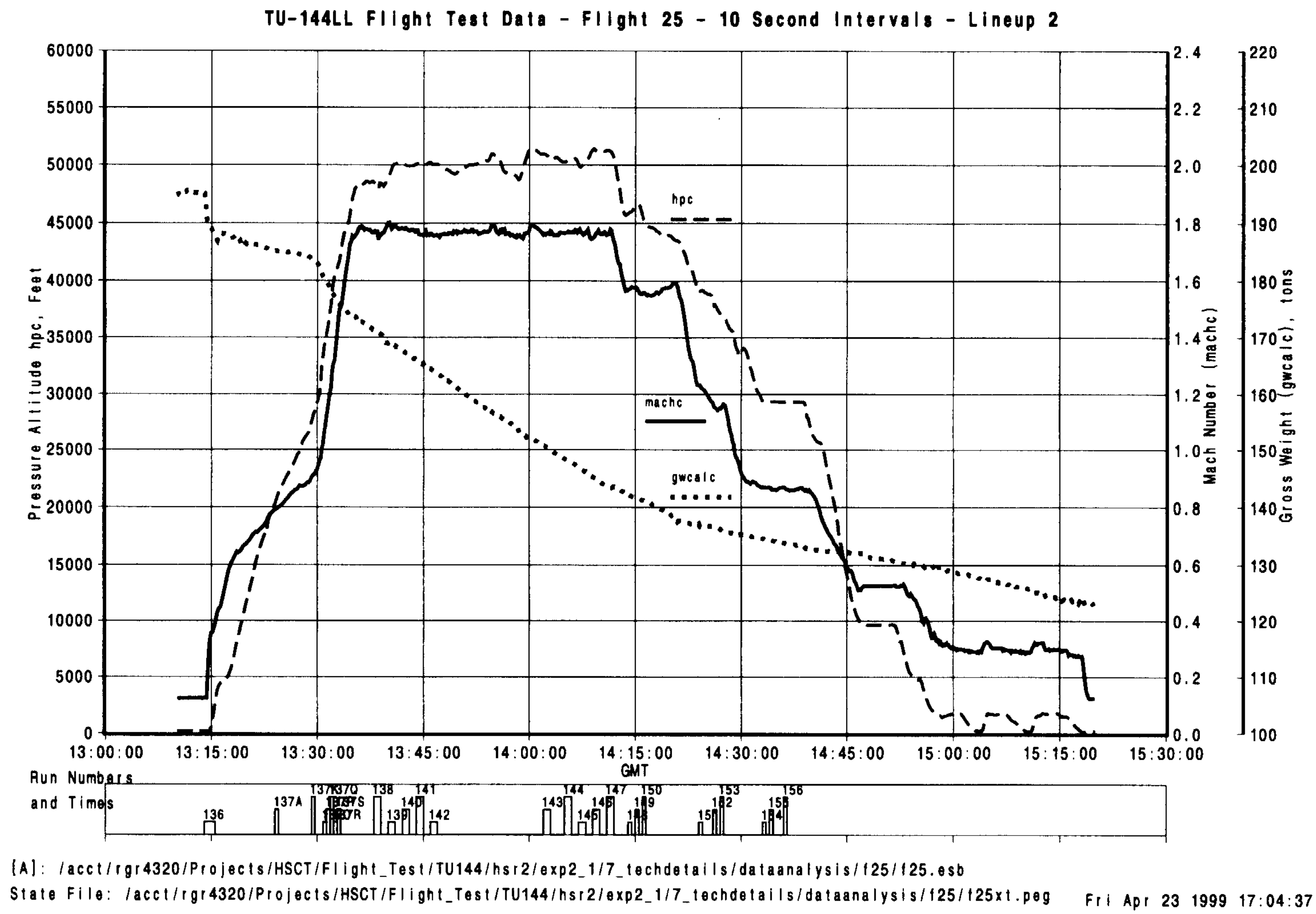


Figure 26: Flight 25 auxiliary data.

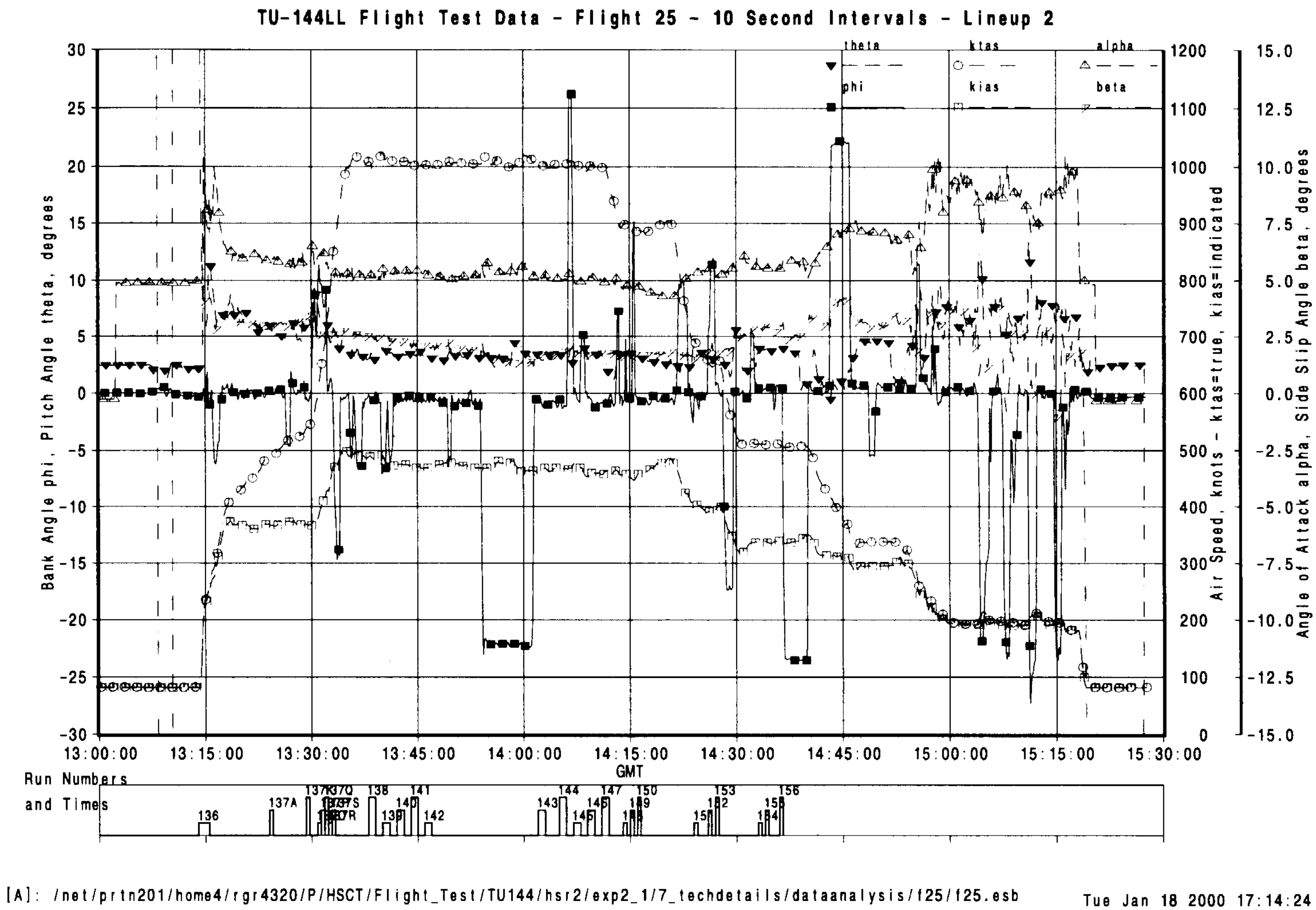
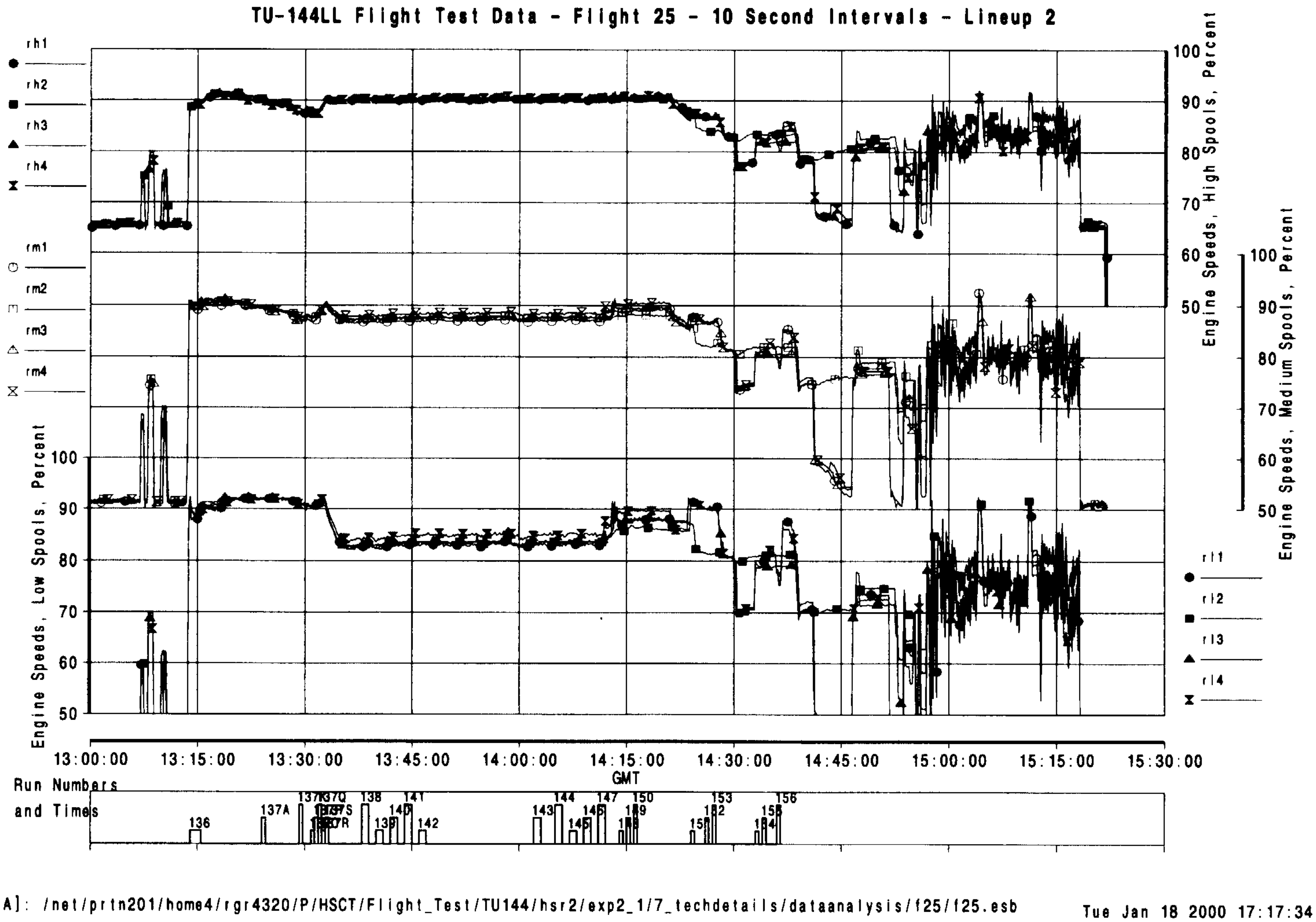


Figure 26 (continued)



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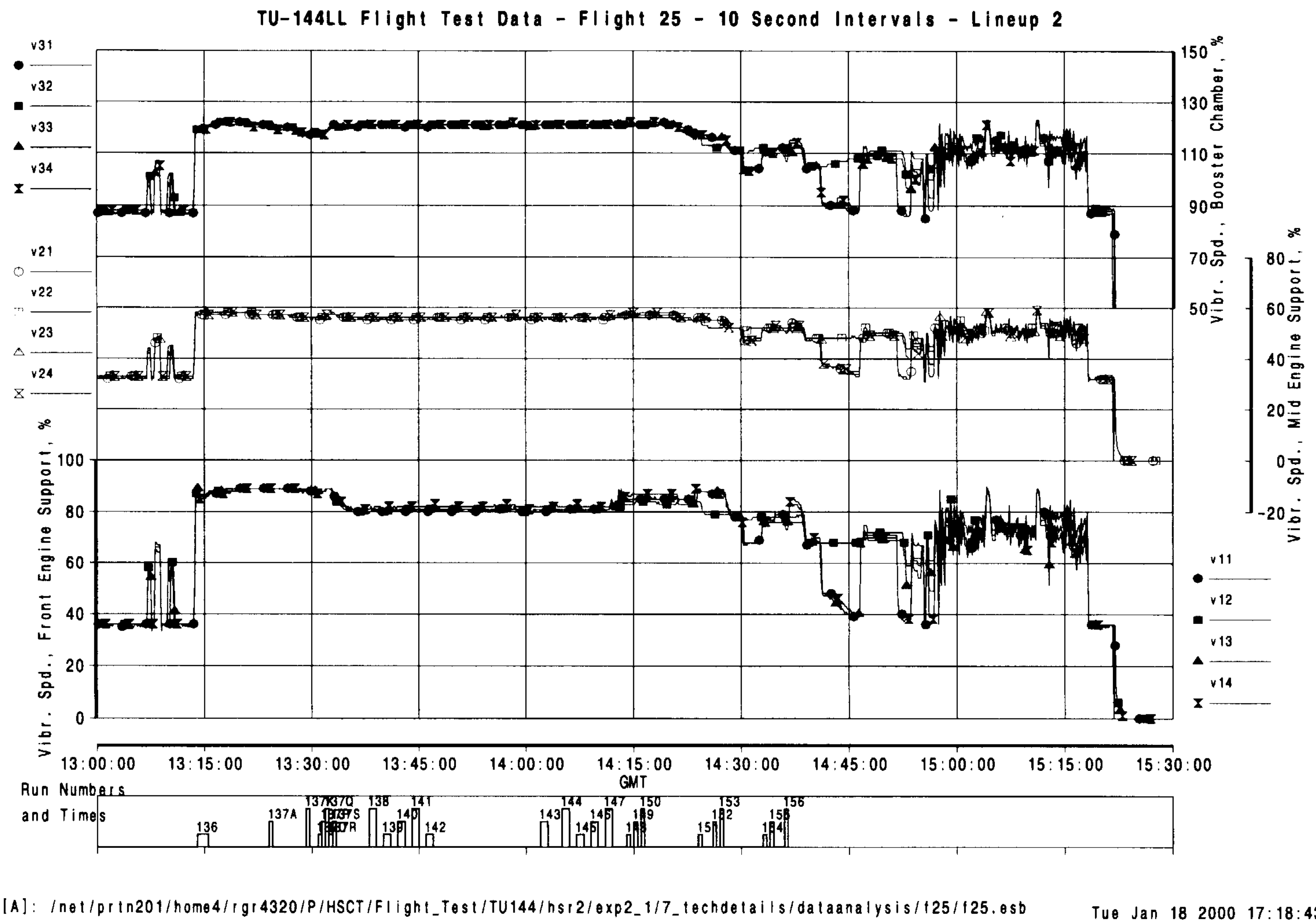


Figure 26 (continued)

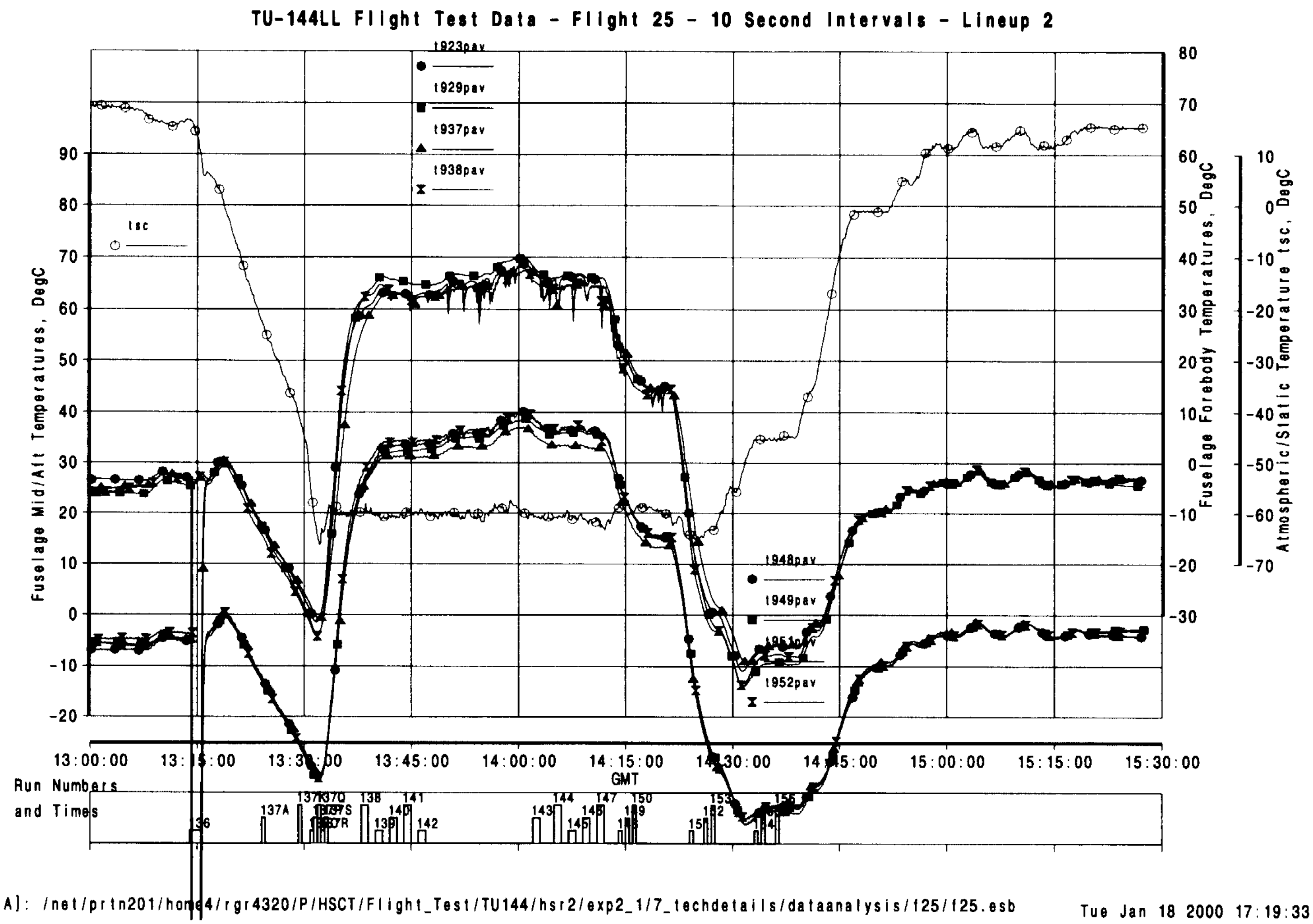
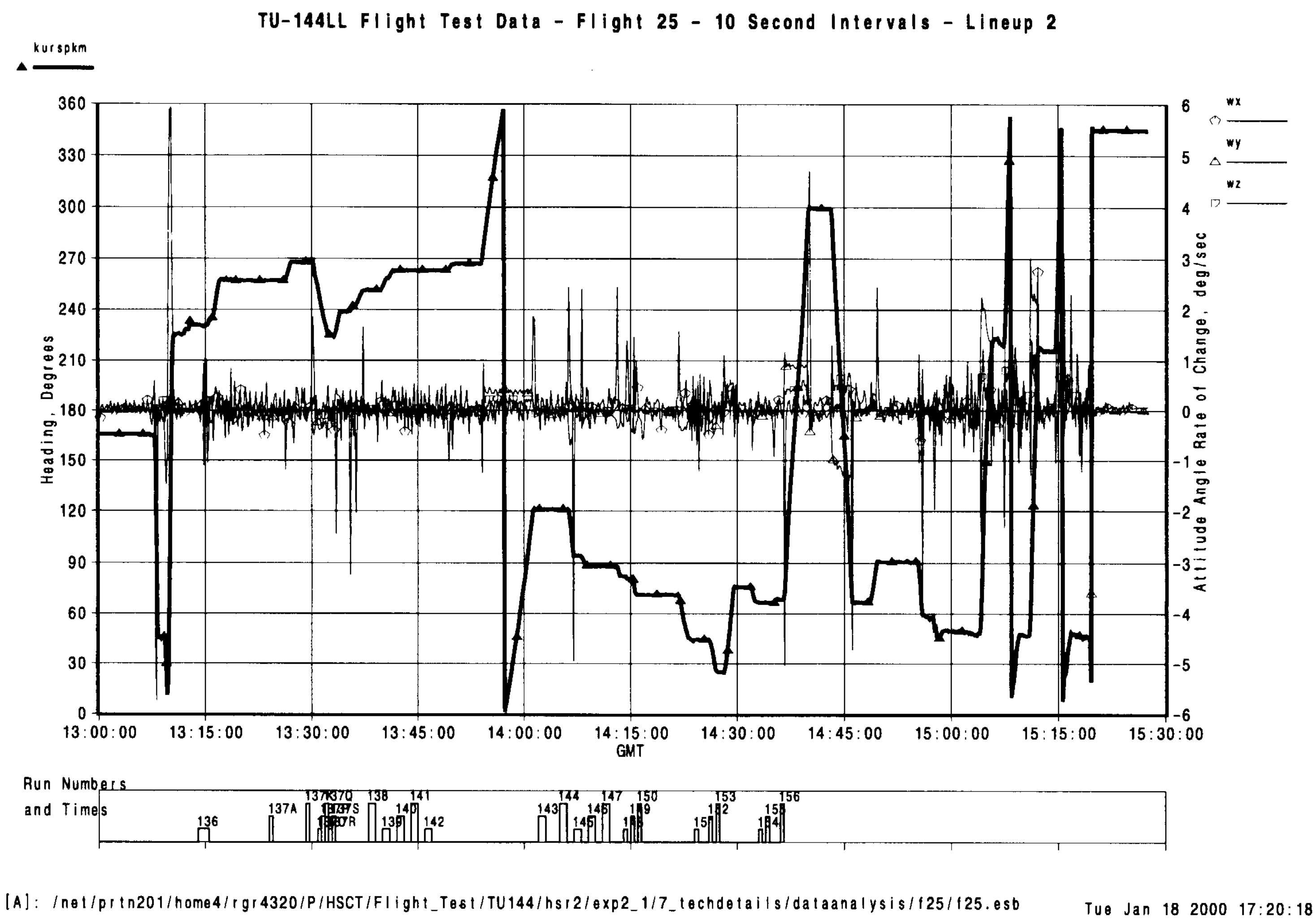


Figure 26 (continued)



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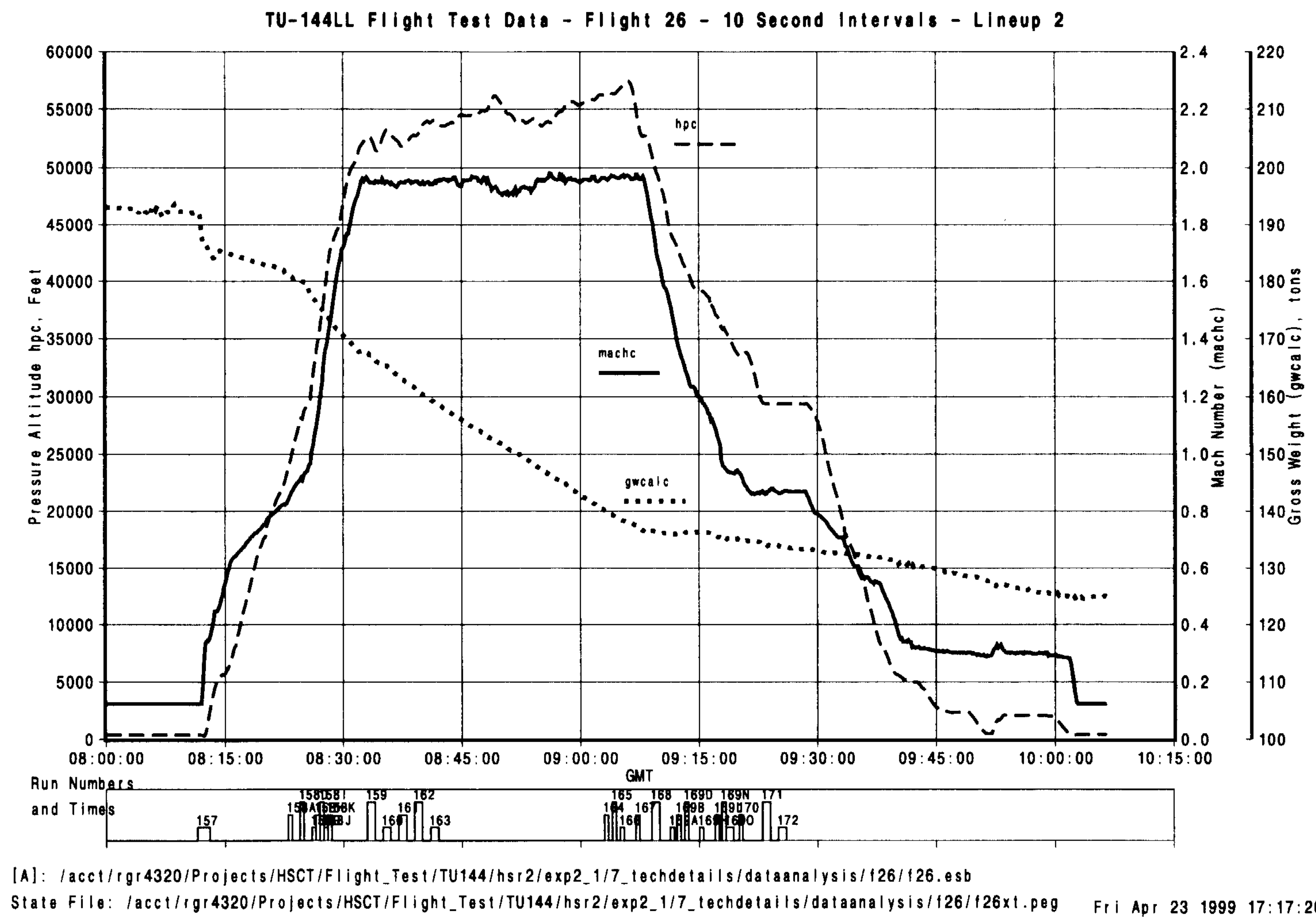


Figure 27: Flight 26 auxiliary data.

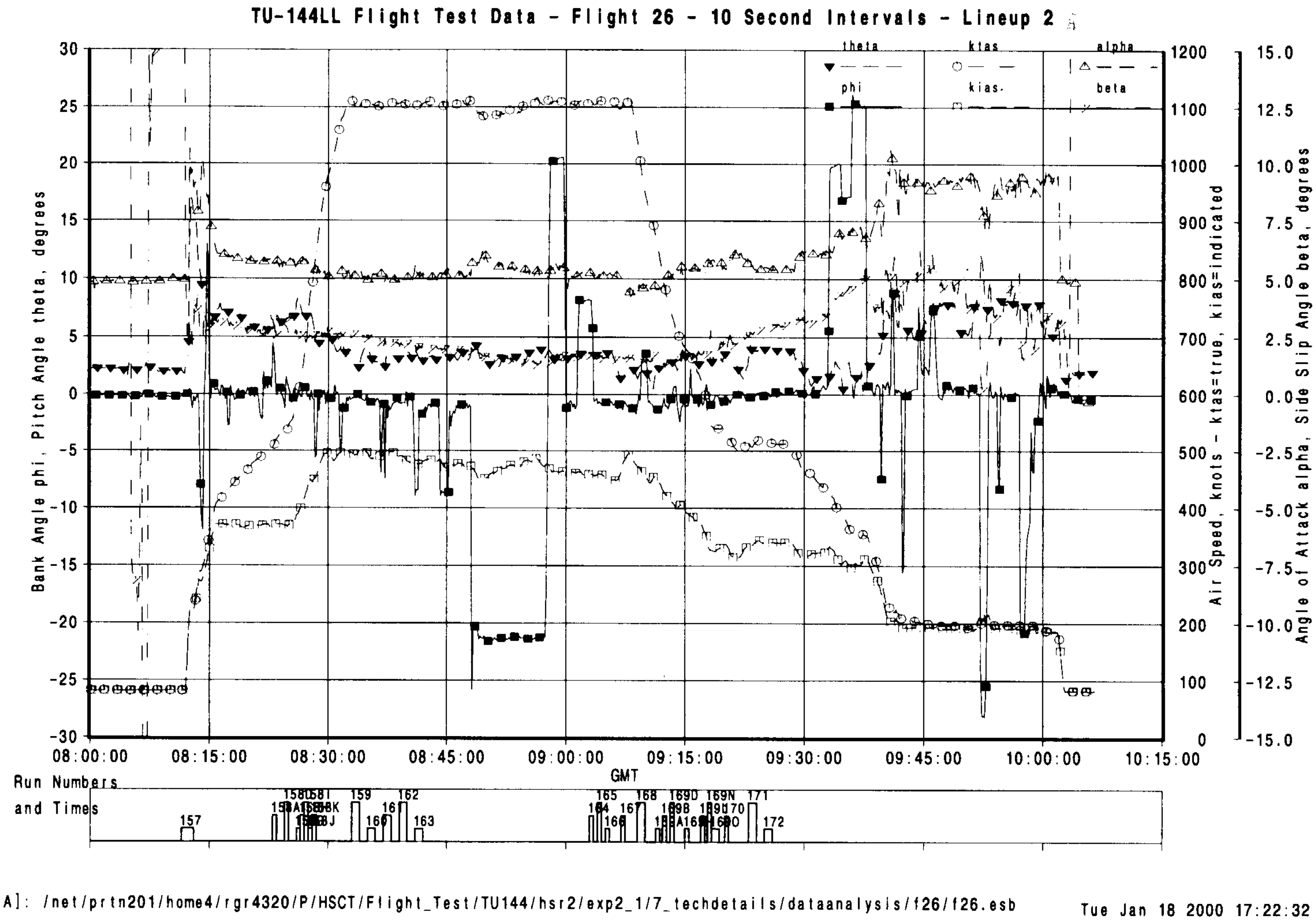
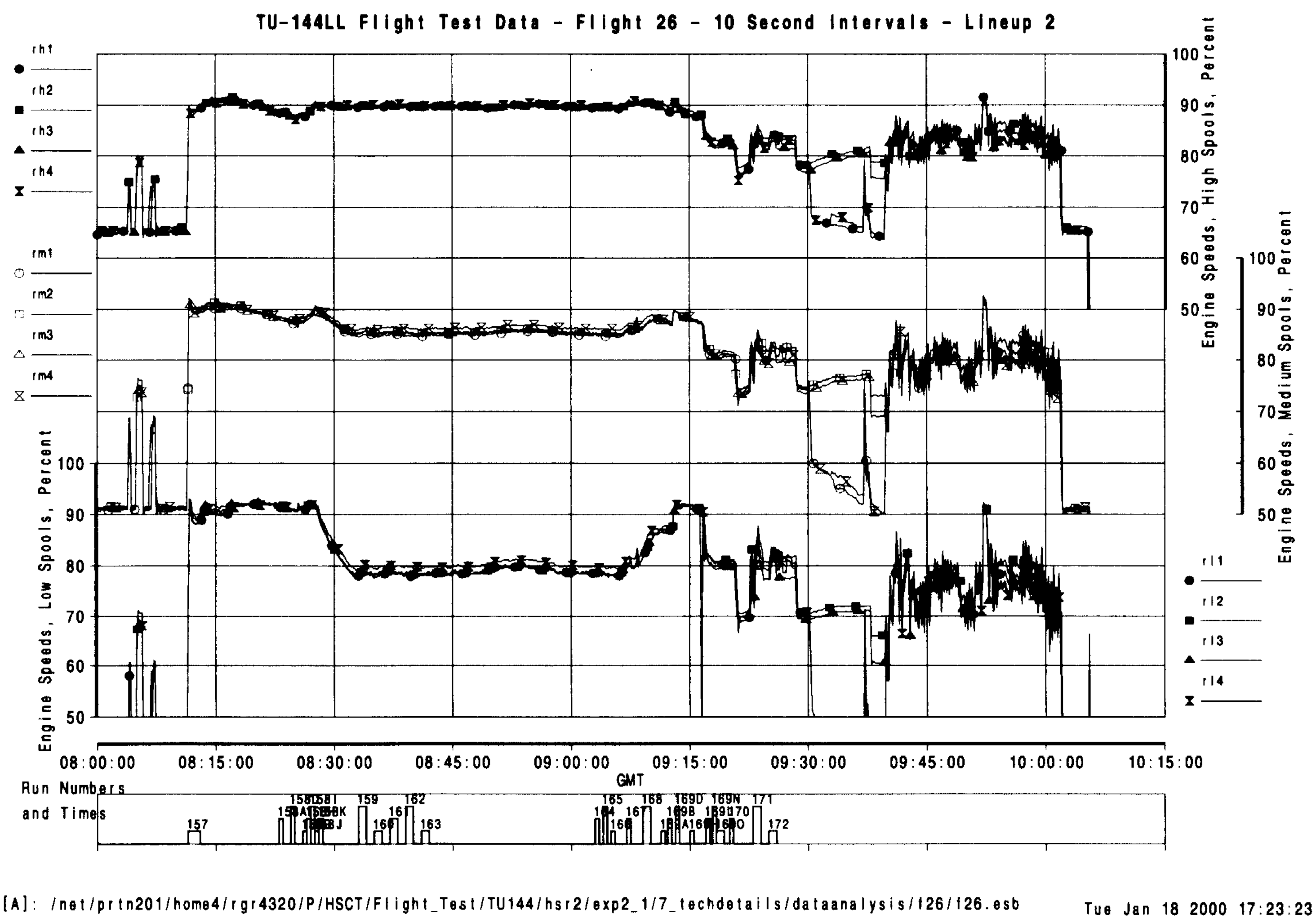


Figure 27 (continued)



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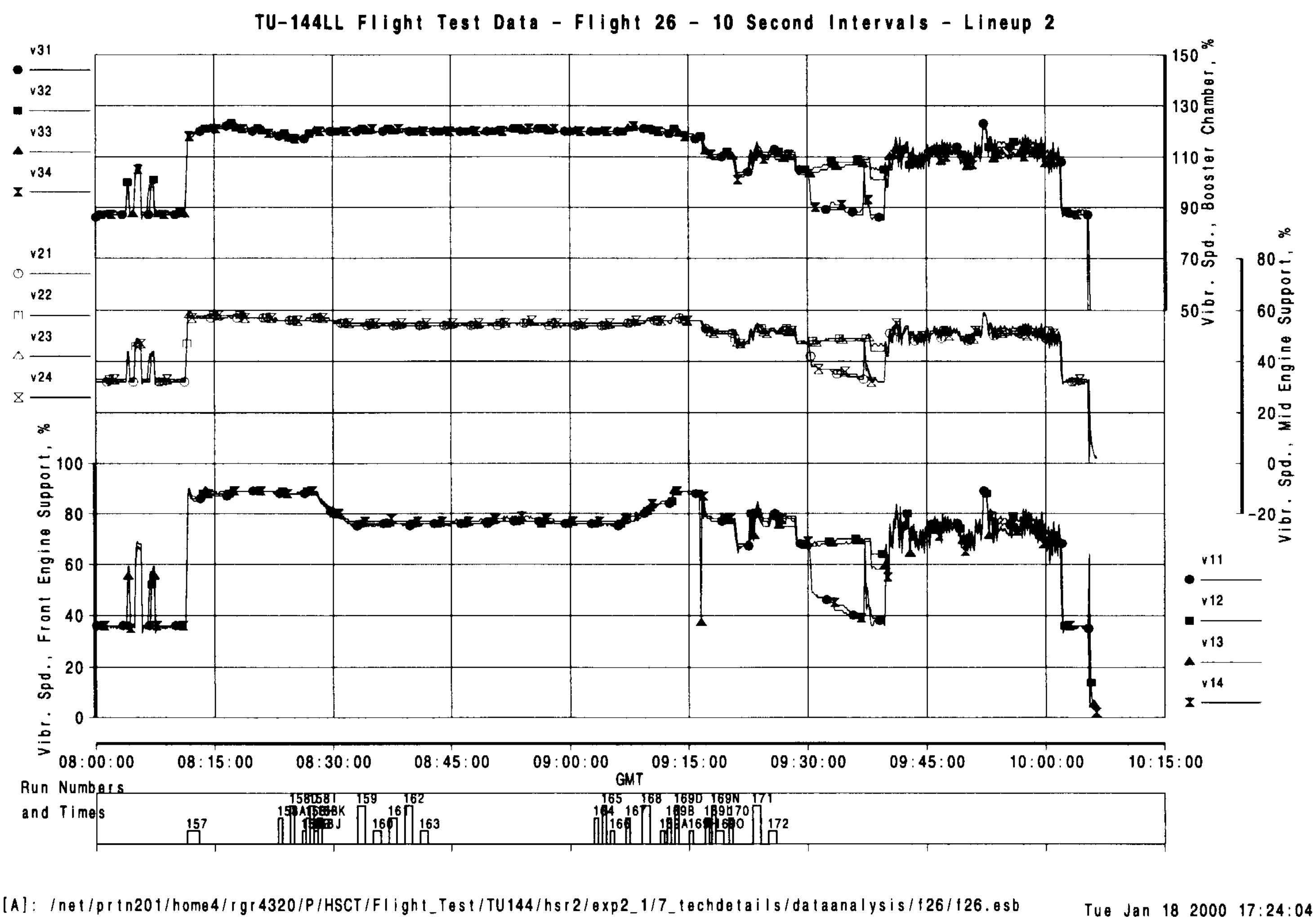

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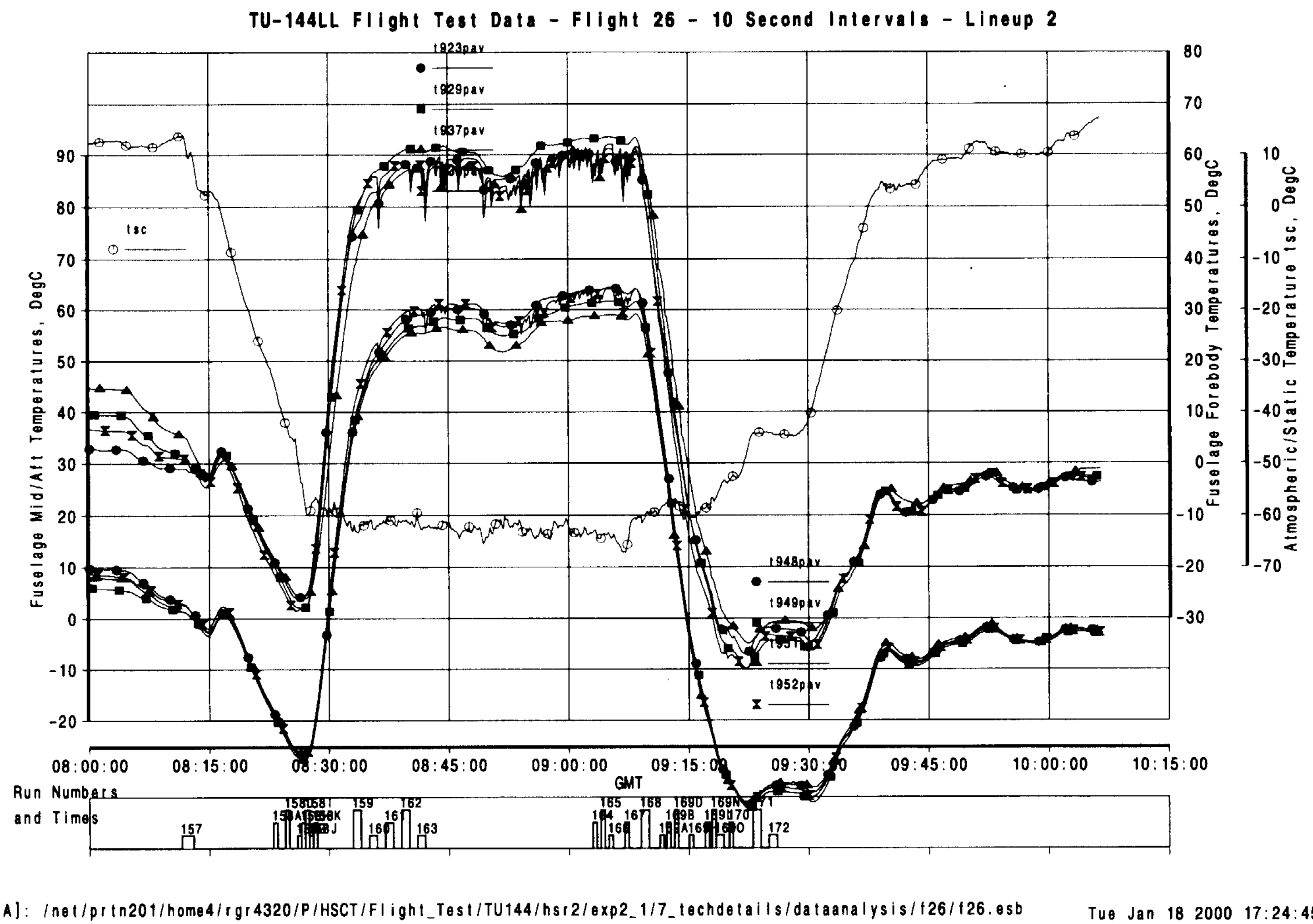

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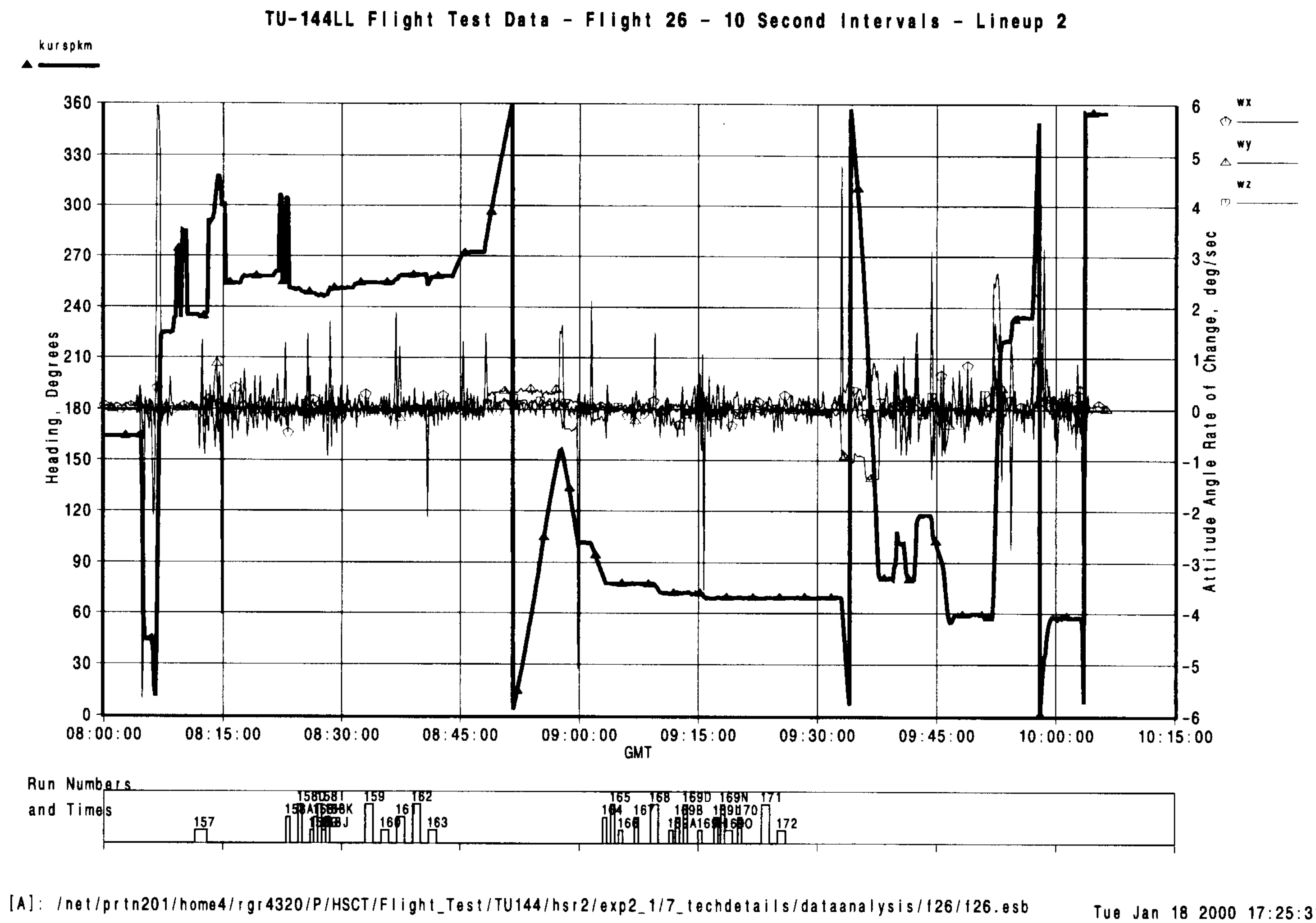

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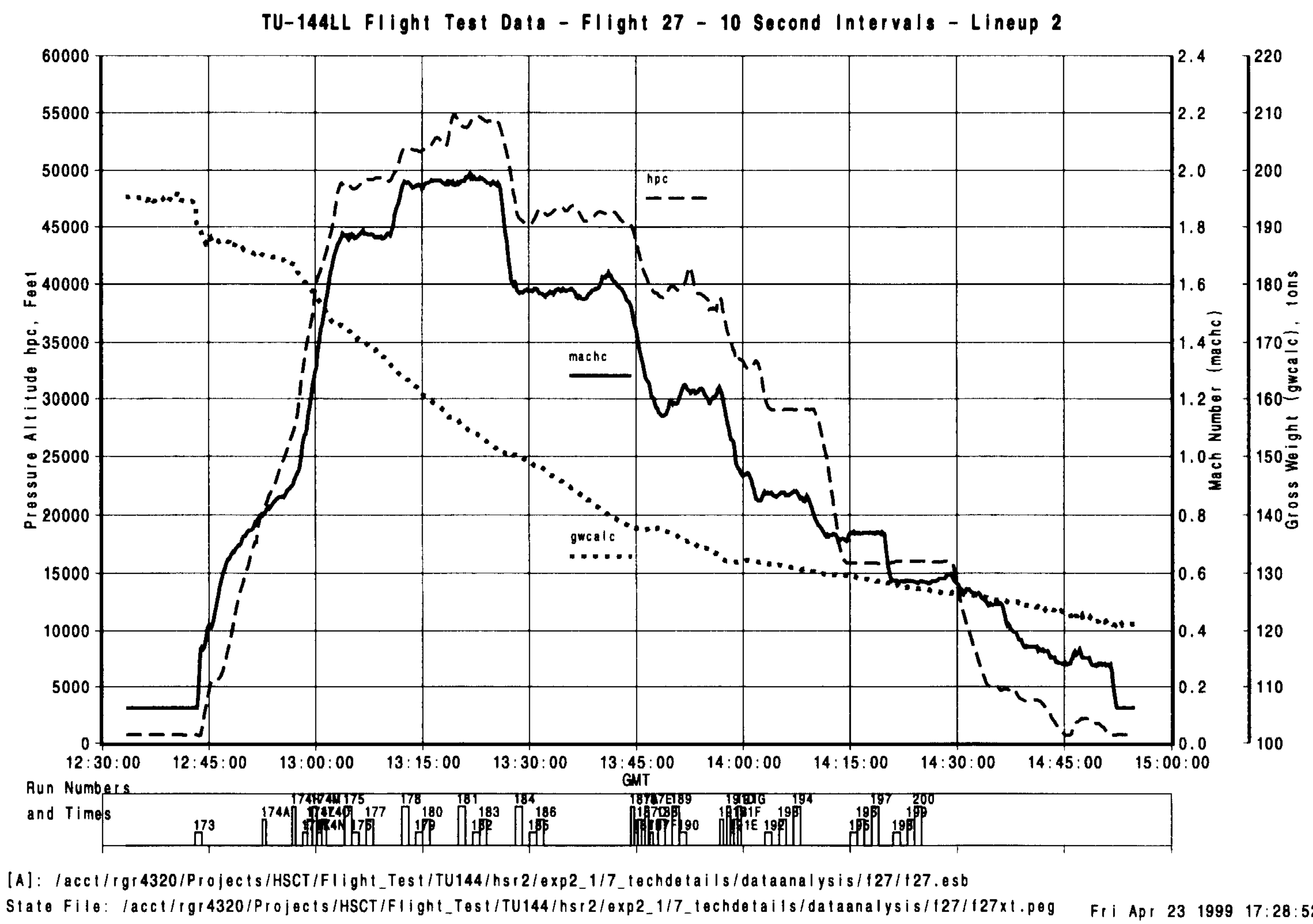
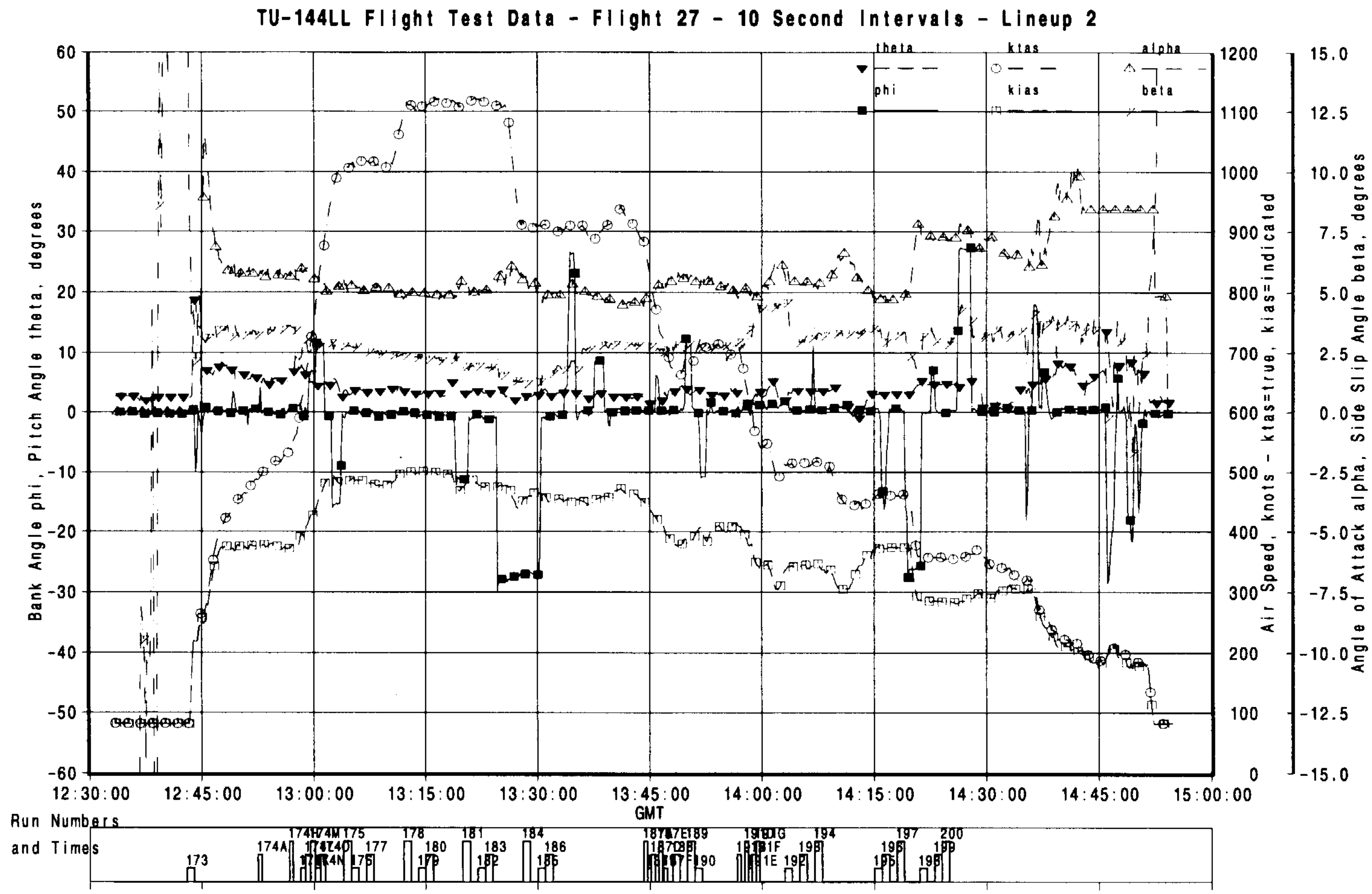
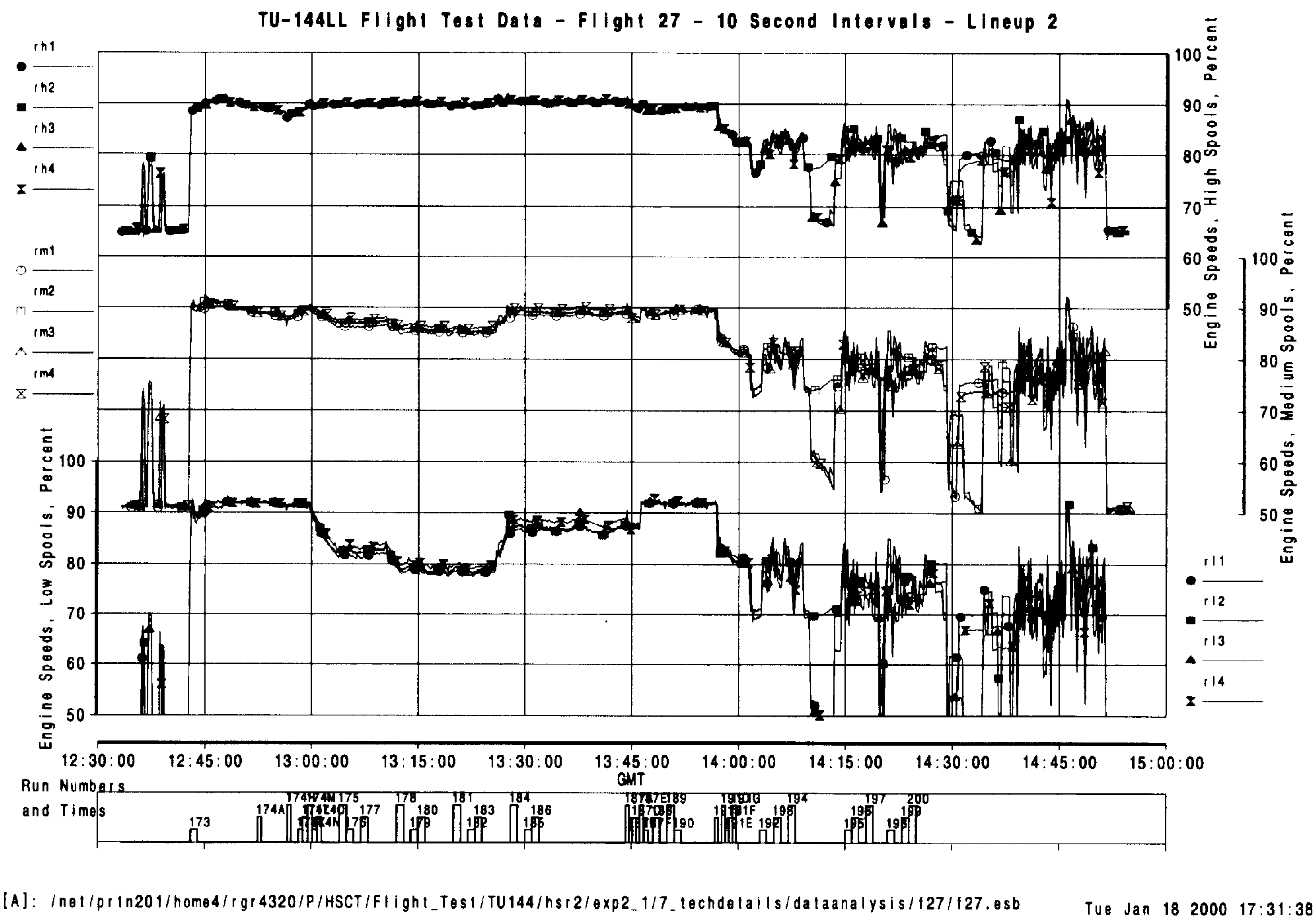


Figure 28: Flight 27 auxiliary data.



[A]: /net/prtn201/home4/rgr4320/P/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/f27/f27.esb   Tue Jan 18 2000 17:30:35

Figure 28 (continued)



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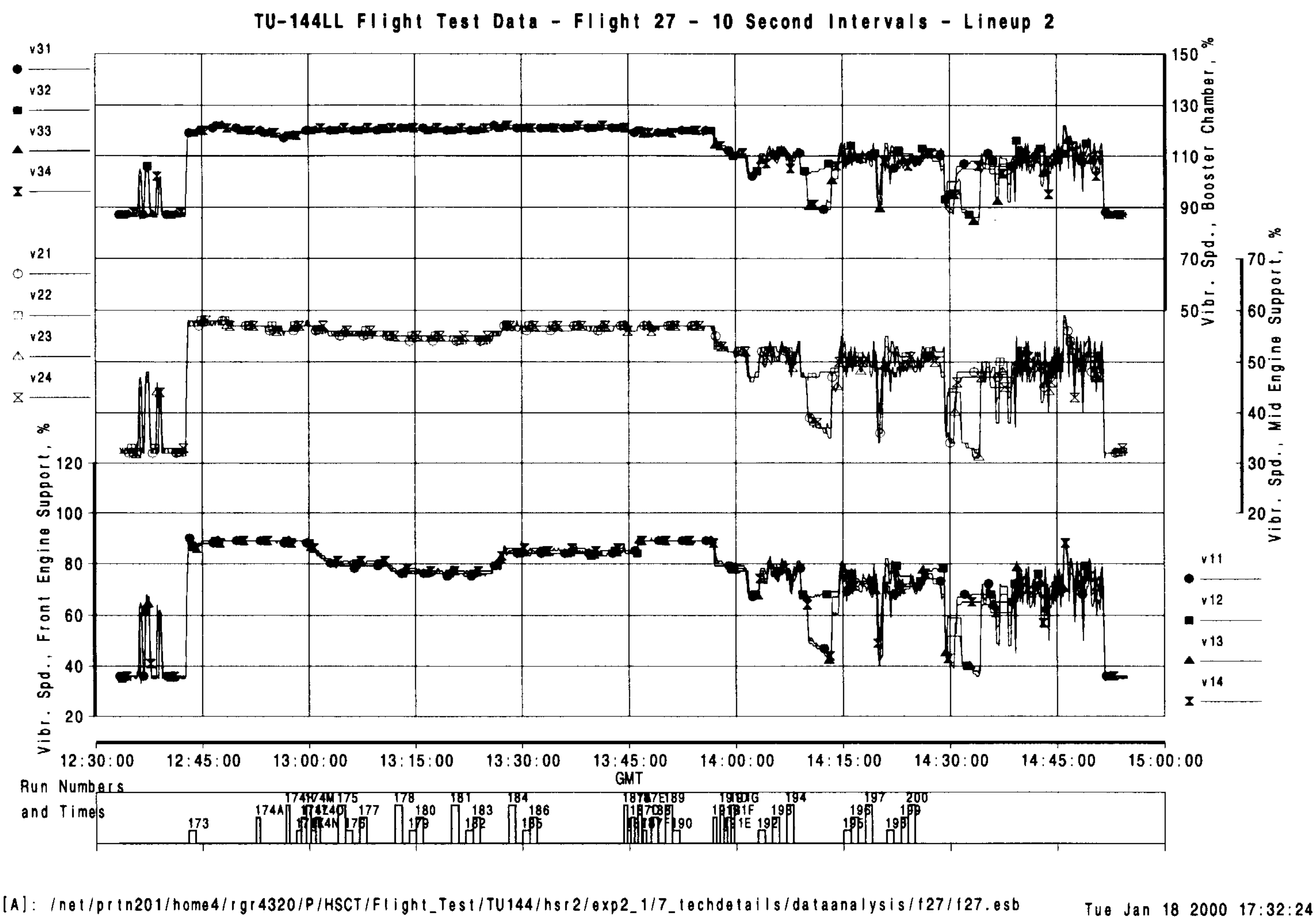

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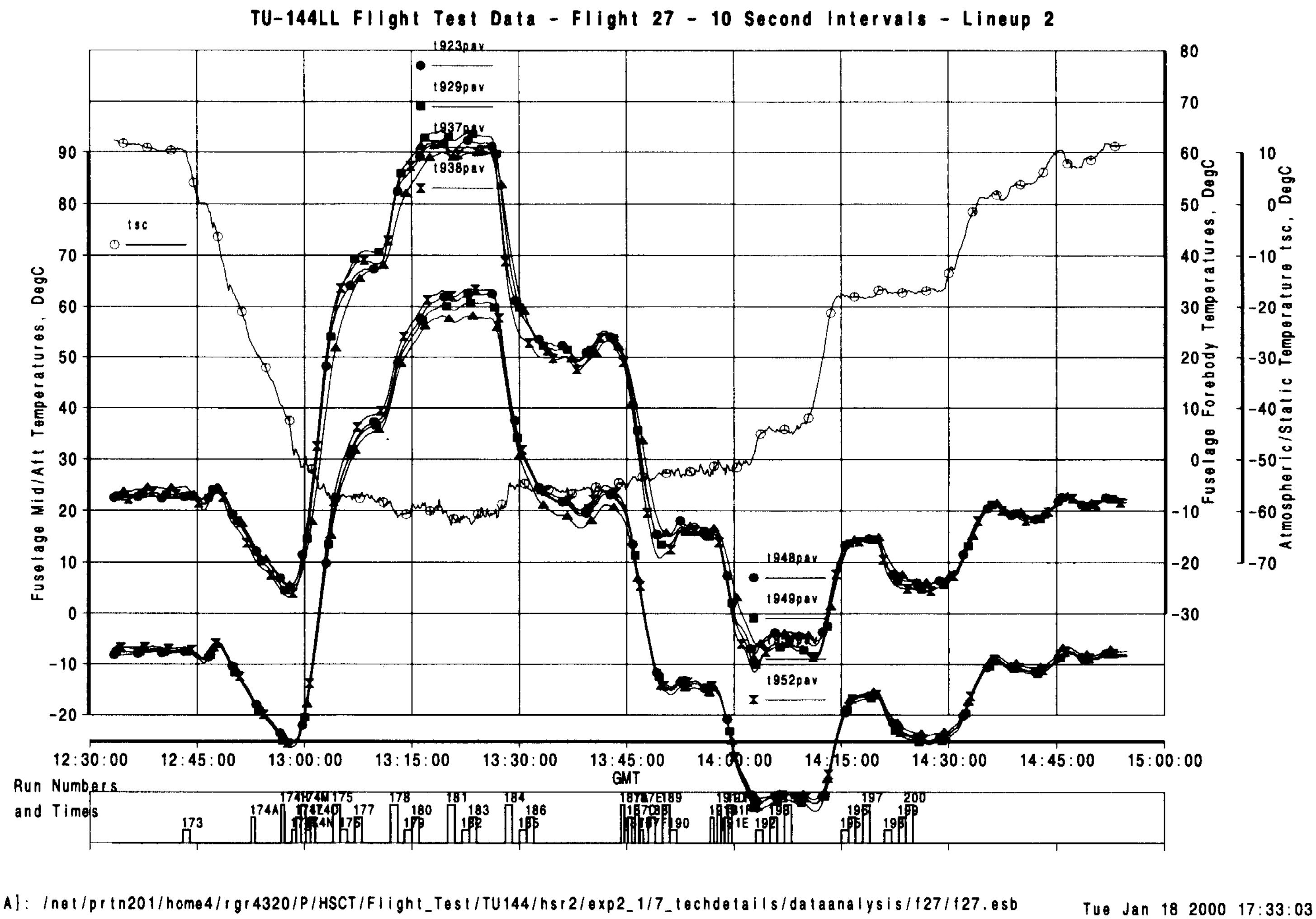

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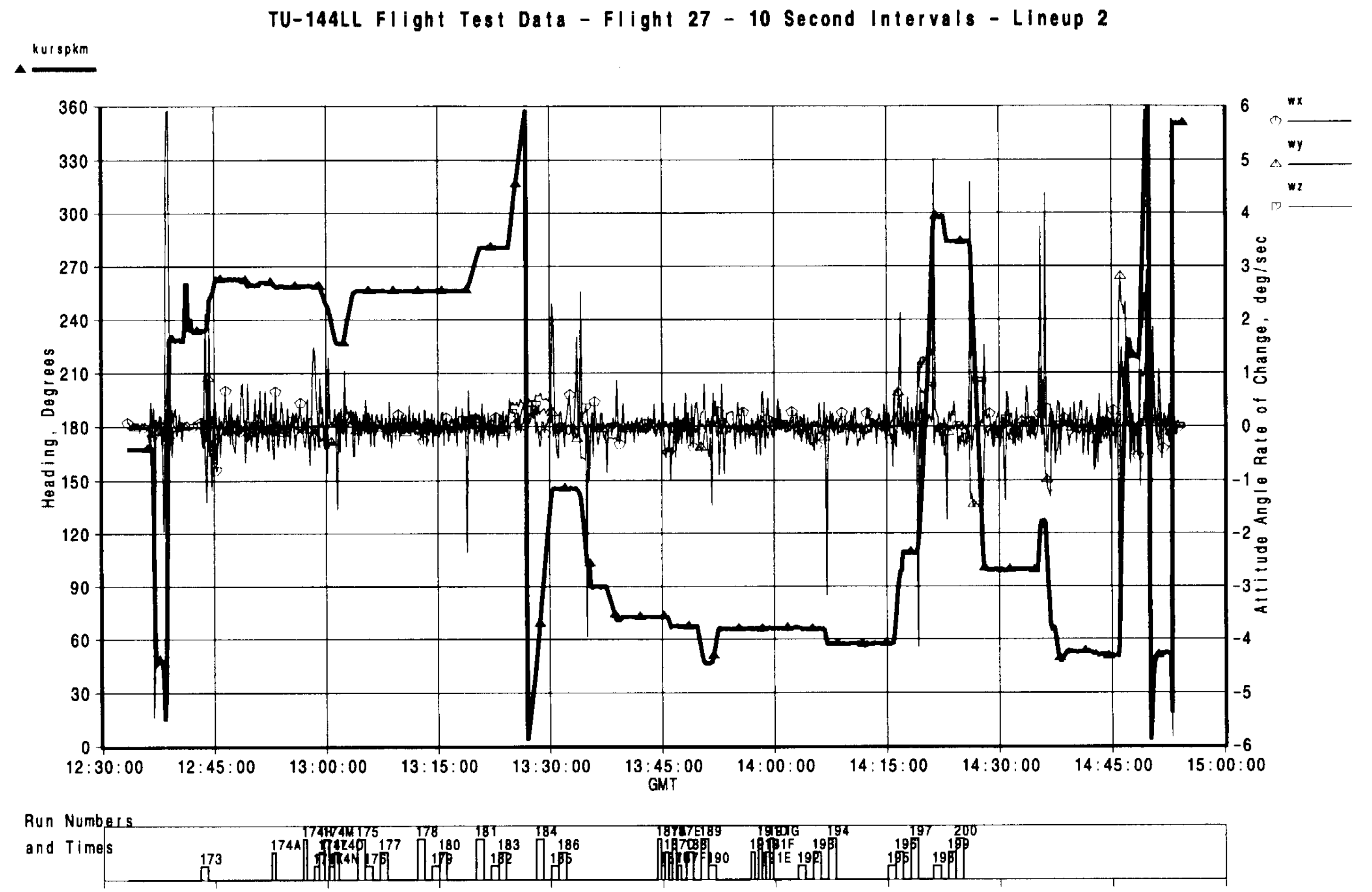

[A]: /net/prtn201/home4/rgr4320/P/HSCT/Flight_Test/TU144/hsr2/exp2_1/7_techdetails/dataanalysis/127/127.esb   Tue Jan 18 2000 17:33:48

Figure 28 (continued)

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13. ABSTRACT *(Maximum 200 words)*

This follow-on flight experiment on the TU-144LL Supersonic Flying Laboratory, conducted during the period September 1998 to April 1999, was a continuation of previous Structure/Cabin Noise Experiment 2.1. Data was obtained over a wide range of altitudes and Mach numbers. Measured were: turbulent boundary layer pressure fluctuations on the fuselage over its length; structural response on skin panels using accelerometers; and flow direction over three windows using 'flow cones'. The effect of steps in the flow was also measured using two window blank pairs; each pair bridged by a plate which created small sharp forward and aft facing steps. The effect of transducer flushness with the exterior surface was also measured during flight. Flight test points were chosen to cover much of the TU-144's flight envelope, as well as to obtain as large a unit Reynolds number range as possible at various Mach numbers: takeoff, subsonic, transonic, and supersonic cruise conditions up to Mach 2. Data on engine runups and background noise were acquired on the ground. The data in the form of time histories of the acoustic signals, together with auxiliary data and basic MATLAB processing modules, are available on CD-R disks.

14. SUBJECT TERMS
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