TP 14399E

Evaluation of Widebody Aircraft Braking Performance with the Determined Runway Friction Index from Tests Conducted in Japan in 2003

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By
Zoltan Rado and Edit F. Radone
Transportation Infrastructure Consulting and Services Ltp.
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The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

Project Team

Zoltan Rado

Edit Fasi Radone

Un sommaire français se trouve avant la table des matières.

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16. Abstract

The main objective of this study was to determine the braking friction value of wide-body aircraft during landing and compare it with the International Runway Friction Index (IRFI) according to the ASTM E2100 standard measured and reported by different ground friction measuring devices right after the aircraft landing. The most important priority of the study was to use actual in-service passenger flights to obtain aircraft braking performance data. To achieve the main objective, the data recorded in the flight data management systems of the selected aircraft were collected and analyzed, and the aircraft braking friction was calculated.

The study also included special aircraft measurements, called tare measurements, to obtain the individual effects of the spoilers, ailerons, flaps and aircraft body with regard to the aerodynamic drag and lift; the effect of the thrust-reverser; and the effects of the wheel drag (rolling resistance).

The correlation of the IRFI to the aircraft friction was not possible due to the lack of winter conditions at New Chitose Airport and the lack of the International Reference Vehicle (IRV) at Akita Airport. However, correlation was developed between the aircraft and Akita Airport's SAAB ground friction measuring device, and the obtained correlation coefficient (R^2= 0.88) shows a strong agreement of the aircraft braking friction to the reported ground friction measurements.

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16. Résumé

L'objectif principal de l'étude était de mesurer le frottement de freinage d'avions gros porteurs à l'atterrissage, puis de comparer cette valeur avec l'Indice international de la glissance des pistes (IRFI, pour *International Runway Friction Index*) selon la norme ASTM E2100, tel qu'établi par différents appareils de mesure du frottement au sol tout de suite après l'atterrissage de l'avion. La grande priorité était d'utiliser des vols en service réel pour obtenir les données de performance en freinage d'un avion. Les chercheurs ont donc récupéré et analysé les données stockées dans le système de gestion des données de vol des avions choisis et ils ont calculé le coefficient de frottement de freinage de l'avion.

D'autres mesures, dites «de tare», ont aussi été prises, pour tenir compte des effets respectifs des déporteurs, des ailerons, des volets et du fuselage de l'avion sur la traînée et la portance aérodynamiques, de même que de l'effet des inverseurs de poussée et des effets de la traînée des roues (résistance au roulement).

Il n'a pas été possible d'établir une corrélation entre l'IRFI et le frottement de freinage de l'avion en raison de l'absence de conditions hivernales à l'aéroport New Chitose et parce que l'aéroport Akita ne disposait pas de véhicule international de référence. On a toutefois examiné la corrélation entre l'avion et le dispositif de mesure du frottement au sol SAAB de l'aéroport Akita. Le coefficient de corrélation obtenu (R^2= 0,88) révèle une concordance étroite entre le frottement de freinage de l'avion et les valeurs de frottement mesurées par le véhicule au sol.

17. Mots clés Indice international de la glissance des pistes, IRFI (*International Runway Friction Index*), enregistreur à accès rapide, QAR (*Quick Access Recorder*), enregistreur des données de vol, FDR (*Flight Data Recorder*), tare, ASTM E2100, performance en freinage des aéronefs	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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On behalf of the JWRFMP, the authors would like to express their thanks and appreciation to All Nippon Airways (ANA) and its pilots for their cooperation and willingness to participate in the successful planning and execution of the testing.

EXECUTIVE SUMMARY

Past experience and research clearly demonstrate that a contaminated runway can degrade safety to the point that takeoff and landing can become hazardous. Within the framework of the Joint Winter Runway Friction Measurement Program (JWRFMP), an extensive data collection and analysis study was conducted in Japan during the winter of 2003. The objective of this test program was to achieve a better understanding of how winter runway contaminants can adversely affect aircraft stopping distance through the comparative analysis of real in-service widebody passenger aircraft landing and ground friction measurement data. Based on the outcome of this study, it is anticipated that more accurate models of the effect of runway contaminants on landing and takeoff performance of aircraft can be developed.

The main objective of this test program was to determine the braking friction value of airplanes such as the B767, B777 or other wide-body aircraft during landing and compare it with the International Runway Friction Index (IRFI) according to the ASTM E2100 standard measured and reported by different ground friction measuring devices. The most important priority of the study was to use actual in-service passenger flights to obtain aircraft braking performance data. To achieve the main objective, the data recorded in the Quick Access Recorder (QAR) from the selected aircraft were collected and analyzed, and the aircraft braking friction was calculated.

According to the original test plan, after each selected wide-body airplane landing, the ERD (Electronic Recorder Decelerometer), IRV (International Reference Vehicle) and the airport's Ground Friction Measuring Device (GFMD) were to make a measurement run and report the IRFI according to ASTM E2100. The reported IRFI and the calculated aircraft braking friction were to be compared to evaluate the IRFI number.

To achieve the project's main objective, the study also included special aircraft measurements, called tare measurements, to obtain the effects of the spoilers, ailerons, flaps and aircraft body with regard to the aerodynamic drag and lift; the effect of the thrust-reverse; and the effects of the wheel drag (rolling resistance).

According to the original test plan, measurements were to be taken at two different locations: New Chitose Airport and Akita Airport. Unfortunately, because of a lack of winter weather conditions, there were no aircraft measurements taken at New Chitose Airport. Winter weather conditions did, however, occur at Akita Airport, where several aircraft landing QAR data sets were recorded together with measurements taken with Akita Airport's SAAB friction measuring device. Furthermore, several tare configuration landings were achieved by aircraft, and the QAR data were collected.

A total of 43 flights were identified as candidates to be included in the study, where the requested procedures were followed on winter surfaces. The flight data recorded in the QAR systems were saved and paired with additional airport data for future analysis. The data validation, checking of actual runway conditions, inspection of the ground friction measurement data, and other consistency assessments eliminated a number of landing data sets.

Of the 43 flights, 10 flights proved to be valid friction limited landings. For these landings, a correlation between the B767-300 and Akita Airport's SAAB friction measuring device was developed, and the obtained correlation coefficient (R^2= 0.88) shows a strong dependence of the aircraft braking friction on the reported ground friction measurements.

Akita Airport's SAAB friction measuring device was not calibrated to report the IRFI. However, it is anticipated that the difference in the result would be only the difference of the correlation values, but that the quality of the correlation (R^2) would be similar or improved.

SOMMAIRE

Tant l'expérience passée que la recherche démontrent qu'une piste contaminée peut compromettre la sécurité au point de rendre le décollage et l'atterrissage hasardeux. Le Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH) a donné lieu à d'importants travaux de collecte et d'analyse de données au Japon, à l'hiver 2003. L'objectif des essais était de mieux comprendre comment la contamination hivernale peut allonger la distance d'arrêt des avions, en comparant les données recueillies à l'atterrissage d'avions passagers gros porteurs avec les données d'appareils de mesure du frottement au sol. Il ressort de l'étude qu'il est possible d'élaborer des modèles plus précis de l'effet de pistes contaminées sur la performance des avions au décollage et à l'atterrissage.

L'objectif principal du programme d'essais était de mesurer le frottement de freinage d'avions comme un B767, un B777 ou un autre gros porteur à l'atterrissage, puis de comparer cette valeur avec l'Indice international de la glissance des pistes (IRFI, pour *International Runway Friction Index*) selon la norme ASTM E2100, tel qu'établi par différents appareils de mesure du frottement au sol tout de suite après l'atterrissage de l'avion. La grande priorité était d'utiliser des vols en service réel pour obtenir les données de performance en freinage d'un avion. Les chercheurs ont donc récupéré et analysé les données stockées dans l'enregistreur à accès rapide (QAR, pour *Quick Access Recorder*) des avions choisis et ils ont calculé le coefficient de frottement de freinage de l'avion.

Selon le plan d'essai initial, après chaque atterrissage d'un des gros porteurs choisis, le décéléromètre électronique (ERD, pour *Electronic Recorder Decelerometer*), le véhicule international de référence (IRV, pour *International Reference Vehicle*) et le dispositif de mesure du frottement au sol de l'aéroport devaient être lancés sur la piste pour mesurer le coefficient de frottement et en établir la valeur IRFI selon la norme ASTM E2100. On devait ensuite comparer l'IRFI ainsi établi et le frottement de freinage de l'avion calculé, de façon à évaluer la pertinence de l'IRFI.

D'autres mesures, dites «de tarage», ont aussi été prises, pour tenir compte des effets respectifs des déporteurs, des ailerons, des volets et du fuselage de l'avion sur la traînée et la portance aérodynamiques, de même que de l'effet des inverseurs de poussée et des effets de la traînée des roues (résistance au roulement).

Il était prévu de réaliser l'essai à deux sites, soit à l'aéroport New Chitose et à l'aéroport Akita. Malheureusement, en raison de l'absence de conditions hivernales à l'aéroport New Chitose, ce site a dû être écarté. Mais de nombreuses mesures ont été prises à l'aéroport Akita. Ainsi, plusieurs ensembles de données d'atterrissage QAR ont été enregistrés, de même que les mesures issues de l'appareil SAAB de l'aéroport Akita. De plus, plusieurs atterrissages en configuration nominale ont été effectués, et les données QAR correspondantes ont été récupérées.

Un total de 43 vols ont été désignés «vols candidats»; il s'agissait de vols pour lesquels les procédures requises pour l'atterrissage sur des surfaces hivernales avaient été suivies. Les données de vol enregistrées dans les systèmes QAR ont été conservées et jumelées avec d'autres données de l'aéroport, pour analyse future. La validation des données, la vérification

de l’état réel de la piste, l’examen des données de mesure du frottement au sol, et d’autres contrôles de cohérence ont mené à l’élimination d’un certain nombre d’ensembles de données d’atterrissage.

C’est ainsi que des 43 vols candidats, 10 ont finalement été jugés des cas valides d’atterrissage sur une surface à frottement limité. Pour ces atterrissages, on a calculé la corrélation entre le B767-300 et le dispositif de mesure du frottement au sol SAAB de l’aéroport Akita; le coefficient de corrélation obtenu (R^2= 0,88) révèle une concordance étroite entre le frottement de freinage de l’avion et les valeurs de frottement mesurées par le véhicule au sol.

L’appareil de mesure du frottement au sol de l’aéroport Akita n’a pas été étalonné pour pouvoir donner une valeur IRFI. Mais tout porte à croire que si tel était le cas, la différence entre les résultats tiendrait uniquement aux valeurs de la corrélation, et que la qualité de la corrélation (R^2) serait semblable, voire meilleure.

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ACRONYMS

ANA	All Nippon Airways
ASTM	American Society for Testing and Materials
CRFI	Canadian Runway Friction Index
ERD	Electronic Recording Deceleration
GFMD	Ground Friction Measuring Device
ICAO	International Civil Aviation Organization
IRD	International Reference Device
IRFI	International Runway Friction Index
IRV	International Reference Vehicle
JAR	Joint Aviation Requirements
JWRFMP	Joint Winter Runway Friction Measurement Program
METAR	Aviation Routine Weather Report
NOTAM	Notice to Airmen
QAR	Quick Access Recorder
SNOWTAM	NOTAM concerning runway conditions in snow

1 INTRODUCTION

Past experience and research clearly demonstrate that a contaminated runway can degrade safety to the point that takeoff and landing can become hazardous. Within the framework of the Joint Winter Runway Friction Measurement Program (JWRFMP), an extensive data collection and analysis study was conducted in Japan during the winter of 2003. The objective of this test program was to achieve a better understanding of how winter runway contaminants can adversely affect aircraft stopping distance through the comparative analysis of real in-service widebody passenger aircraft landing and ground friction measurement data. It is anticipated that more accurate models of the effect of runway contaminants on landing and takeoff performance of aircraft can be developed.

For many years the international aviation community has had no uniform runway friction reporting practices. Airport operations personnel, in taking on the responsibility of conducting friction measurements during winter storms, find it difficult to keep up with the rapid changes in the weather. The equipment used and procedures followed in taking friction measurements varies from country to country. Friction readings at various airports may not be comparable because of differences in the ground friction measurement equipment, instrumentation and standing operating procedures.

After six winters of testing in the JWRFMP program, a significant amount of data has been collected. However, until the 2003 Japan tests, the program was still lacking data from widebody aircraft such as the B767, Airbus 320 and other widely used aircraft types.

2 OBJECTIVES

The main objective of the test program was to determine the braking friction value of airplanes such as the B767, B777 or other wide-body aircraft during landing and compare it with data measured right after each landing with different ground friction measuring devices. The most important priority of the study was to use actual in-service passenger flights to obtain aircraft braking performance data. To achieve the main objective, the data recorded in the Quick Access Recorder (QAR) or other digital Flight Data Recorder (FDR) or management systems from the selected aircraft were collected and analyzed, and the aircraft braking friction was calculated.

According to the original test plan, after each selected wide-body airplane landing, the ERD (Electronic Recorder Decelerometer), IRV (International Reference Vehicle) and the airport's Ground Friction Measuring Device (GFMD) were to make a measurement run and report the International Runway Friction Index (IRFI) according to the ASTM E2100 standard. The reported IRFI and the calculated aircraft braking friction were to be compared to evaluate the IRFI number.

To achieve the project's main objective, the plan also included special aircraft measurements, called tare measurements, to obtain the following parameters:

1. The effects of the spoilers (speed brakes), ailerons, flaps and aircraft body with regard to the aerodynamic drag and lift.
2. The effect of the thrust-reverser.
3. The effects of the wheel drag (rolling resistance).

3 SCOPE

According to the original test plan, measurements were to be taken at two different locations: New Chitose Airport and Akita Airport. Unfortunately, because of a lack of winter weather conditions, there were no aircraft measurements taken at New Chitose Airport. Two SAAB friction testers used throughout the measurement program at New Chitose Airport were calibrated against the IRV reference measuring device.

Almost at the same time, due to the availability of the desired winter weather conditions at Akita Airport, several aircraft landing QAR data sets were recorded together with measurements taken with Akita Airport's SAAB friction measuring device in winter conditions. Furthermore, several tare configuration landings were achieved by aircraft, and the QAR data were collected. The data were assembled from the aircraft for the tare and normal landing configurations and from the ground friction measurements by the Japanese personnel.

Because the International Reference Device (IRD) was only available at New Chitose Airport, Akita Airport's SAAB friction measuring device was not calibrated to report the IRFI. Therefore, the scope of this report includes only a correlation between the B767-300 and Akita Airport's SAAB friction measuring device. It is anticipated that the difference in the result would only be the difference of the correlation values, but that the quality of the correlation (R^2) would be similar or improved.

In this report, all the test data refer to measurements taken at Akita Airport only.

4 FIELD TESTS

Two types of landing configurations and procedures for aircrafts were designed and prepared in the test plan. One was to ensure that the configuration and pilot procedure of the landing aircraft produced data recorded in the aircraft QAR that enabled the calculation of the aircraft braking friction during normal landing. These were called braking runs. The other was to ensure that the configuration and pilot procedure of the landing aircraft produced data recorded in the aircraft QAR that enabled the calculation of:

1. The effect of the spoilers (speed brakes), ailerons, flaps and aircraft body,
2. The effect of the thrust-reversal, and
3. The effects of the wheel drag (rolling resistance).

These aircraft landings were called tare runs.

4.1 Tare Runs

The objective of these landings was to generate flight recorder data that allowed otherwise unknown aircraft parameters to be deduced. The recommended pilot procedures together with the utilized aircraft configuration were designed to ensure that special and clear QAR data, with two distinct time windows, were produced during the landings. The first time window was to create a sufficiently long time trace of aircraft parameters with no braking and no thrust-reversal applied. The other time window was to ensure that all the collected aircraft parameters were available for a minimum time trace with normal flap configuration and thrust-reverser setting, but no braking.

To obtain the above goals and generate the necessary QAR data, the following procedure was recommended for the pilots:

1. After the nose gear touches the ground and before the braking starts, the aircraft should coast with no brake and no thrust-reversal for 4-5 seconds.
2. After the initial 4-5 second coasting, the thrust-reverser should be turned on, but no brake applied, and the aircraft should coast for another 4-5 seconds.
3. After that the normal braking procedure should be applied.

4.2 Braking Runs

The braking runs were essentially normal aircraft landings that took place on winter contaminated surfaces under normal airport operations. One aim of the study was to observe aircraft landing operations under normal airport operations and collect the data only on those winter contaminated surfaces that occur under normal winter operations. The objective of these landings was to generate the time traces of all aircraft parameters in the flight data recorder where friction limited braking sections were achieved. This can only be obtained with as high as possible auto-brake settings.

To obtain the above, the following procedure was proposed for the pilots:

1. After the nose gear touches the ground and before the braking starts, the aircraft should coast with no brake and no thrust-reversal for 1-2 seconds.
2. After the steady-state coasting, the thrust-reverser should be turned on, but no brake applied, and the aircraft should coast for another 1-2 seconds.
3. When the stabilized baseline thrust-reverser deceleration is achieved, the normal landing procedure should be applied with as high as possible auto-brake settings.
4. After reaching taxi-speed, the aircraft should coast for 1-2 seconds with no brake and no thrust-reversal, if possible, to provide control data.

With this procedure the standard landing procedure was followed, with as little deviation from it as possible. After touchdown, first the thrust reverser, then the brake was switched on. After reaching the appropriate low speed, the thrust reverser was switched off, and when the airplane reached taxi speed, the brake was switched off. The only change request was that the pilots delay switching on the thrust-reverser and the brake based on best judgment, possibly with 1-2 seconds each. At the end of the landing manoeuvre, when normal taxi speed was reached, a short second coasting (no thrust, no thrust reverser, and no brakes) for 1-2 seconds was inserted before proceeding with normal taxiing.

5 FLIGHT DATA FROM AKITA AIRPORT TESTS

A total of 43 flights were identified as candidates to be included in the study, where the requested procedures were followed on winter surfaces. The flight data recorded in the QAR systems were saved and paired with additional airport data for future analysis. The data validation, checking of actual runway conditions, inspection of the ground friction measurement data, and other consistency assessments eliminated a number of landing data sets. After this elimination, the flights listed in Table 1 were included in aircraft braking friction run analysis.

Table 1 Aircraft Braking Friction Runs

Landing Date/Time	Flight No	AC	Data File
JAN20_03/13:24	F873	B767-300	S9.txt
JAN20_03/20:53	F879	B767-300	S4.txt
JAN21_03/19:05	F877	B767-300	S5.txt
JAN22_03/10:55	F873	B767-300	S6.txt
JAN22_03/12:23	F875	B767-300	S2.txt
JAN23_03/19:03	F877	B767-300	S12.txt
JAN23_03/21:14	F879	B767-300	S17.txt
JAN24_03/10:43	F873	B767-300	S10.txt
JAN24_03/21:11	F879	B767-300	S8.txt
JAN24_03/18:46	F877	B767-300	S3.txt
JAN29_03/10:27	F873	B767-300	S7.txt
JAN29_03/12:45	F875	B767-300	S1.txt
JAN29_03/18:37	F877	B767-300	S13.txt
JAN29_03/21:30	F879	B767-300	S15.txt
JAN30_03/12:30	F875	B767-300	S11.txt
JAN30_03/21:01	F879	B767-300	S14.txt
JAN31_03/20:55	F879	B767-300	S16.txt

Four tare runs were completed during the test:

Table 2 Tare Runs

Data File	Flight No	Landing Date/Time	AC
T1.txt	F743	MAR09_2003	B767-300
T2.txt	F744	MAR09_2003	B767-300
T3.txt	F970	MAR10_2003	B767-300
T4.txt	F097	MAR13_2003	B767-300

5.1 Aircraft Systems Description

5.1.1 Landing Gear

The Boeing 767-300ER aircraft is equipped with:

- Hydraulically retractable tricycle type; Cleveland Pneumatic main gear, with two four-wheel bogies, retracts inward
- Oleo-pneumatic shock-absorbers
- Honeywell wheels
- Main wheel tires of current production versions H46×18.0-20 32 ply for 200ER/300ER
- Nose wheel tires size H37×14.0-15 (22/24 ply)
- Steel disc brakes on all main wheels (since 1999 the manufacturer also offers Messier-Bugatti's latest heat-sink material, Sepcarb®III, a carbon and carbon-composite material brakes on the main wheels)
- Electronically controlled anti-skid units

During the planning period of the project, provisions were made to collect information for each of the aircraft and interview their pilots after each landing. The original plan was to train technical and maintenance personnel to record the physical conditions after each and every one of the recorded aircraft landings of the following:

- For the aircraft landing gear conditions
    - Size of tire
    - Type of tire
    - Manufacturer of tire
    - Tire inflation pressure
    - Percentage wornness of tire

- For the pilot interview
  - Pilot experienced braking action
  - Pilot experienced directional stability
  - Observed runway conditions
  - Experienced difficulties

Unfortunately, during the project it was not possible to collect the planned information because of constraints in the available resources.

5.2 Field Test Data

The aircraft flight data management system records a vast amount of performance data that is included in the QAR records. After careful examination of the available data, a subset of the collected parameters was selected. These data points formed the necessary basis of performance records for the full dynamic simulation of the aircraft landing and data to check the validity and soundness of the dynamic simulation.

The QAR data listed in Table 3 were downloaded after each landing.

Table 3 Complete QAR Parameter List

Parameter No.	Parameter Name
113	JST HH:MM:SS
242	PRESSURE ALTITUDE
209	CAS LEFT
200	AILERON INBD LEFT
201	AILERON INBD RIGHT
202	AILERON OUTBD LEFT
203	AILERON OUTBD RIGHT
349	AIR/GRD SENSOR 1
350	AIR/GRD SENSOR 2
351	AIR/GRD SENSOR 3
352	AIR/GRD SENSOR 4
356	AUTOBRAKE MODE 1
357	AUTOBRAKE MODE 2
358	AUTOBRAKE MODE 3
359	AUTOBRAKE MODE 4
355	AUTO BRAKE DISARM
360	AUTOBRAKE MODE 5(MAX)
361	AUTOBRAKE MODE OFF
362	AUTOBRAKE MODE RTO
100	BARO CORR CAP
101	BARO CORR F/O

1017	BODY PCHRATE LEFT
206	BRAKE PRESS LEFT
207	BRAKE PRESS RIGHT
700	CONTROL COLUMN POSITION
701	CONTROL WHEEL POSITION
212	ELEV POS LEFT
213	ELEV POS RIGHT
214	FLAP HANDLE POS
216	FUEL FLOW LEFT
217	FUEL FLOW RIGHT
219	GROSS WEIGHT LSD
220	GROSS WEIGHT MSD
221	GRD SPEED
222	INERTIAL VERTICAL SPD
416	GEAR LEVER DOWN
223	LATG 1
224	LATG 2
225	LATG 3
226	LATG 4
228	LONG 1
229	LOMG 2
230	LONG 3
231	LONG 4
233	MAG HEADING
234	N1 ACTUAL LEFT
235	N1 ACTUAL RIGHT
236	N2 ACTUAL LEFT
237	N2 ACTUAL RIGHT
239	PITCH ATTITUDE
240	PRESENT POSITION LATITUDE
241	PRESENT POSITION LONGITUDE
243	RADIO ALTITUDE 1
244	RADIO ALTITUDE 2
245	ROLL ATTITUDE
703	RUDDER PEDAL POSITION
246	RUDDER POSITION
704	SPPOILER HANDLE POSITION
702	HORIZONTAL STAB POSITION
252	STATIC AIR TEMP
256	TOTAL FUELQTY LSP
257	TOTAL FUELQTY MSP
253	THROTTLE RESLVANGLE LEFT
254	THROTTLE RSLVANGLE RIGHT
1076	REVERSER POS LEFT
1077	REVERSER POS RIGHT
255	TOTAL AIR TEMP
1081	TRUE AIRSPD LEFT

261	VERTICAL G 1
262	VERTICAL G 2
263	VERTICAL G 3
264	VERTICAL G 4
265	VERTICAL G 5
266	VERTIACL G 6
267	VERTICAL G 7
268	VERTICAL G 8
271	WIND DIRECTION
272	WIND SPEED
378	AUTO BRAKE #3
552	L/D GEAR LEVER

Most parameters were recorded every second; some of the vital parameters were stored four times a second, while non-critical data was stored every two seconds.

The aircraft QAR data were provided in electronic format as Microsoft Excel data sheets. The different parameters with different sampling rates were compiled and made to be available at the highest frequency. This was achieved by re-sampling the low frequency data at the highest 4 Hz sampling rates involving linear interpolation between data points. The aircraft brake simulation used the uniform time-based parameters for the dynamic calculations.

Besides the QAR data, Flight Operation – Engineering – All Nippon Airways (ANA) provided the following datasheets for each landing:

1. SNOWTAM
2. Weight and balance manifest
3. METAR

From these data sheets, the data listed in Table 4 were organized into a table and used in the data analysis.

Table 4 Flight Data

Data File	Landing Weight (from Aircraft Specification) (lb/kg)	Reported Landing weight (lb/kg)	Air Temp (°C)	Pressure Altitude (ft)	Air Pressure (kPa/in Hg)	Rel. hum. (%)	SAAB Friction Measurement
T1.txt	254720/114624	Not reported	-8	150	101.30/29.92	86	Not reported
T2.txt	248960/112032	Not reported	8	-160	101.30/29.92	88	Not reported
T3.txt	241920/108864	Not reported	21	-260	100.60/29.71	94	Not reported
T4.txt	234880/105696	Not reported	4	-300	99.80/29.47	90	Not reported
S1.txt	234880/105696	238700/107415	-4	780	99.60/29.41	95	34/35/35
S2.txt	241920/108864	242800/109260	-1	300	101.30/29.92	75	95/95/95
S3.txt	245120/110304	245800/110610	-1	288	100.70/29.75	100	33/32/35
S4.txt	235520/105984	235200/105840	-2	450	100.80/29.78	90	95/95/95
S5.txt	227840/102528	231000/103950	-4	330	101.20/29.90	92	95/95/95
S6.txt	237440/106848	239900/107955	-2	310	101.40/29.95	90	95/95/95
S7.txt	235520/105984	236100/106245	-4	810	99.50/29.40	95	28/29/29
S8.txt	255680/115056	255800/115110	-1	430	100.85/29.79	80	95/95/95
S9.txt	230080/103536	230500/103725	-3	420	100.90/29.81	75	95/95/95
S10.txt	230720/103824	232900/104805	0.5	595	100.40/29.64	88	95/32/27
S11.txt	238720/107424	240500/108225	-3	380	101.10/29.85	100	27/29/27
S12.txt	247680/111456	249600/112320	0	720	99.80/29.47	100	26/26/26
S13.txt	245760/110592	247400/111330	-5	720	99.90/29.49	100	34/26/39
S14.txt	239360/107712	240000/108000	2.5	270	101.50/29.97	80	39/36/34
S15.txt	248960/112032	253400/114030	-5	685	99.90/29.49	100	35/35/35
S16.txt	242560/109152	243300/109485	-4	225	101.60/30.02	86	95/31/29
S17.txt	238720/107424	242100/108945	0	750	99.75/29.46	100	24/24/24

6 GROUND VEHICLE, WEATHER CONDITIONS DATA AND PROCEDURES

6.1 Weather and Runway Conditions

Various additional data from the airport were collected and used in the data preparation, validation and simulation processes of the study. Akita Airport provided all the METAR and SNOWTAM sheet hardcopies for the selected landings to the test coordinator at ANA. ANA personnel then compiled these data and bound them into a file, indicating each of the landings on the hardcopies of the printed conditions and weather data sheets. The digitized version of the relevant SNOWTAM data is included as Appendix A. The corresponding METAR data sheets in digitized version are included in Appendix C. Data from these reports as well as the official weight and balance reports for each aircraft (see Appendix B) were used in the simulation program. The actual results were validated on a case-by-case basis, using the reports and comparing them with the simulation results to see whether any unexplainable deviation could be discovered from the expected performance based on the conditions report and the actual simulation results.

6.2 Ground Vehicle Data Collection Procedures

Unfortunately, the calibration of the SAAB ground friction measuring device to the IRFI standard through the correlation of the device to the IRV was not feasible. The actual collection of the weather, conditions and ground friction measurement data was carried out by Akita Airport ground personnel and the data were provided to the test coordinator at ANA.

The SAAB friction measuring device used throughout this study was:

- SFT –serial number: 0123 (purchased in 1999)

The device was maintained according to the manufacturer's prescription and calibrated every 10 days throughout the study. Prior to the study, the device had been calibrated every two weeks and a calibration log kept at the airport to identify any unusual behaviour. A copy of the calibration log and the outputs of the calibrations throughout the study could not be obtained.

7 BRAKING FRICTION CALCULATION PROCEDURES

All monitored parameters collected from the flight data management system were fed into a computer simulation program developed in 1998 for a separate research project. The dynamic simulation program calculates, through a three-dimensional dynamic model, all relevant physical processes involved in the aircraft landing manoeuvre. The output of the simulation program is the time or distance history of all relevant, separated, interdependent decelerations. These decelerations are cumulatively measured by the onboard measurement system and reported in the flight data stream. The separated decelerations calculated from the different physical processes make it possible to calculate the true deceleration developed only by the actual affective braking friction coefficient of the landing aircraft. The deceleration caused by the wheel braking system of the aircraft, together with other parameters and weather data, can be used in turn to calculate the true aircraft braking friction coefficient.

Using the recorded data stream of the aircraft with the parameters indicated in Table 3, plus weather and environmental factors reported by the airport, together with known performance and design parameters of the aircraft determined through the study or available from design documentation and in the literature, the dynamic simulation calculated all relevant actual retarding forces acting on the aircraft as a function of the true ground and air speeds, travel distance and time. Using the simulation results, the dynamic wheel loads of all main gear and the nose gear can be calculated.

Since the full deceleration of the aircraft is measured by the onboard inertial instrumentation, the deduction of the calculated retarding forces by means of known aircraft mass, together with the determined gravitational measurement biases introduced by runway geometry and aircraft physics, can be completed. From this computation the true deceleration and actual retarding forces effectively caused by the aircraft's braking system can be calculated. Using the obtained retarding force, together with the aircraft landing weight and the calculated dynamic lifting forces and moments, the actual effective generated braking friction force, and consequently the necessary braking torque, can be constructed. Using the calculated effective true frictional forces, together with parameters measured by the aircraft data management system (such as downstream hydraulic braking pressure), a logical algorithm based on the physics of the braking of pneumatic tires with antiskid braking systems also designed in the 1998 study was designed to determine whether the maximum available runway friction was reached during relevant speed ranges of the landing manoeuvre.

7.1 Aircraft Braking Friction Calculation

Based on the above, the simulation software calculates the brake effective acceleration vs. time based on Equation (1).

$$A_{Be}(V_g) = A_x(V_g) - A_{Drag}(V_g) - A_{Thrust}(V_g) - A_{Other}(V_g) \qquad (1)$$

where A_{Be} is the brake effective acceleration

A_x is the measured deceleration

A_{Drag} is the deceleration due to the drag, aerodynamic and contaminant

A_{Thrust} is the acceleration due to thrust/reverse-thrust

A_{Other} is the cumulative deceleration due to other effects such us rolling resistance, runway longitudinal elevation

V_g is the aircraft ground speed

This acceleration (A_{Be}) is only due to the friction between the surface and the aircraft tires.

7.1.1 Engine Thrust and Reverse Thrust Calculations

For the models of the dynamic simulation, a modified version of the EUROCONTROL Experimental Centre's Base of Aircraft Data (BADA) Revision 3.3 suggested jet engine calculation methods were adapted.[1] It is beyond the scope of this report to provide a complete deduction of the equations or explain in detail the physics behind the mathematical formulas; therefore, only a short interpretation is given.

The basis of all engine thrust calculations is a base formula describing the maximum climb thrust of a particular jet engine.

$$T_{\max,climb} = C_{Tc1} \cdot \left(1 - \frac{h}{C_{Tc2}} + C_{Tc3} \cdot h^2\right) \cdot \left(1 - C_{Tc5} \cdot (\Delta T_{ISA})_{eff}\right) \quad (2)$$

where

$$(\Delta T_{ISA})_{eff} = \Delta T_{ISA} - C_{Tc4} \quad (3)$$

If h < 3000 ft and $V<V_{min,Approach}$+10 kn

$$T_{des,ld} = C_{Tdes,ld} \cdot T_{max,climb} \quad (4)$$

In Equations (2) and (3), the $\boldsymbol{C_{Tci}}$ constants (i=1,2,3,4,5) are engine-dependent number constants. In the calculation of the landing thrust (Equation 4) the $\boldsymbol{C_{Tdes,ld}}$ is also a constant. The actual retarding force from the engine thrust-reversers is calculated based on Equation (5).

$$T_{rev,ld} = P\left(N, F_f, R, T_{des,ld}\right) \quad (5)$$

The nonlinear function of $\boldsymbol{P(N,F_f,R,T_{des,ld})}$ is an operator dependent on engine rpm, fuel flow, thrust reverser setting and calculated engine landing thrust. The different parameters involved in Equation (5) were calculated and validated using the tare runs.

The deceleration from the engine thrust reversers then can be calculated from the basic equation:

$$A_{Thrust} = \frac{T_{rev,ld}}{m_{aircraft}} \quad (6)$$

7.1.2 Calculation of Deceleration Due to Rolling Resistance

The calculation of resistive forces due to the tire rolling resistance is important mostly at higher aircraft ground speed. With lower ground speed, the resistive rolling resistance force diminishes. The well-known tire rolling resistance calculation is used in the

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[1] *USER MANUAL FOR THE BASE OF AIRCRAFT DATA (BADA) REVISION 3.3* EUROCONTROL Experimental Centre, Publications Office, .P. 15, 91222 - Bretigny-sur-Orge CEDEX, France

modified form for aircraft accommodating the increasing load on the rolling tires as the aircraft air speed is increased non-linearly with reduced aircraft speed.

$$f_r = f_1 + \frac{1}{f_2 \cdot \left(1 - \frac{L}{g \cdot m_{aircraft}}\right)} \cdot V_g^2 \tag{7}$$

where $\boldsymbol{f_1}$ and $\boldsymbol{f_2}$ are tire dependent constants and $\boldsymbol{L}$ is the calculated lift force.

$$L = \frac{1}{2}\rho_{corrected} \cdot \mathrm{V}_{\mathrm{TAS}}^2 \cdot S \cdot C_L \tag{8}$$

where $\rho_{corrected}$ is the corrected air density

S is the wing reference area

V_{TAS} is the true airspeed

The deceleration due to the rolling resistance then can be calculated using Equation (9).

$$A_{fr} = f_r \cdot g \tag{9}$$

7.1.3 Calculation of the Coefficient of Lift and Profile Drag

From the QAR data of the tare runs after the different retarding forces and their induced decelerations have been calculated, the drag force can be obtained from the remaining deceleration.

The drag coefficient can be calculated from the processed deceleration of the tare runs. The calculated deceleration, after removing all relevant decelerations from the data of the tare runs (such as the rolling resistance), runway slope was used to calculate the remaining drag force.

$$D = A_{corrected} \cdot m_{aircraft} \tag{10}$$

The calculated drag force then can be used to determine the aerodynamic drag coefficient.

$$C_D = \frac{2 \cdot D}{\rho_{corrected} \cdot V_{TAS}^2 \cdot S} \tag{11}$$

The lift coefficient of the landed aircraft then can be calculated using Equation (12).

$$C_L = \sqrt{\frac{C_D - C_{D0,LDG} - C_{D0,\Delta LDG}}{C_{D2,APP}}} \tag{12}$$

7.1.4 Ground Dynamics Calculation

The determined parameters, and the equations using these, are part of the dynamic simulation model, together with actual load transfer and vertical aircraft movement models. The data measured on the aircraft landings were fed into the simulation program that calculated the retarding forces and determined the actual braking friction force, taking into account:

- the load transfer from the main landing gear to the nose gear due to braking,
- the dynamic vertical movement of the aircraft, and thus the varying load on the main and nose gear,
- the moments acting on the body due to changes in lift, thrust and reverse-thrust.

The final output is the actual calculated deceleration caused by the effective braking of the aircraft. From the brake effective deceleration, the software calculates the friction force based on the formula:

$$F_{Fr} = m_{aircraft} \cdot a = m_{aircraft} \cdot A_{Be} \tag{13}$$

where $m_{aircraft}$ is the landing mass of the aircraft and

A_{Be} is the calculated brake effective deceleration

From the friction force on the braked tires, the software calculates the μ friction coefficient based on

$$\mu = F_{Fr_i} / W' \tag{14}$$

where W' is the calculated vertical force acting on the tire, taking into account dynamic effects such as lift, load transfer and vertical movement.

8 DATA AND ANALYSIS

The following graphs were used for further analysis produced by the simulation software for each landing:

1. Measured acceleration and brake effective acceleration vs. time.
2. Measured ground speed and integrated ground speed and ground/air speed vs. time
3. Main wheel load and brake pressure and wheel friction vs. time
4. Pressure vs. Mu correlation

8.1 Identifying the Friction Limited Landings

For each of the selected landing data sets, the data for the graphs, together with additional time and distance traces, were produced. Some of the produced data were generated by the simulation to cross check the validity of the model and of the aircraft input data traces. These additional data and figures are not discussed in this paper. Based on these graphs, however, the friction limited runs were identified. The identification process was programmed into the simulation method by means of mathematical analysis. The different mathematical techniques employed were programmed using the following logical method:

1. For each landing, the time window was defined where the landing speed was between 60 m/s and 20 m/s. In order to make sure that the auto-brake and antiskid systems of the aircraft were working in their operational range, the algorithm analyzed the data to look for the friction limited sections only in this time window.
2. The data within the determined time window was then analyzed for the deviation of the applied downstream hydraulic brake pressure and the obtained effective braking friction. A sharp deviation from the achieved true effective braking friction calculated by the simulation based on the dynamic model from the hydraulic pressure is the indication of friction limited braking. When sharply increased hydraulic pressure is applied by the braking system, while no significant friction increase is generated, the potential of true friction limited braking occurs.
3. The identified friction limited sections were verified using the effective braking friction and pressure data. If the segmented pressure-friction graph has vertical or declining sections that match the identified friction limited sections, then the braking was friction limited.

The procedure described above is graphically illustrated in Figure 1 through Figure 68 .

S1.txt

Flight No:F875 Landing Date/TimeJAN29_03/12:45

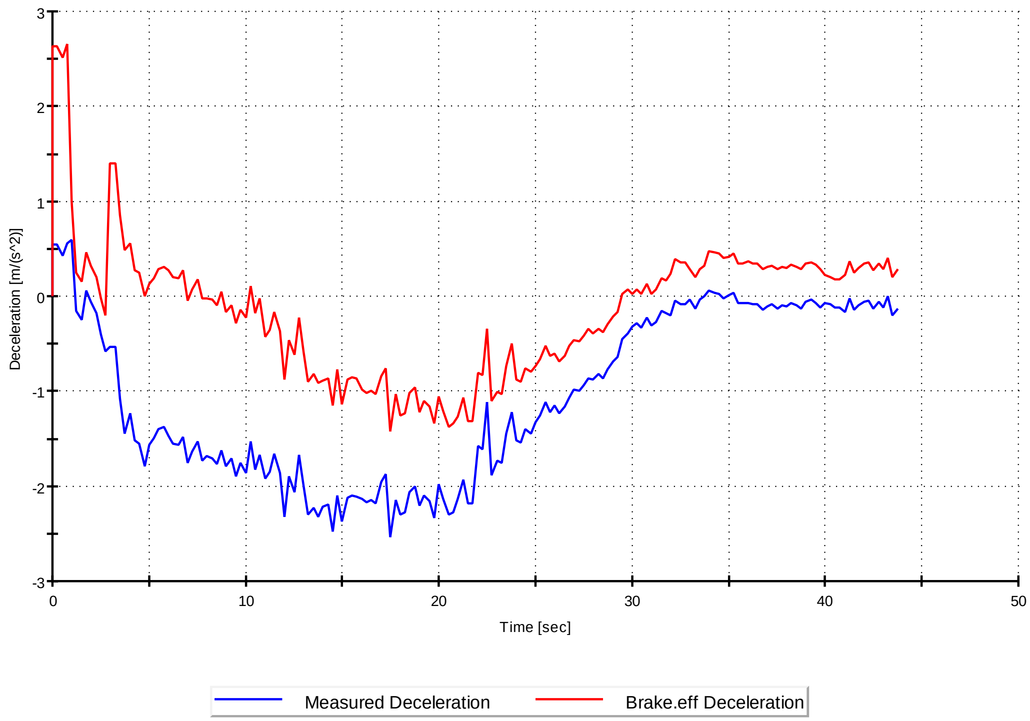

Figure 1 S1.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

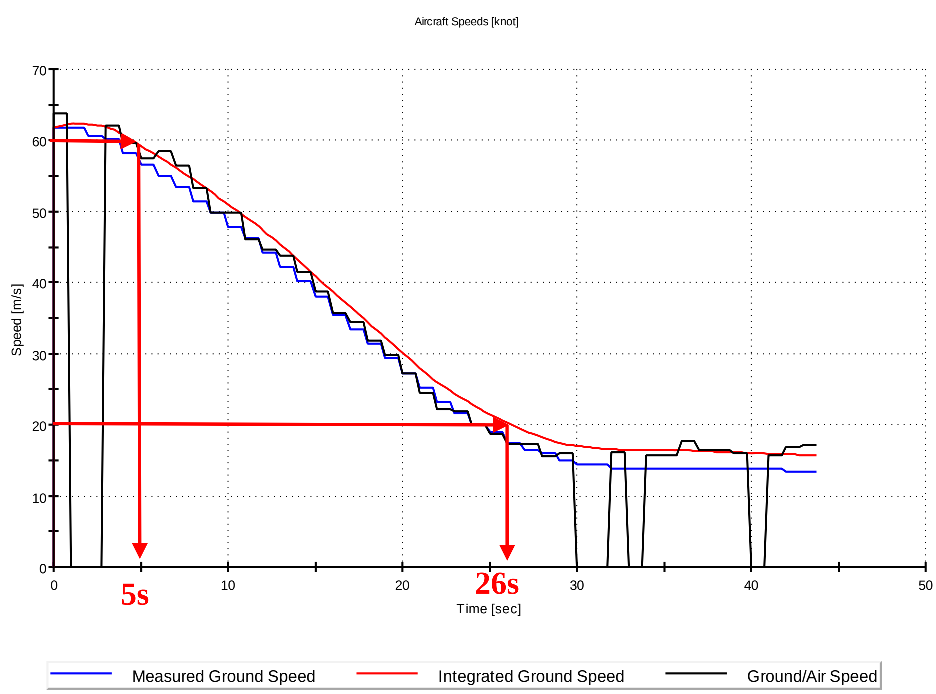

Figure 2 S1.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S1.txt

Flight No:F875 Landing Date/TimeJAN29_03/12:45

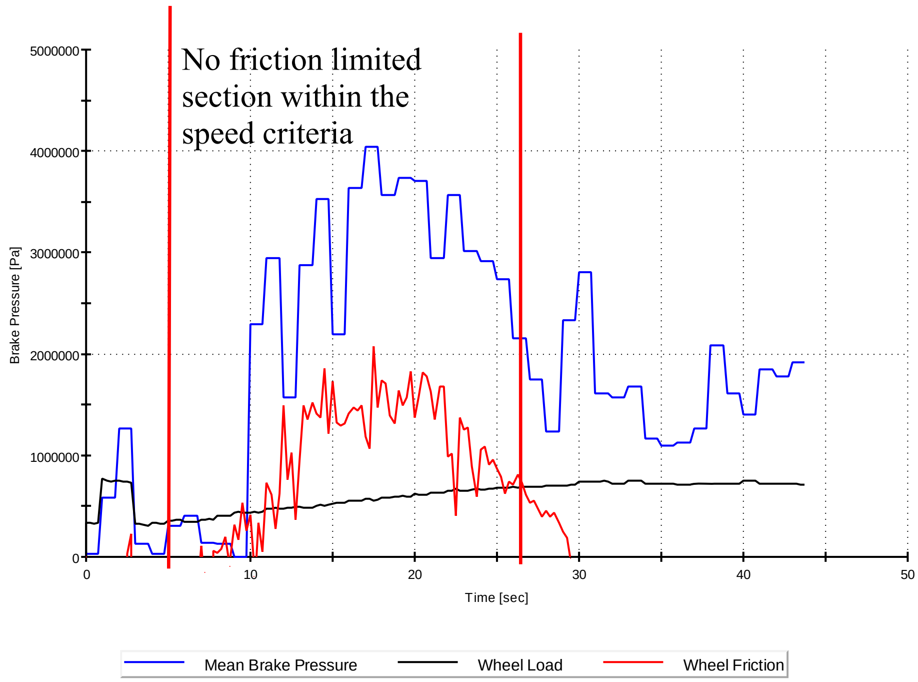

Figure 3 S1.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

S1.txt

Flight No:F875 Landing Date/TimeJAN29_03/12:45

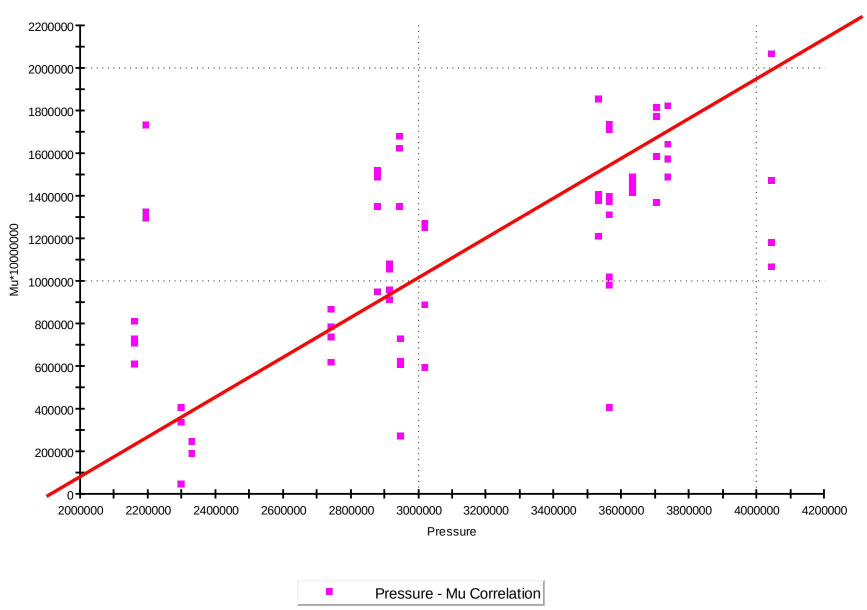

Figure 4 S1.txt Pressure vs. Mu Correlation

THIS LANDING DOES NOT HAVE A FRICTION LIMITED BRAKING.

S2.txt

Flight No:F875 Landing Date/TimeJAN22_03/12:23

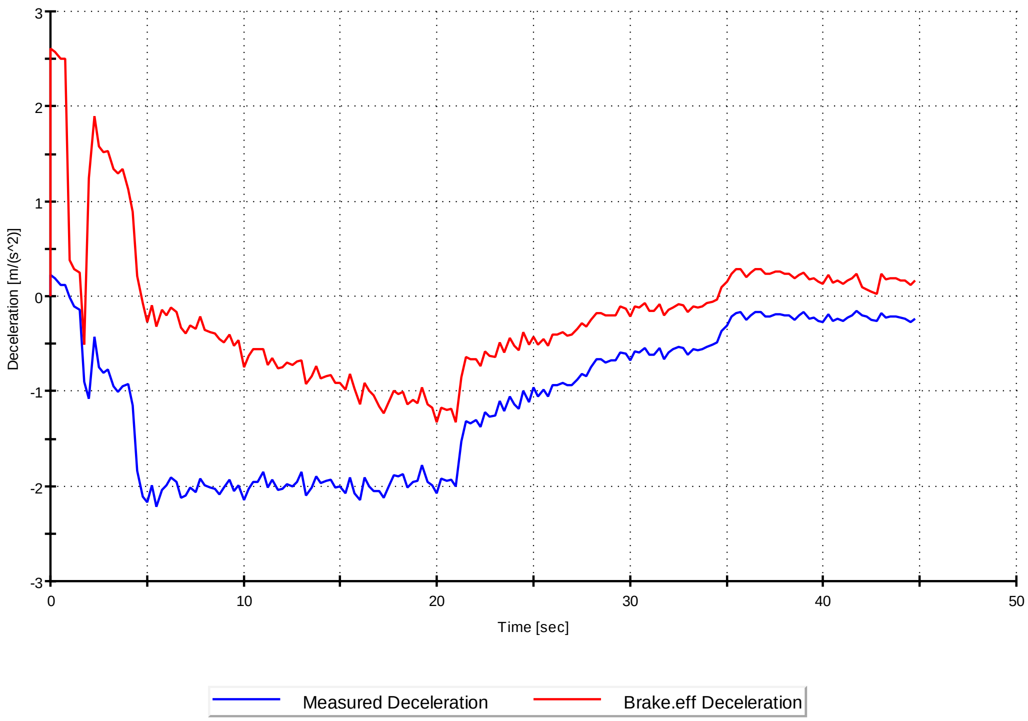

Figure 5 S2.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

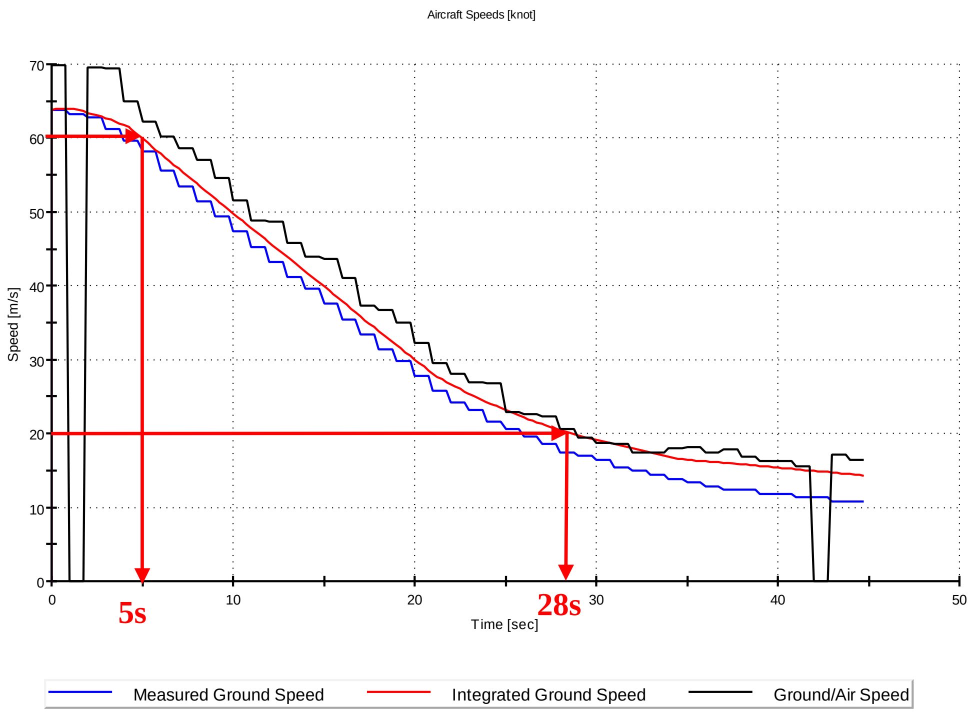

Figure 6 S2.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S2.txt

Flight No:F875 Landing Date/TimeJAN22_03/12:23

Figure 7 S2.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

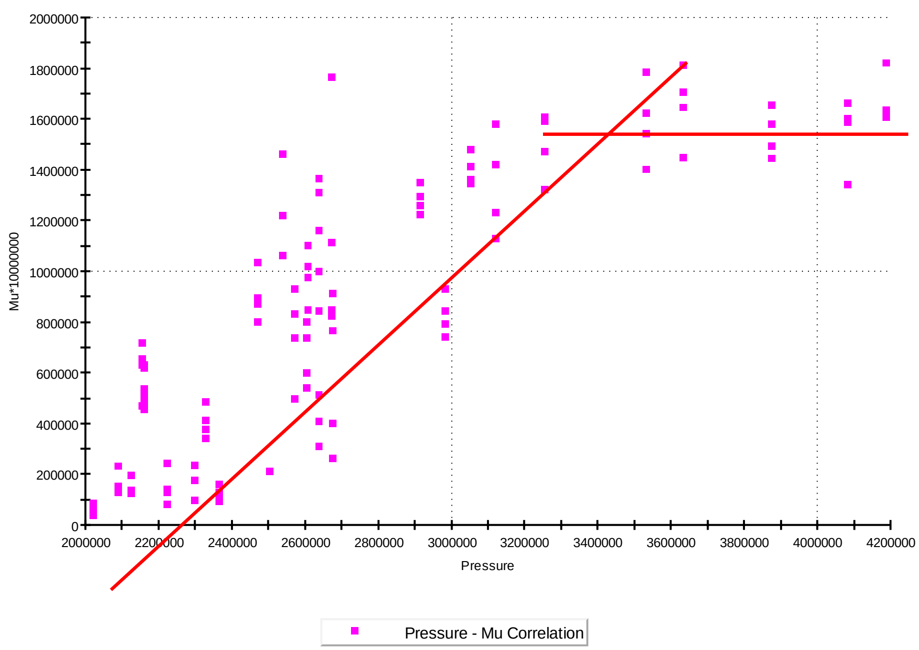

Figure 8 S2.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S3.txt

Flight No:F877 Landing Date/TimeJAN24_03/18:46

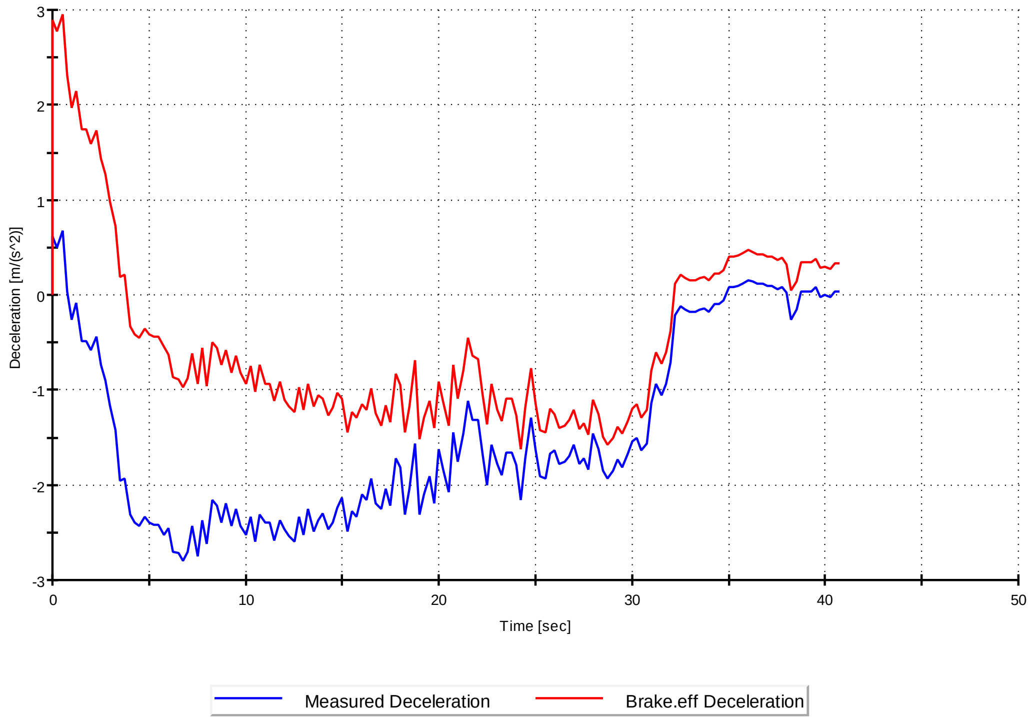

Figure 9 S3.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

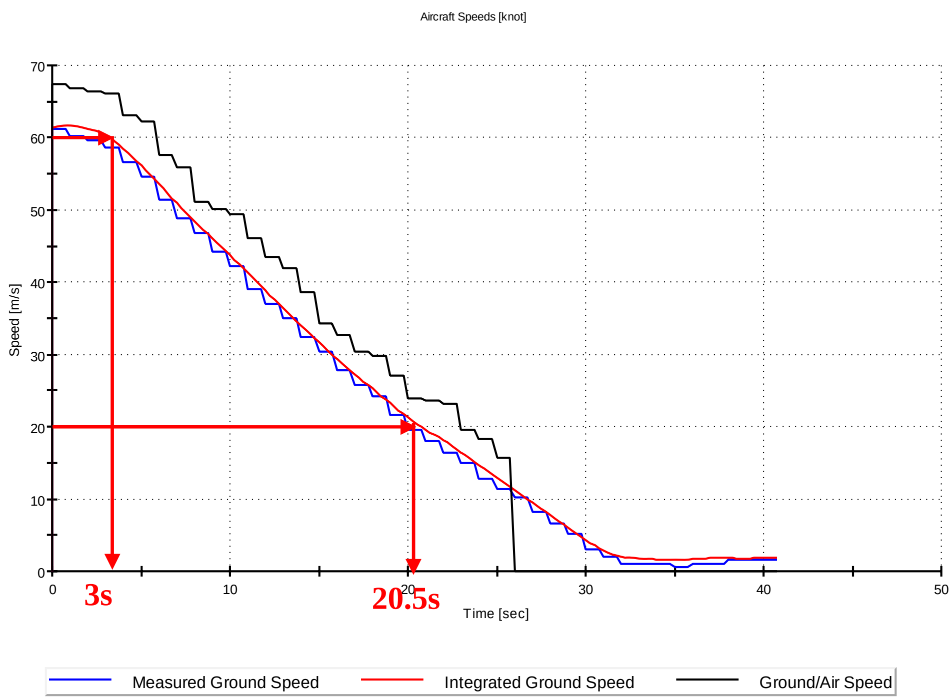

Figure 10 S3.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S3.txt

Flight No:F877 Landing Date/TimeJAN24_03/18:46

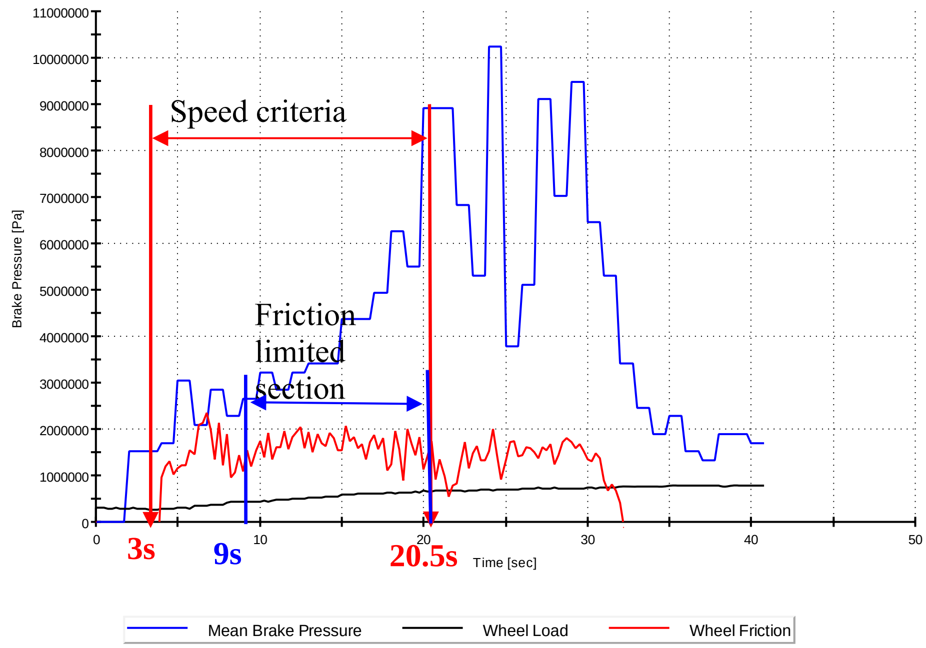

Figure 11 S3.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

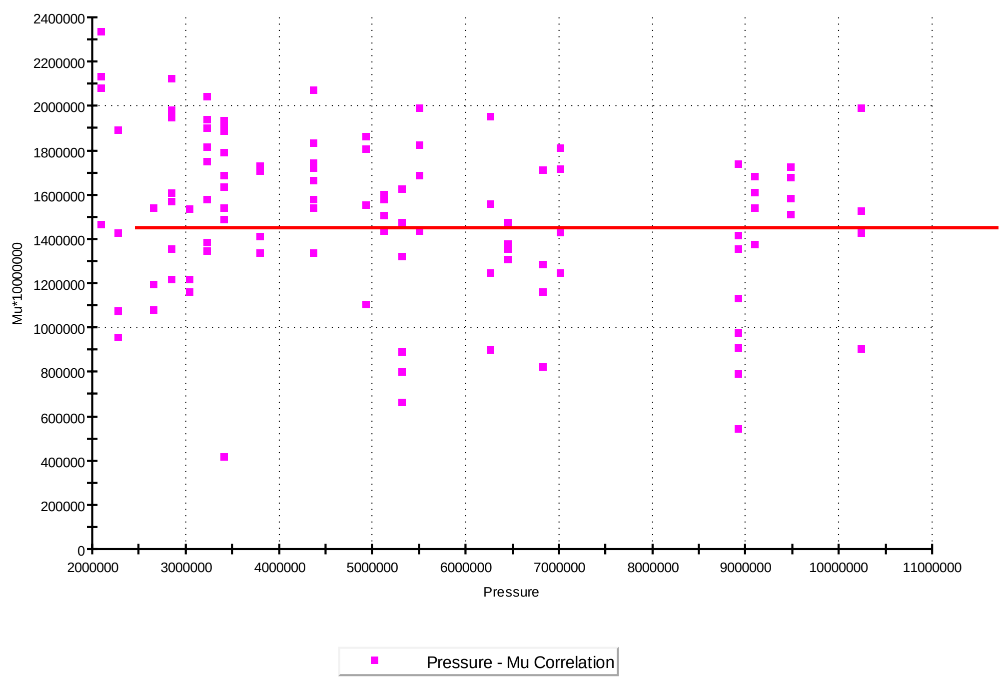

Figure 12 S3.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S4.txt

Flight No:F879 Landing Date/TimeJAN20_03/20:53

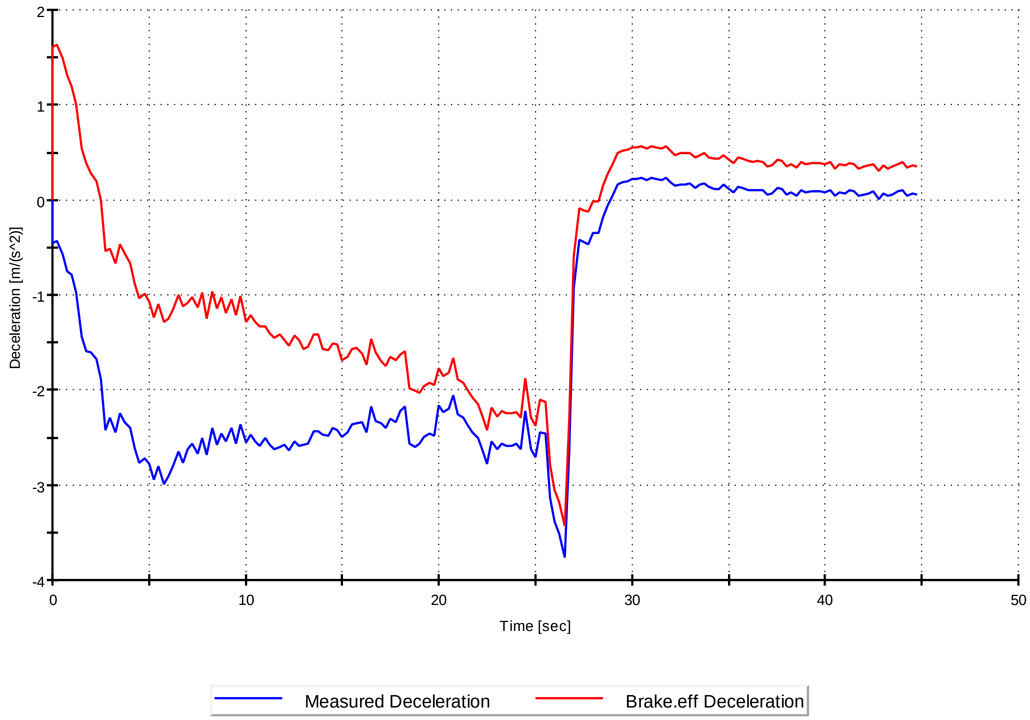

Figure 13 S4.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

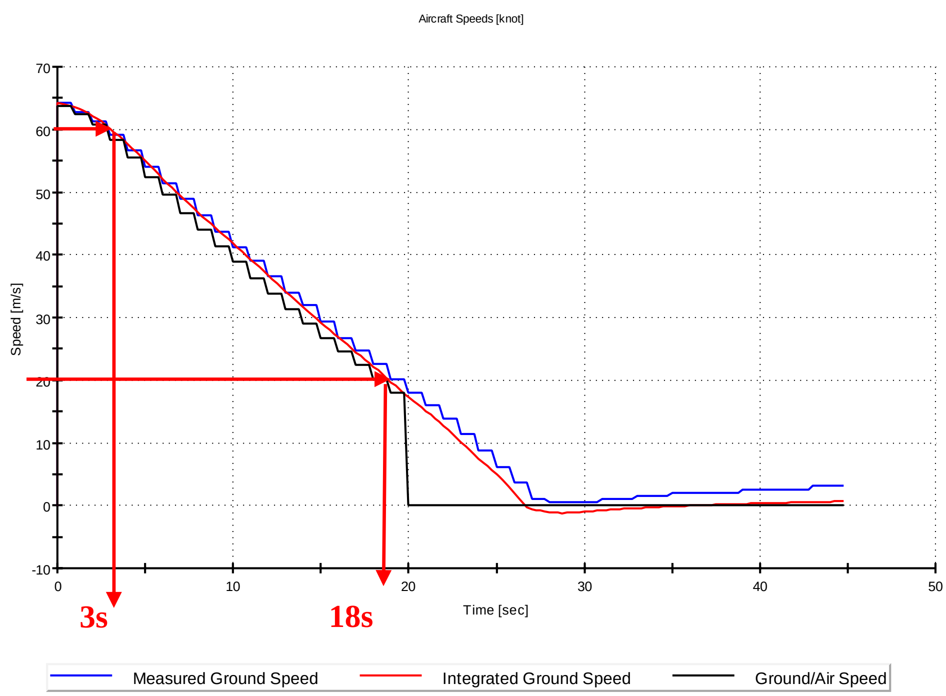

Figure 14 S4.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S4.txt

Flight No:F879 Landing Date/TimeJAN20_03/20:53

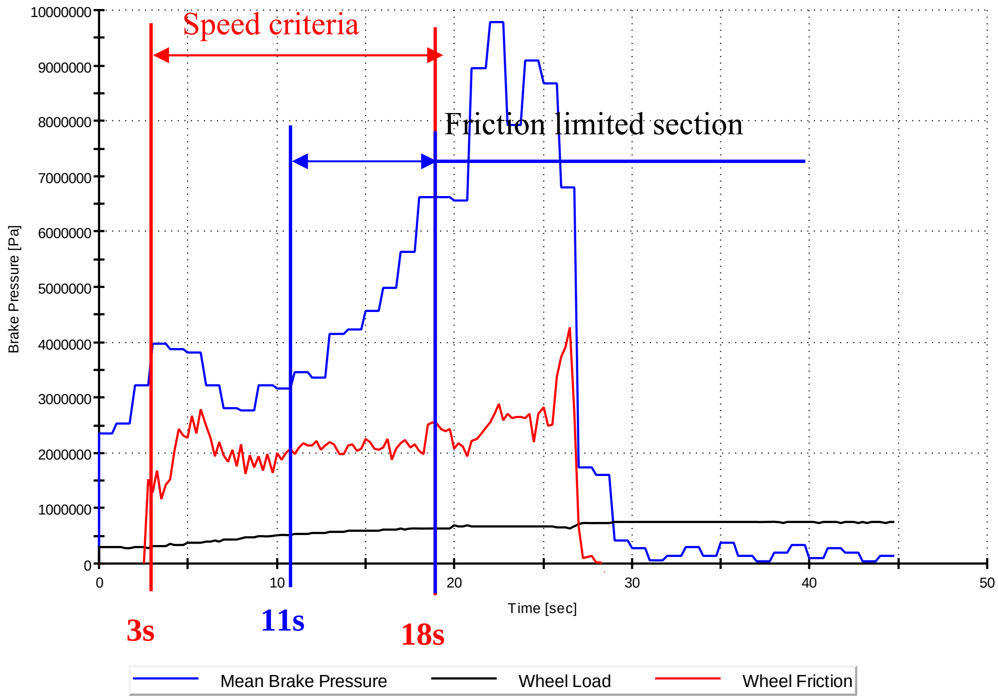

Figure 15 S4.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

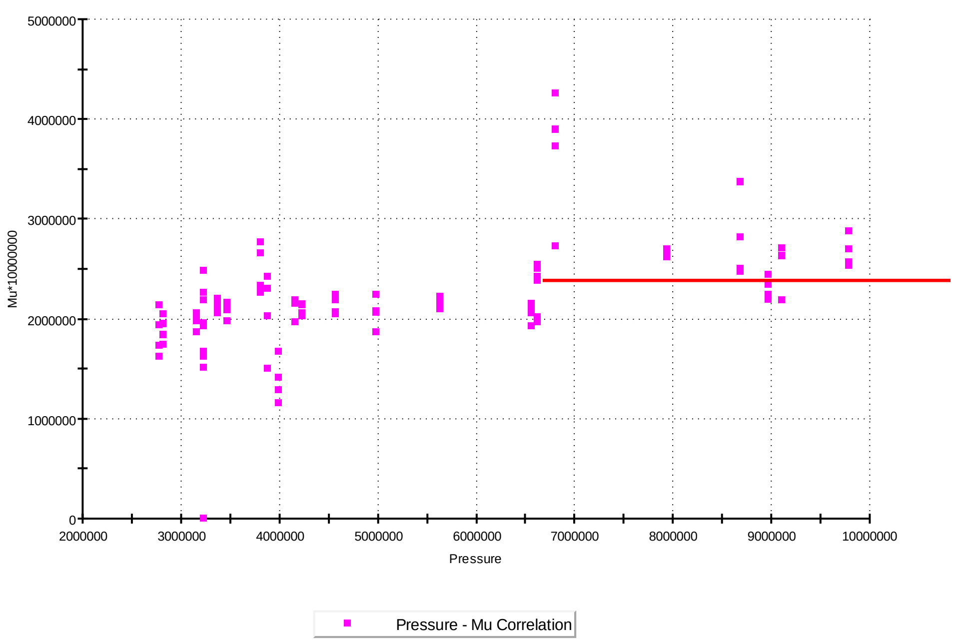

Figure 16 S4.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S5.txt

Flight No:F877 Landing Date/TimeJAN21_03/19:05

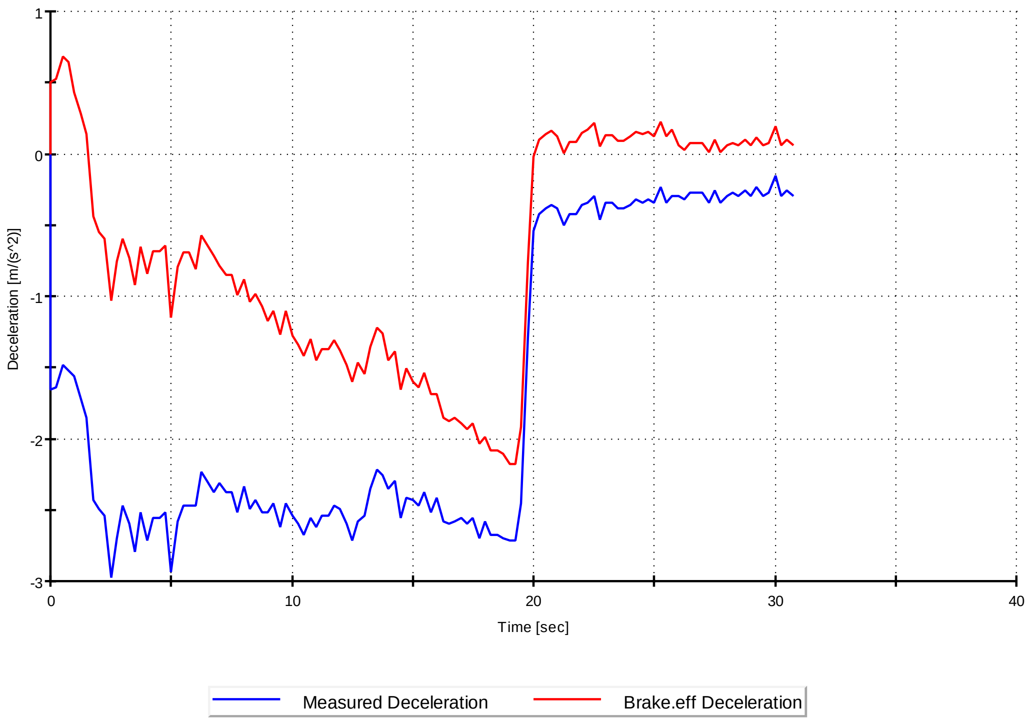

Figure 17 S5.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

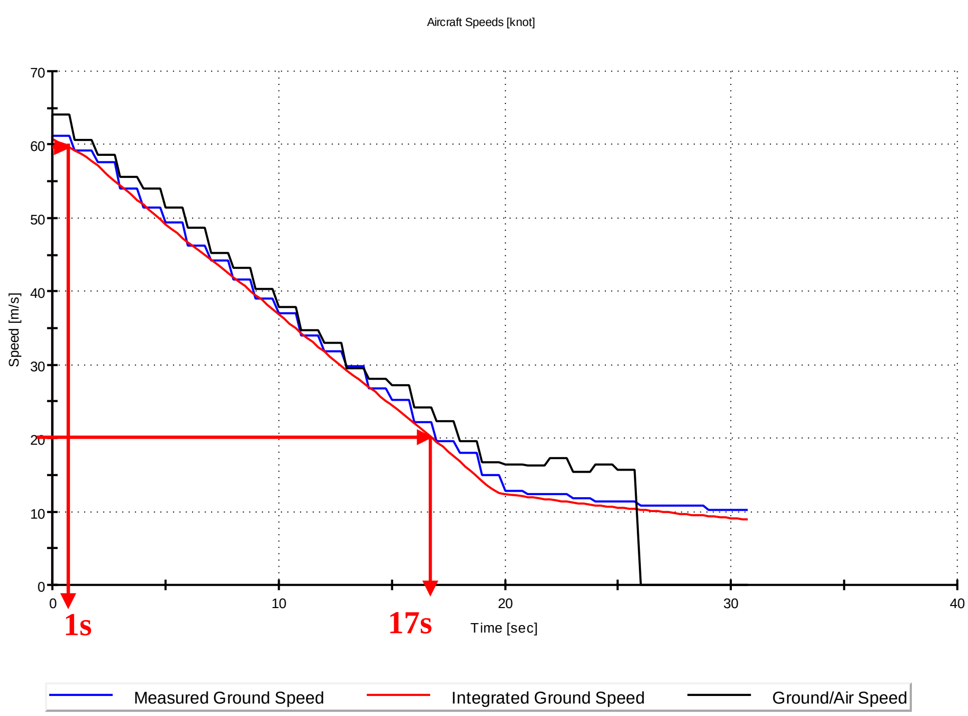

Figure 18 S5.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S5.txt

Flight No:F877 Landing Date/TimeJAN21_03/19:05

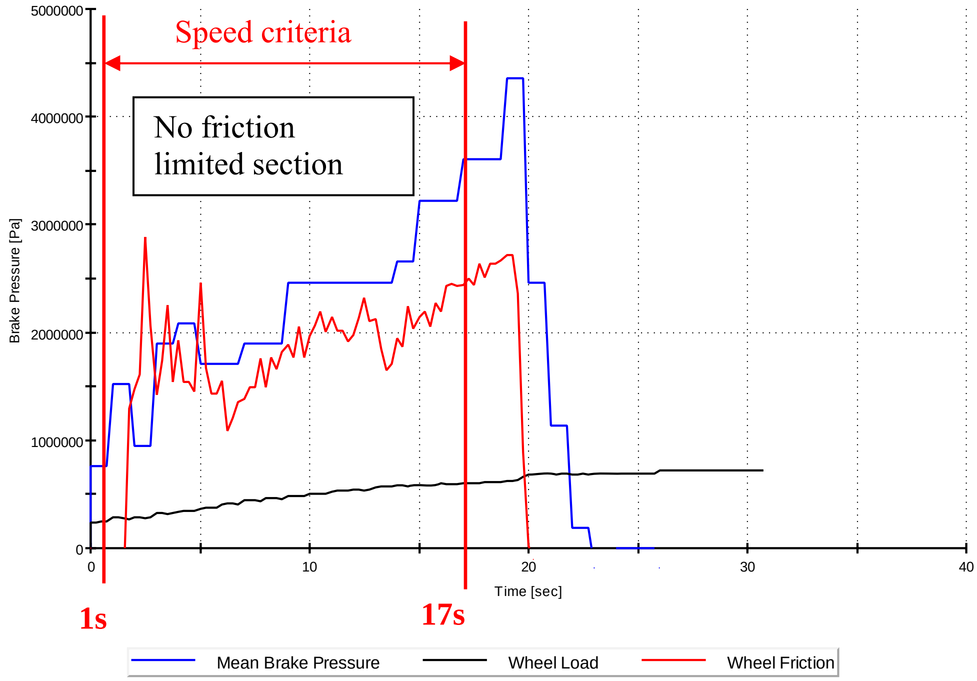

Figure 19 S5.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

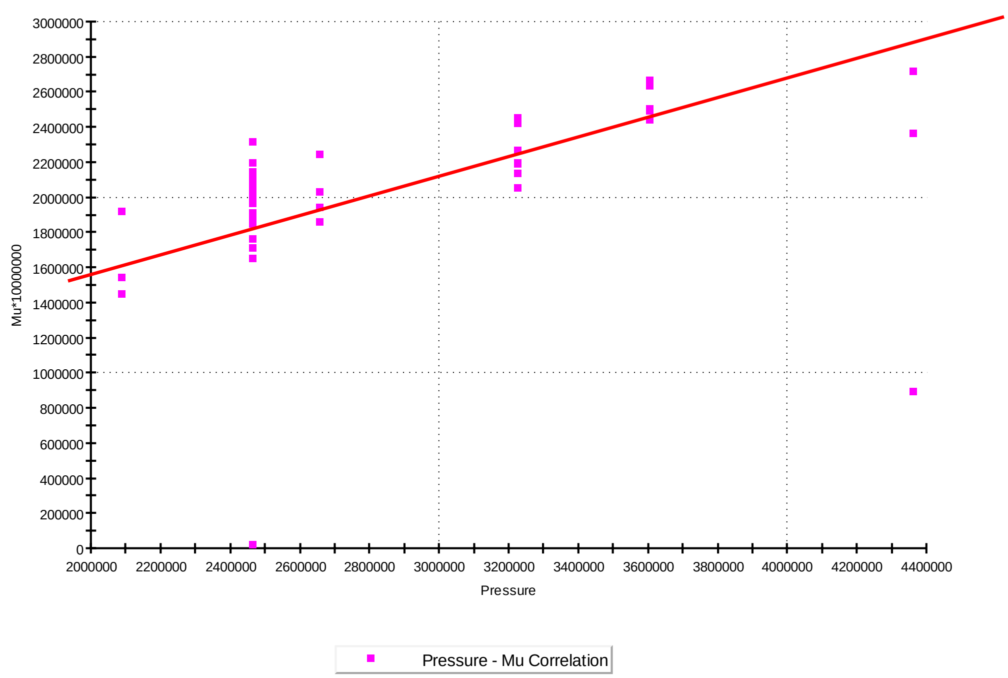

Figure 20 S5.txt Pressure vs. Mu Correlation

THIS LANDING DOES NOT HAVE A FRICTION LIMITED BRAKING.

S6.txt

Flight No:F873 Landing Date/TimeJAN22_03/10:55

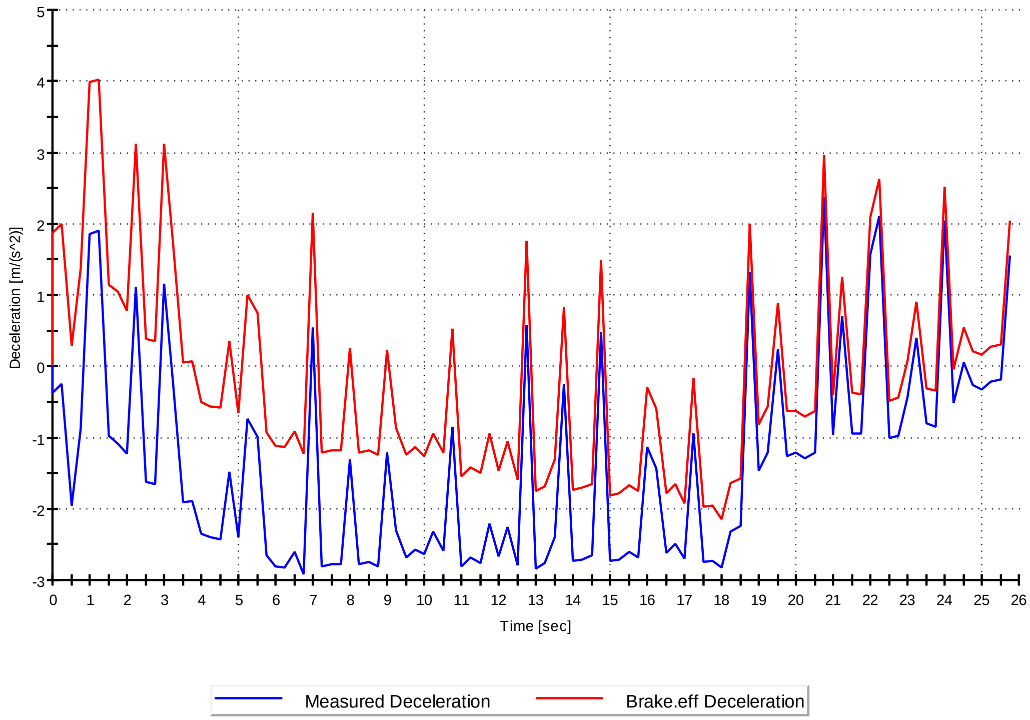

Figure 21 S6.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

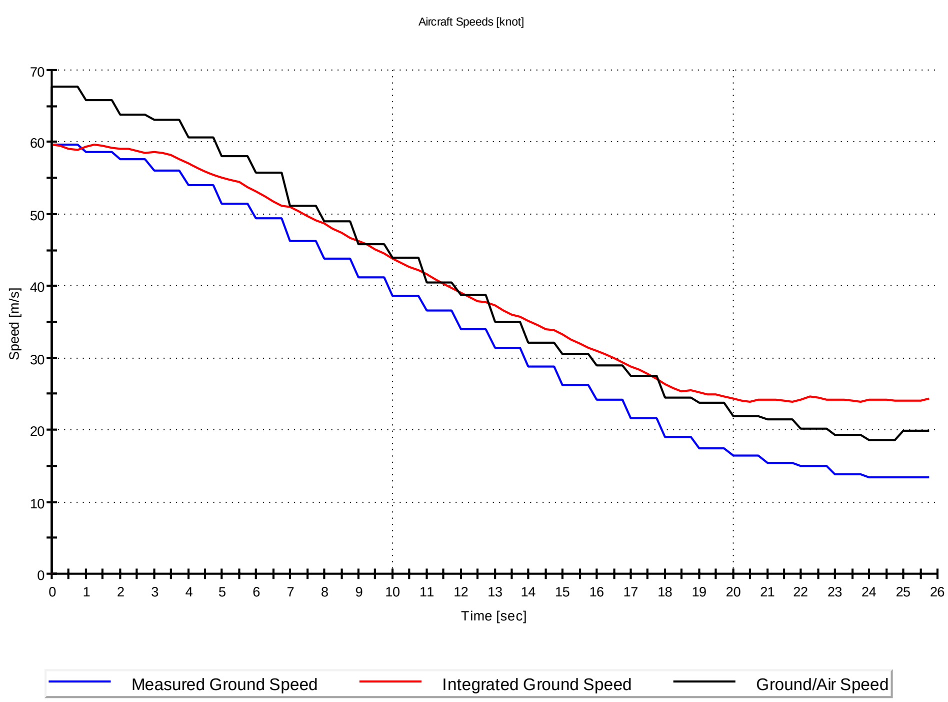

Figure 22 S6.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S6.txt

Flight No:F873 Landing Date/TimeJAN22_03/10:55

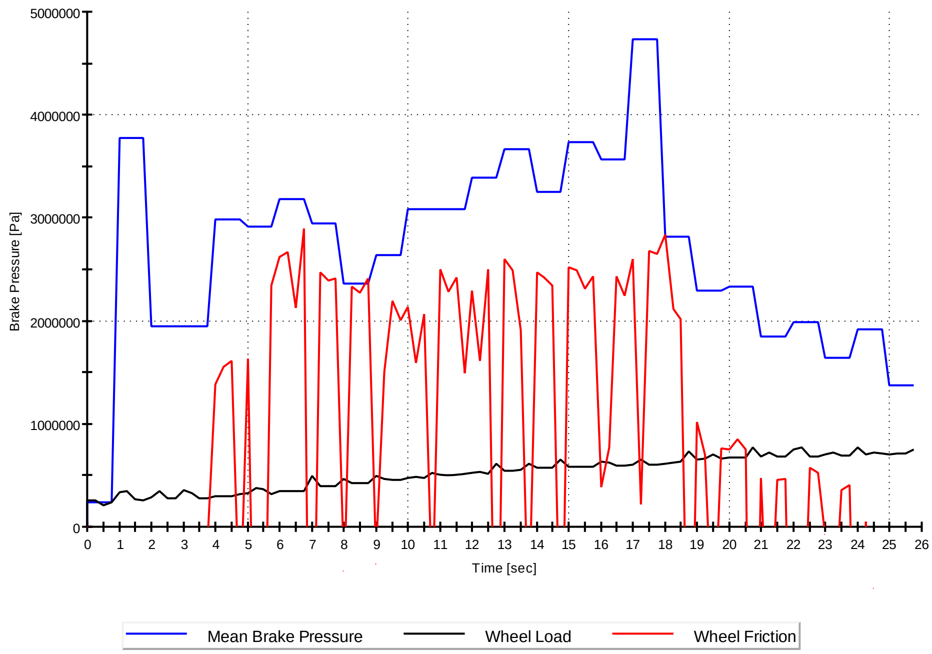

Figure 23 S6.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

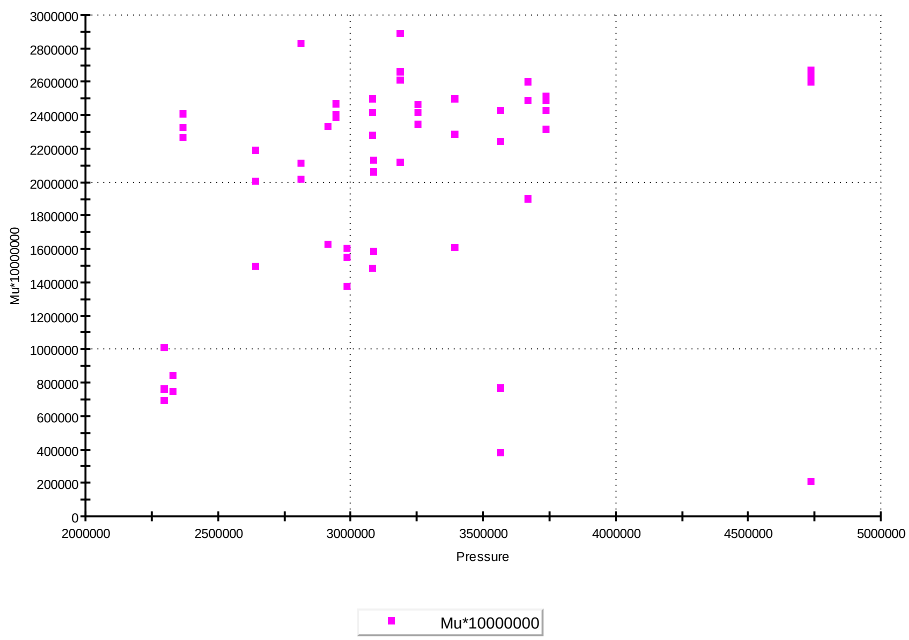

Figure 24 S6.txt Pressure vs. Mu Correlation

THE DATA SET SHOWN IN FIGURES 21 TRHOUGH 24 NEEDS FURTHER INVESTIGATION. IT IS NOT USED IN THE FURTHER ANALYSIS.

S7.txt

Flight No:F873 Landing Date/TimeJAN29_03/10:27

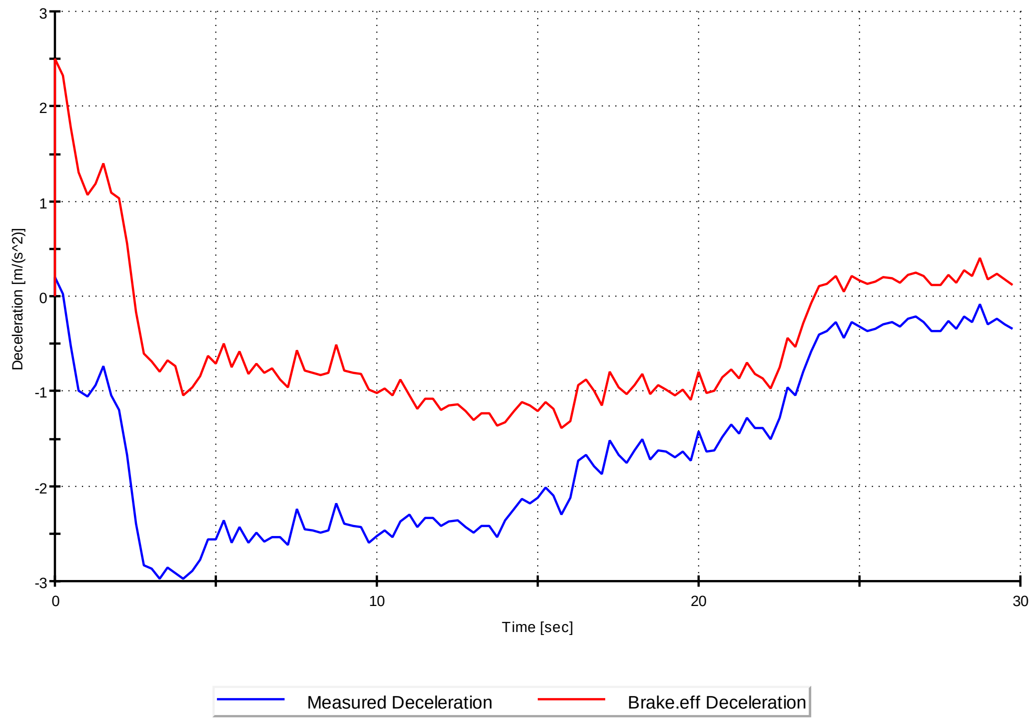

Figure 25 S7.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

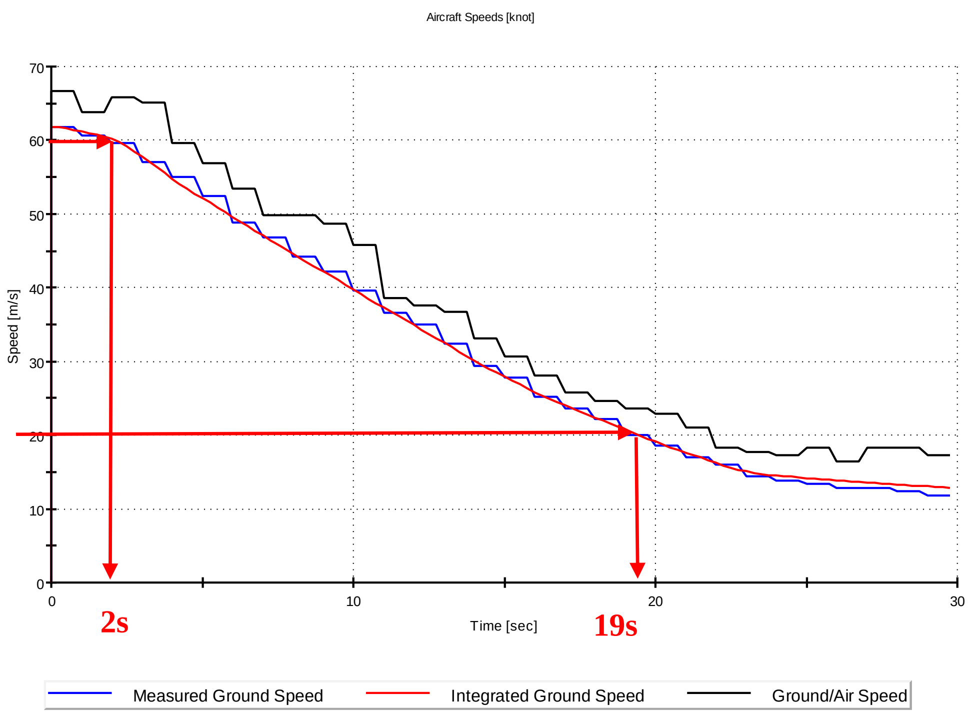

Figure 26 S7.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S7.txt

Flight No:F873 Landing Date/TimeJAN29_03/10:27

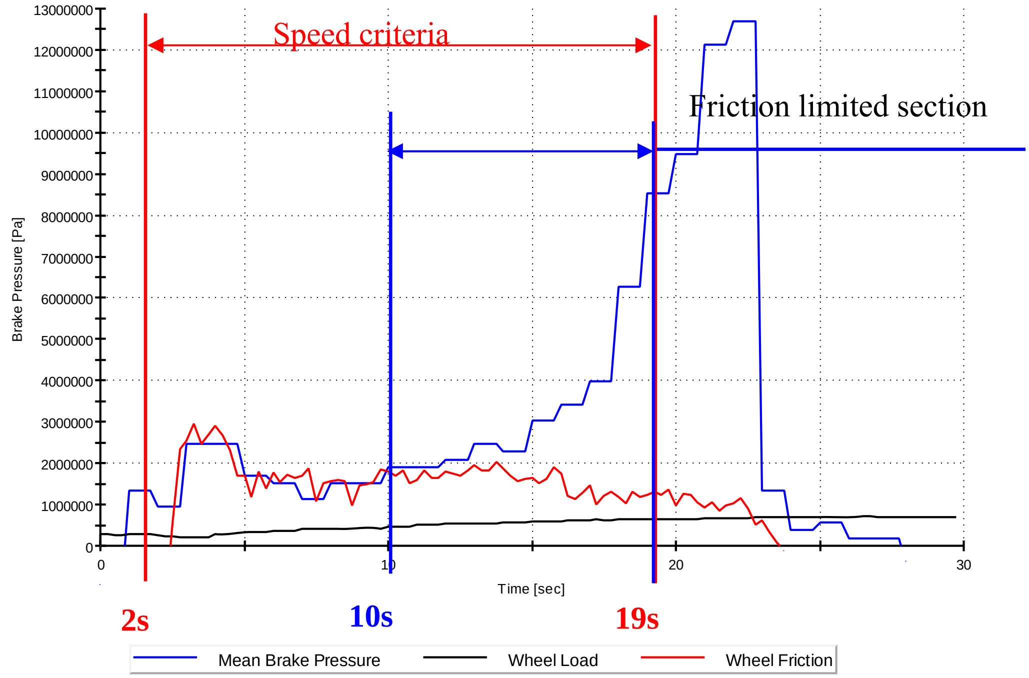

Figure 27 S7.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

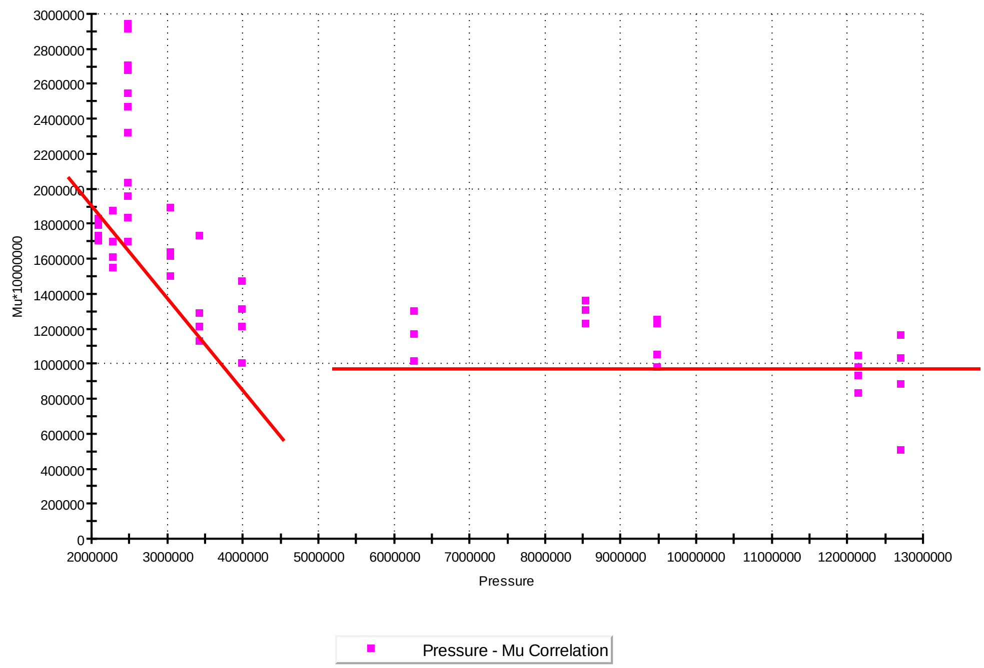

Figure 28 S7.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S8.txt

Flight No:F879 Landing Date/TimeJAN24_03/21:11

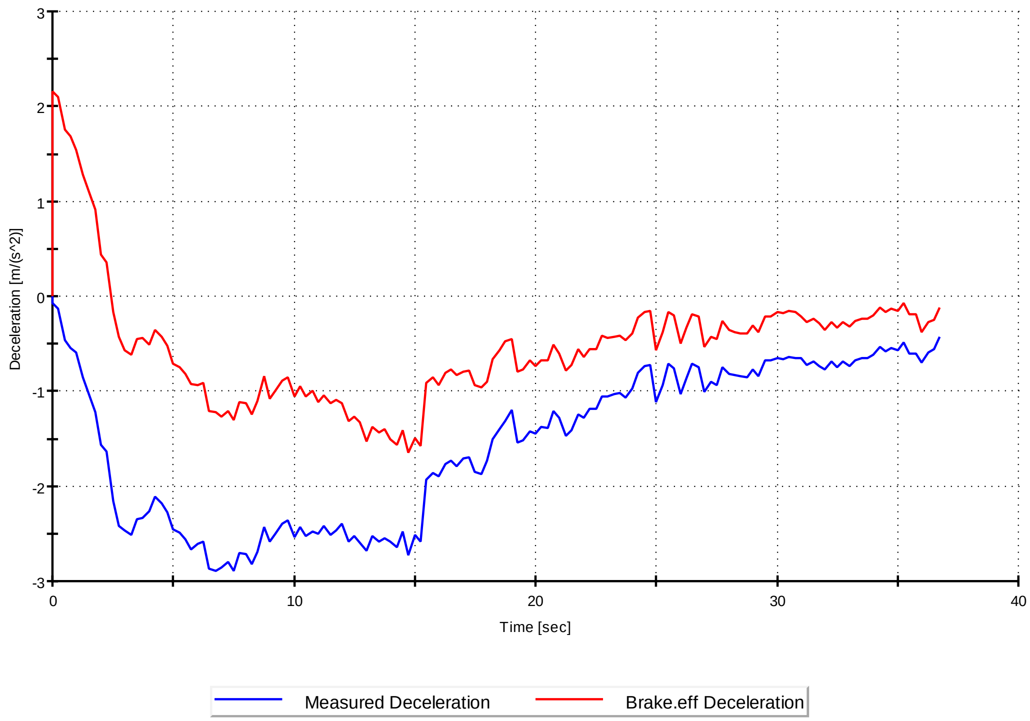

Figure 29 S8.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

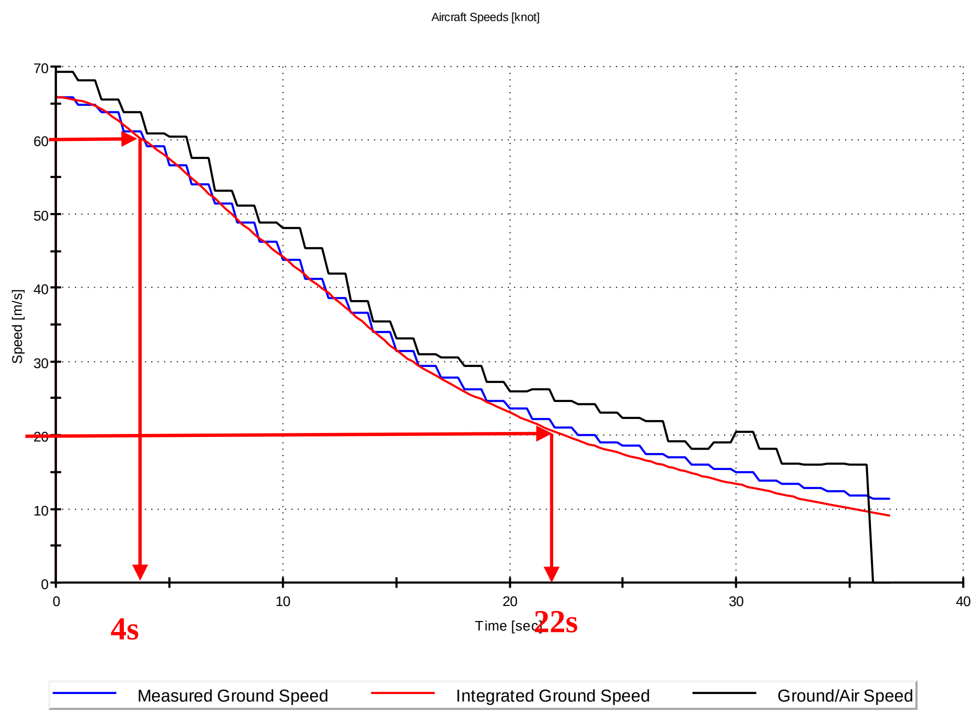

Figure 30 S8.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S8.txt

Flight No:F879 Landing Date/TimeJAN24_03/21:11

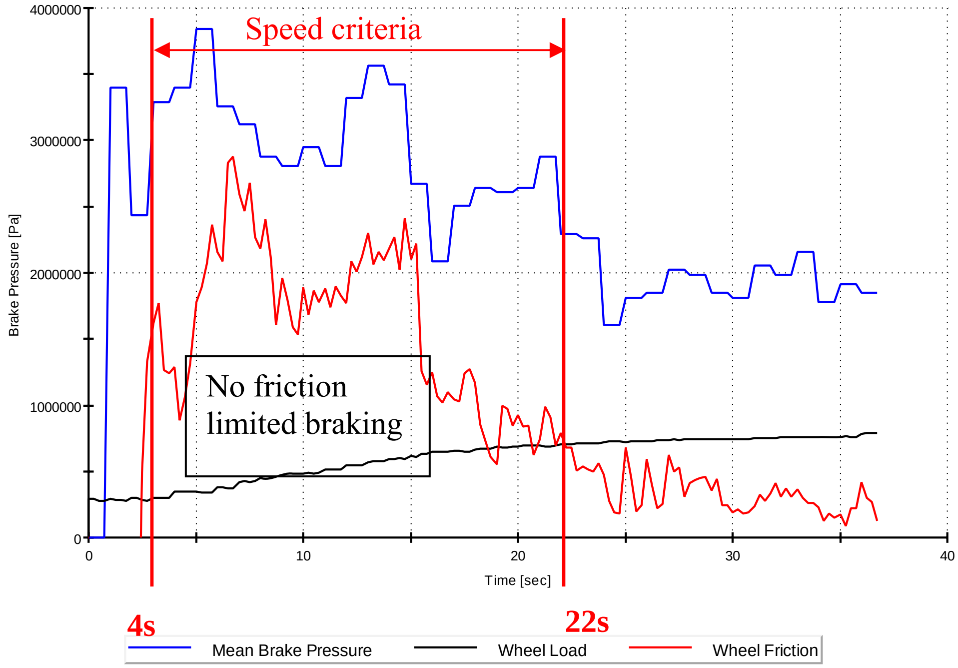

Figure 31 S8.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

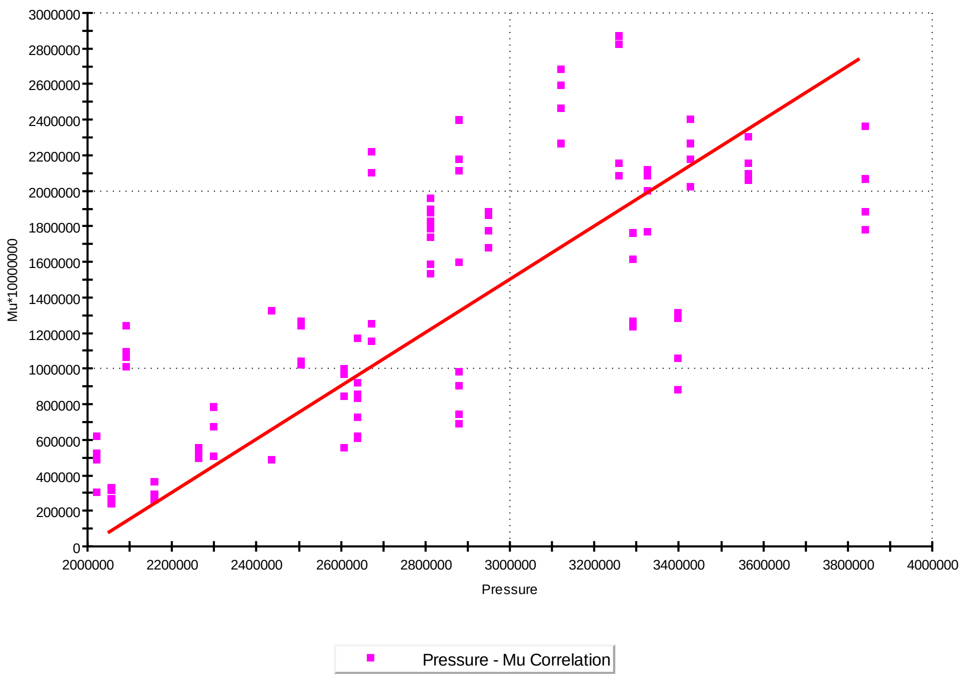

Figure 32 S8.txt Pressure vs. Mu Correlation

THIS LANDING DOES NOT HAVE A FRICTION LIMITED BRAKING.

S9.txt

Flight No:F873 Landing Date/TimeJAN20_03/13:24

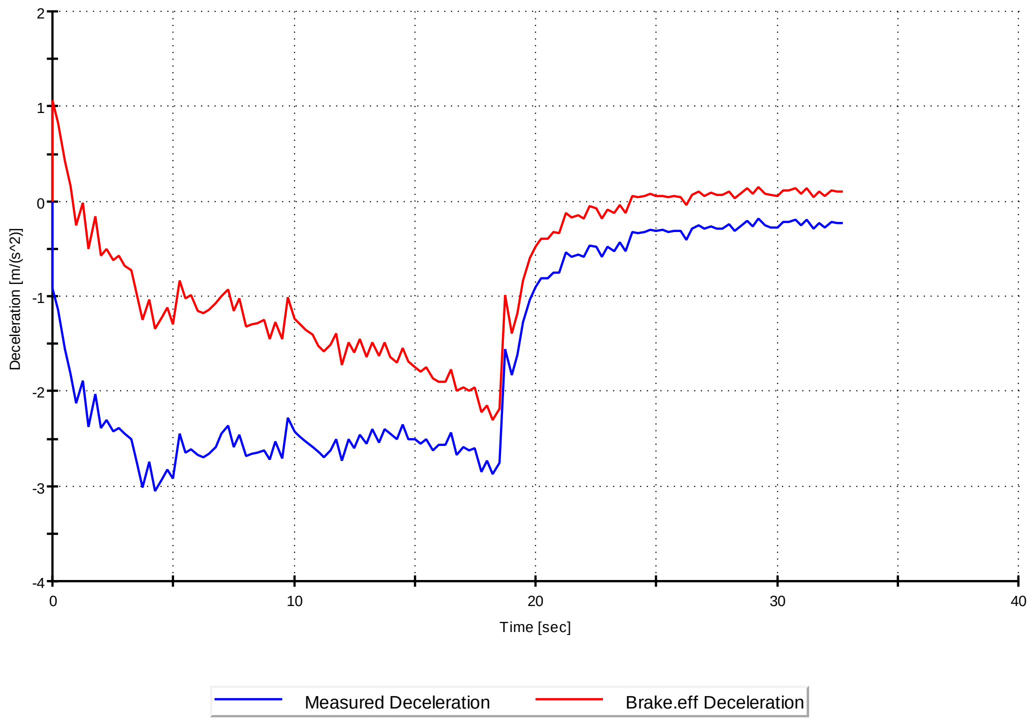

Figure 33 S9.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

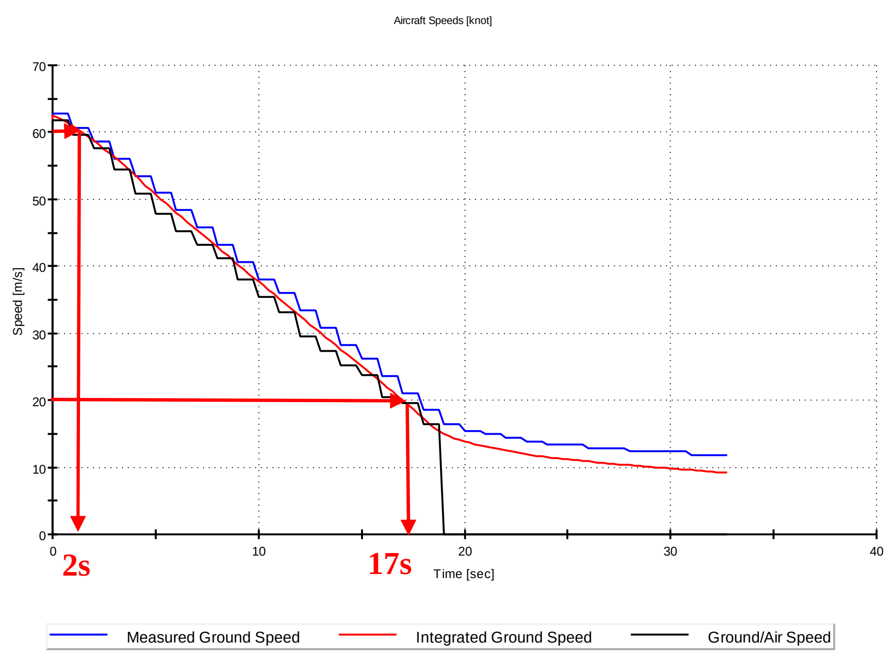

Figure 34 S9.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S9.txt

Flight No:F873 Landing Date/TimeJAN20_03/13:24

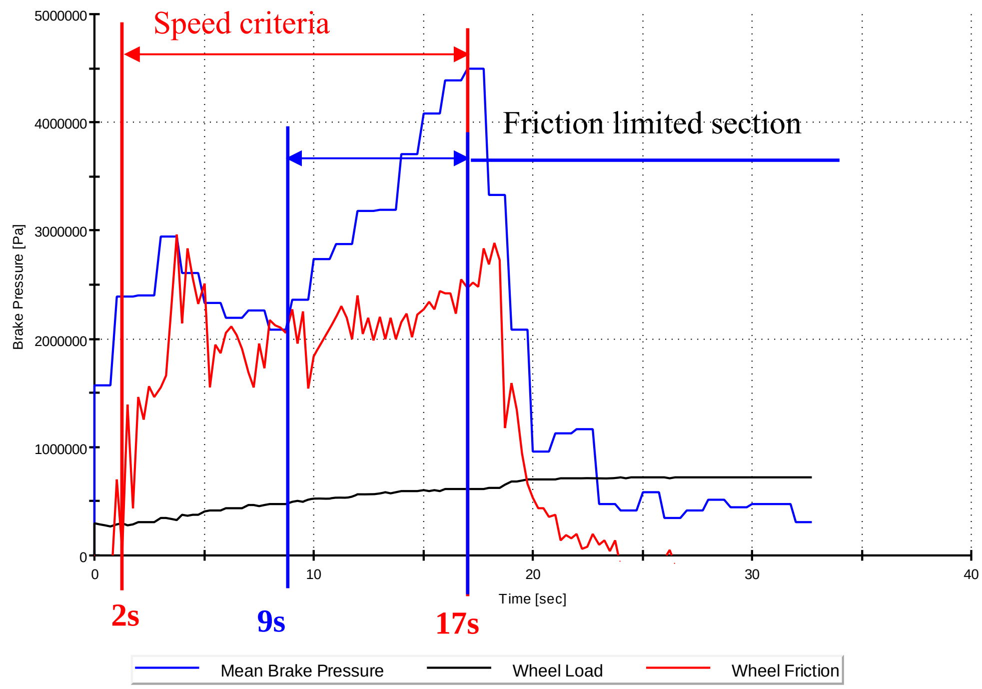

Figure 35 S9.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

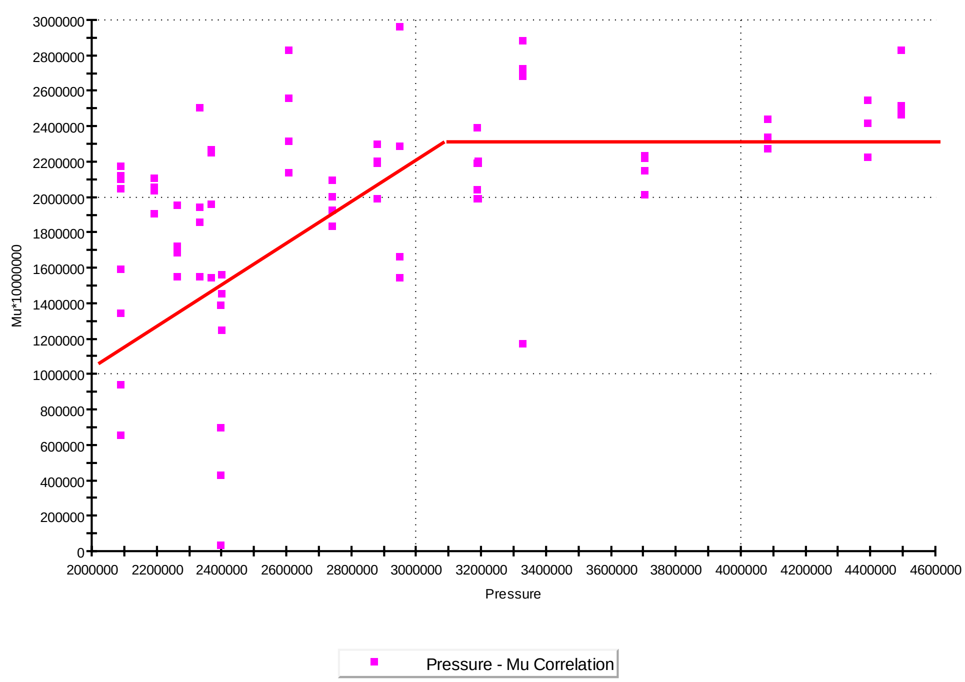

Figure 36 S9.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S10.txt

Flight No:F873 Landing Date/Time: JAN24_03/10:43

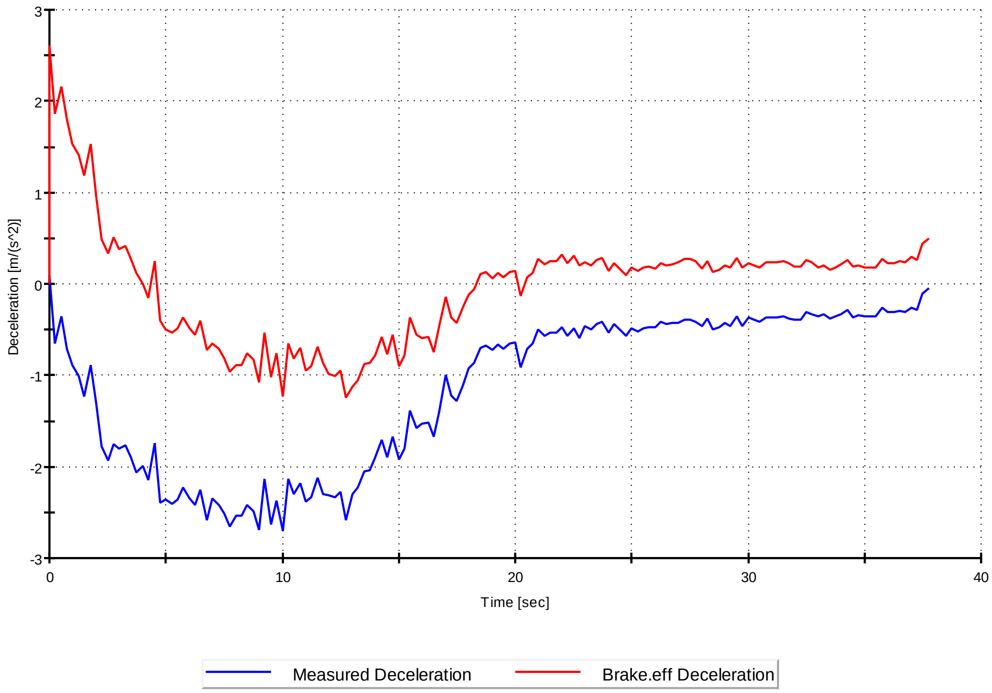

Figure 37 S10.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

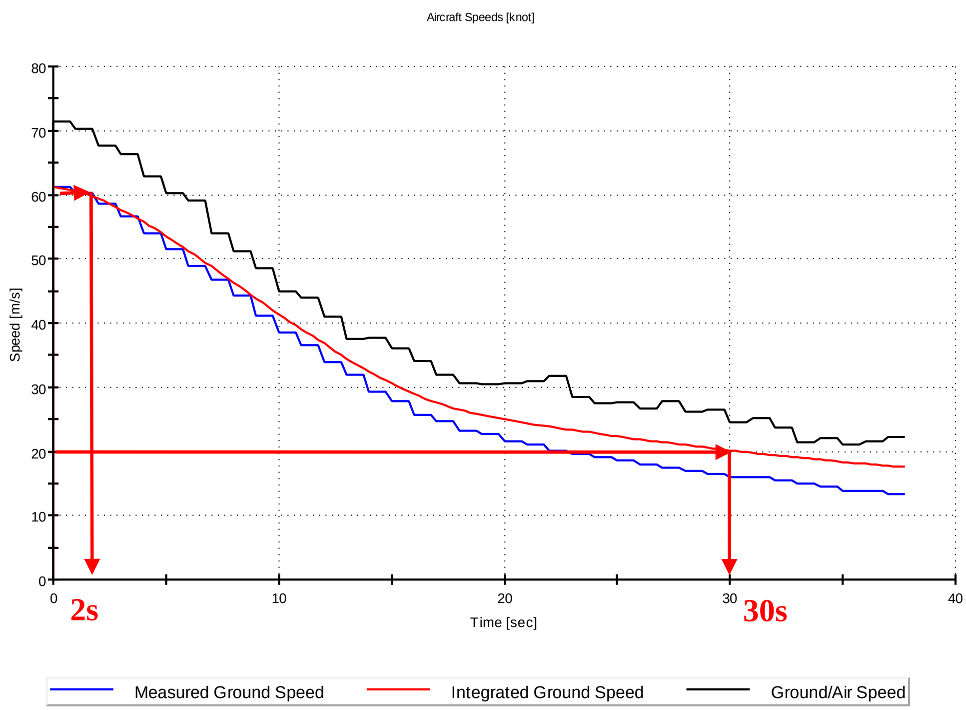

Figure 38 S10.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S10.txt

Flight No:F873 Landing Date/Time: JAN24_03/10:43

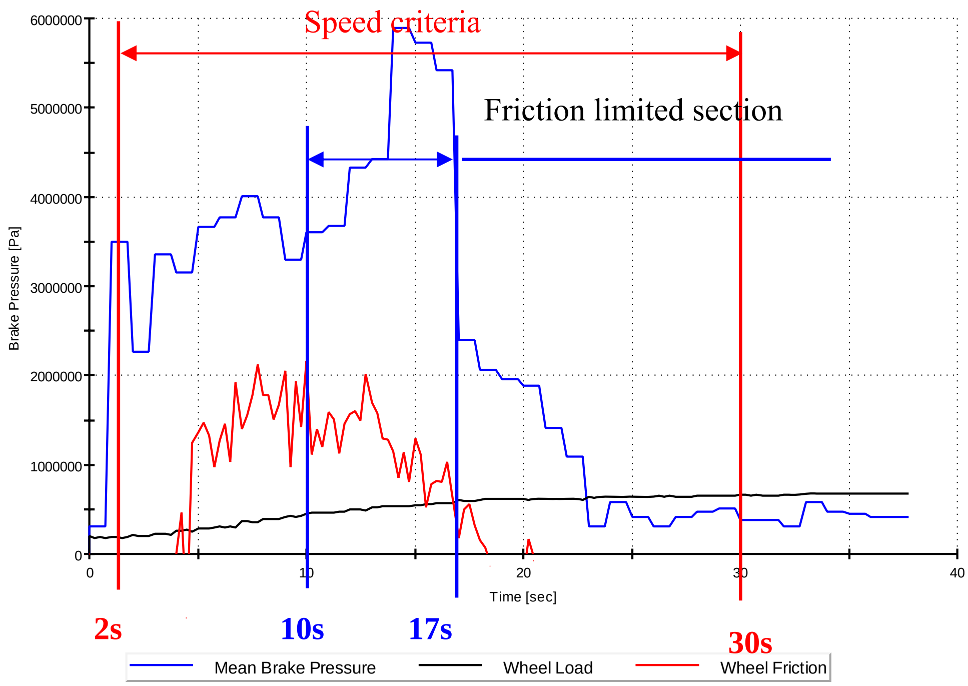

Figure 39 S10.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

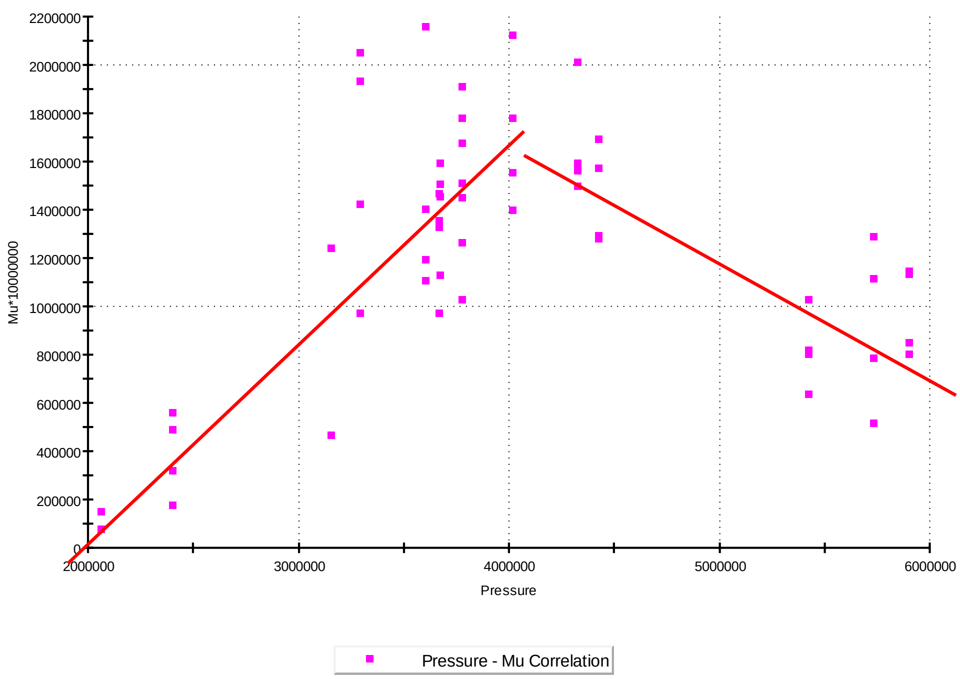

Figure 40 S10.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S11.txt

Flight No:F875 Landing Date/Time: JAN30_03/12:30

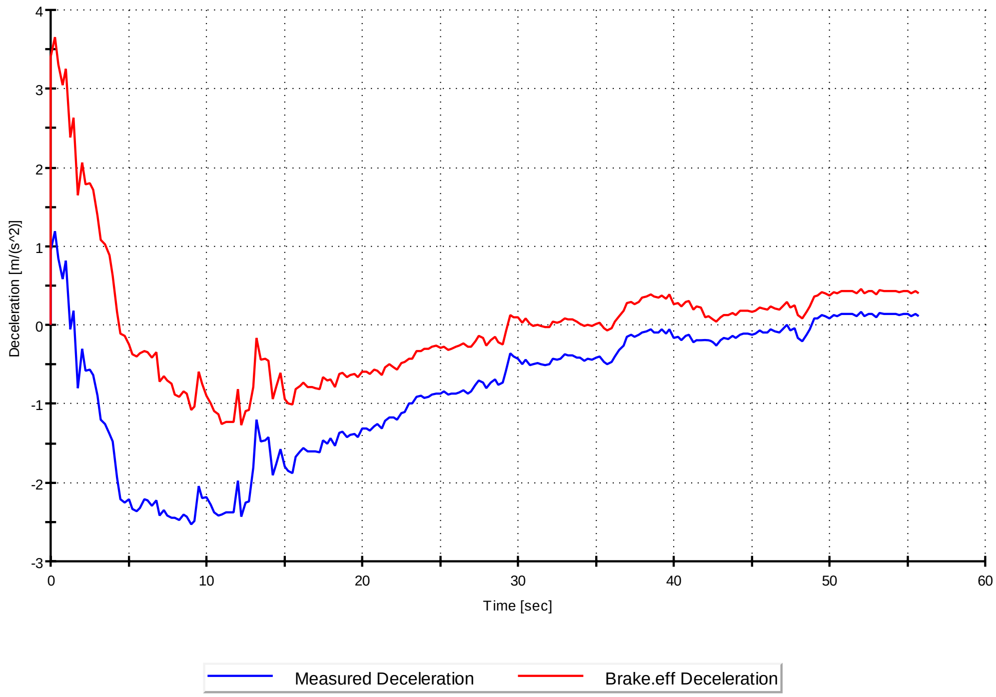

Figure 41 S11.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

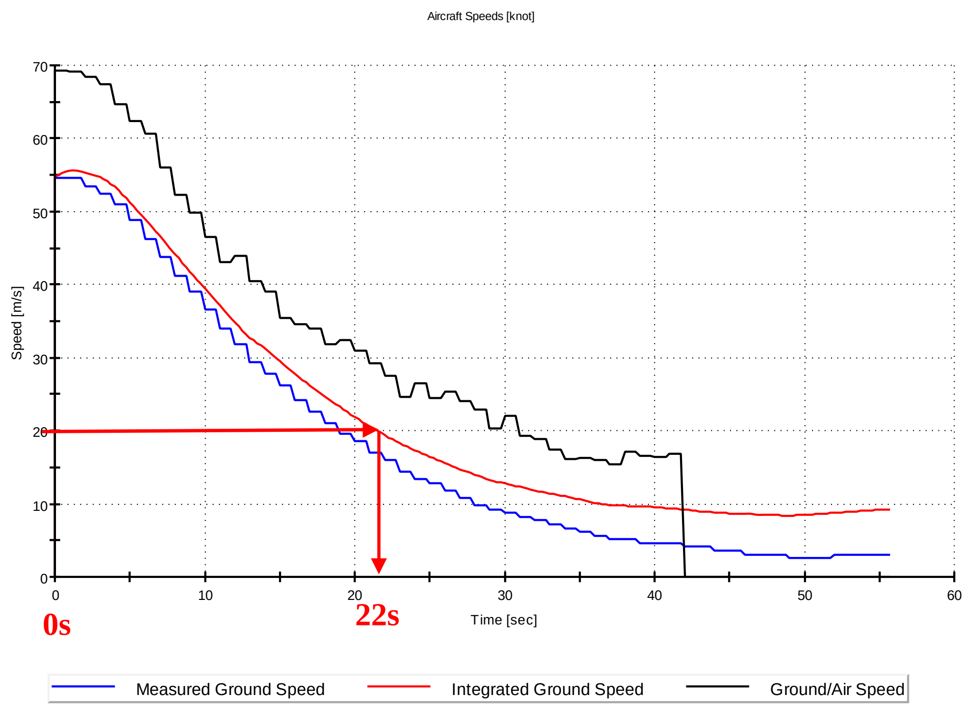

Figure 42 S11.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S11.txt

Flight No:F875 Landing Date/Time: JAN30_03/12:30

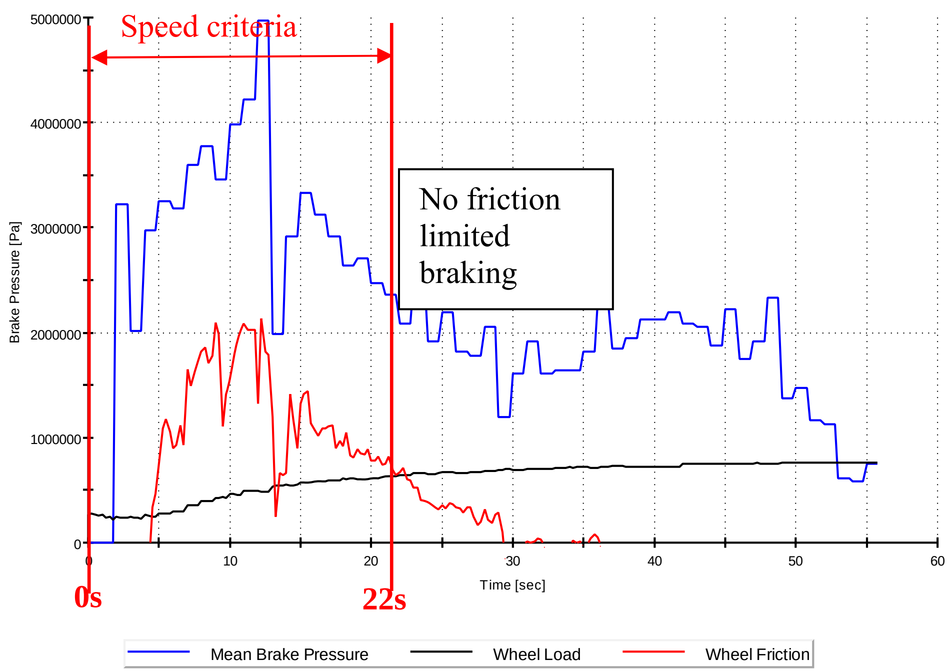

Figure 43 S11.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

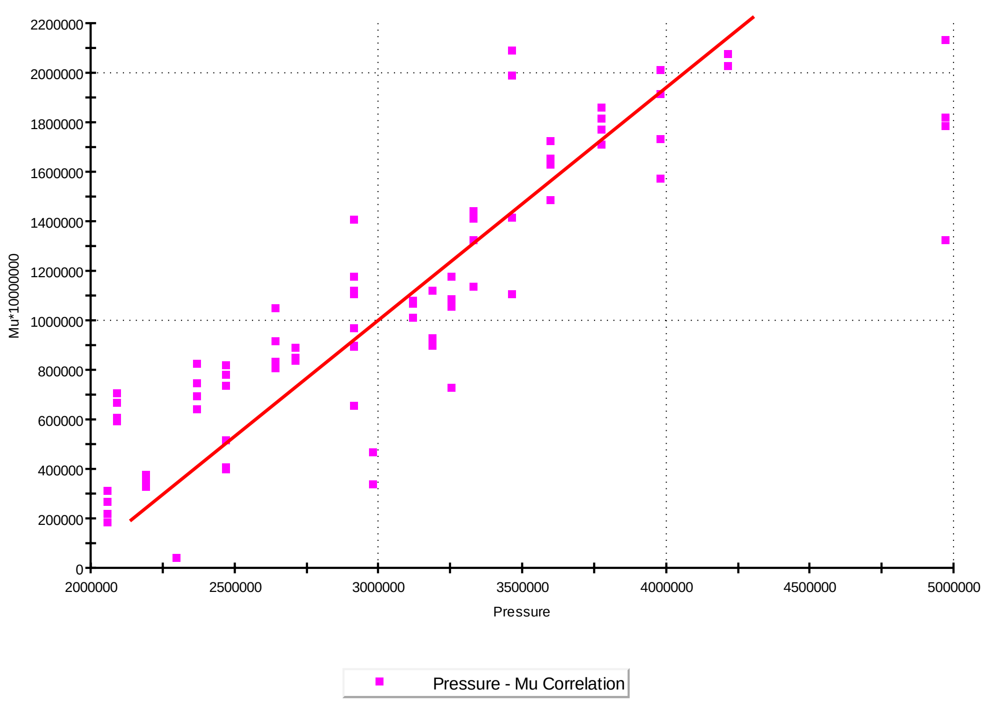

Figure 44 S11.txt Pressure vs. Mu Correlation

THIS LANDING DOES NOT HAVE A FRICTION LIMITED BRAKING.

S12.txt

Flight No:F877 Landing Date/Time: JAN23_03/19:03

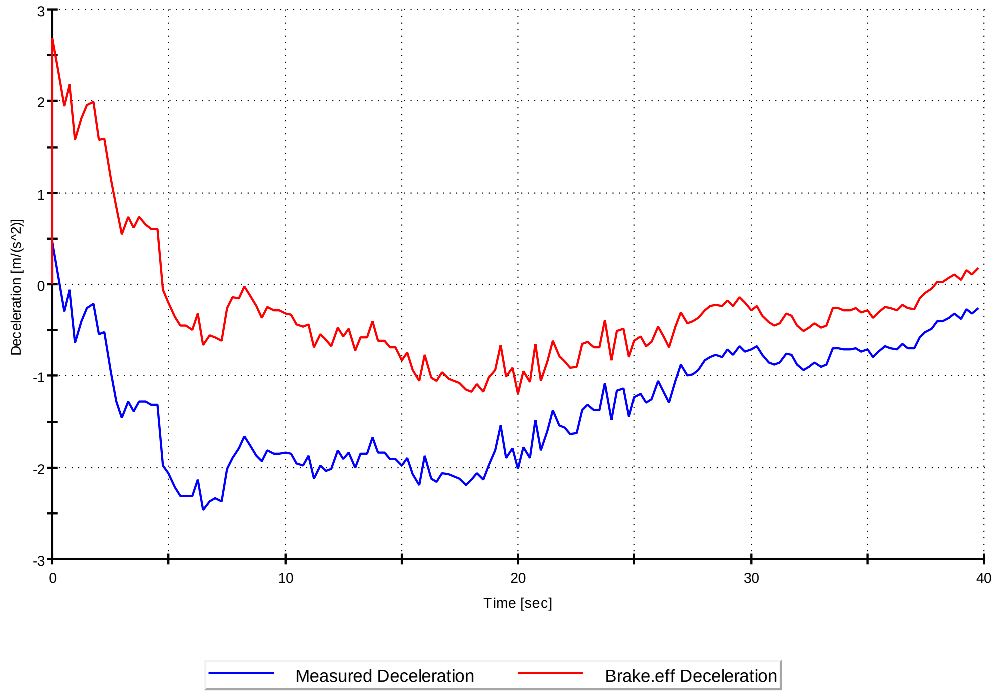

Figure 45 S12.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

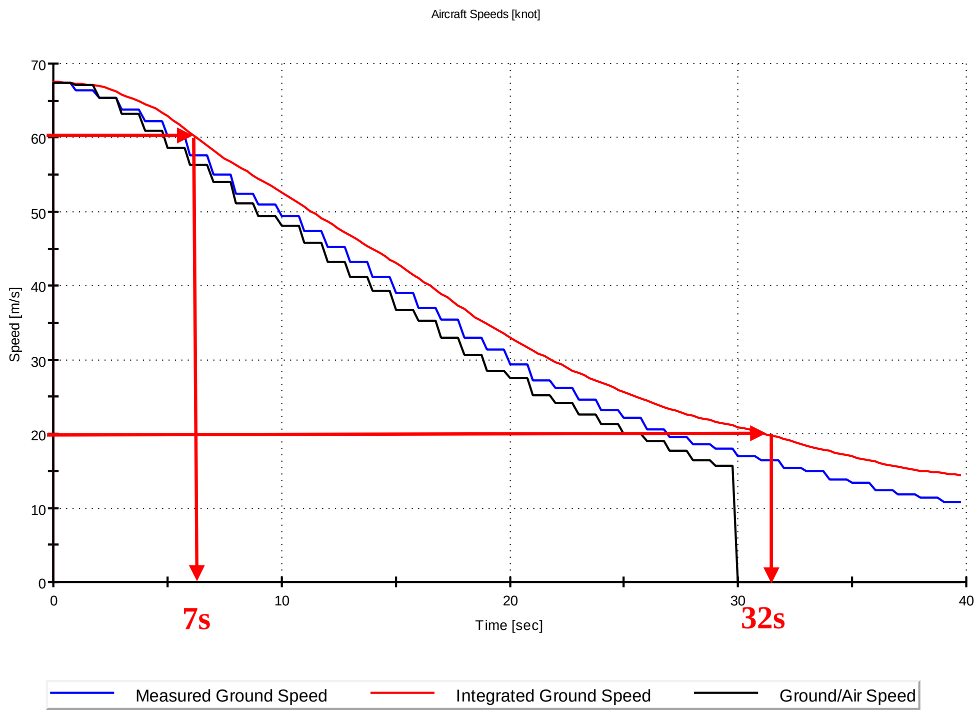

Figure 46 S12.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S12.txt

Flight No:F877 Landing Date/Time: JAN23_03/19:03

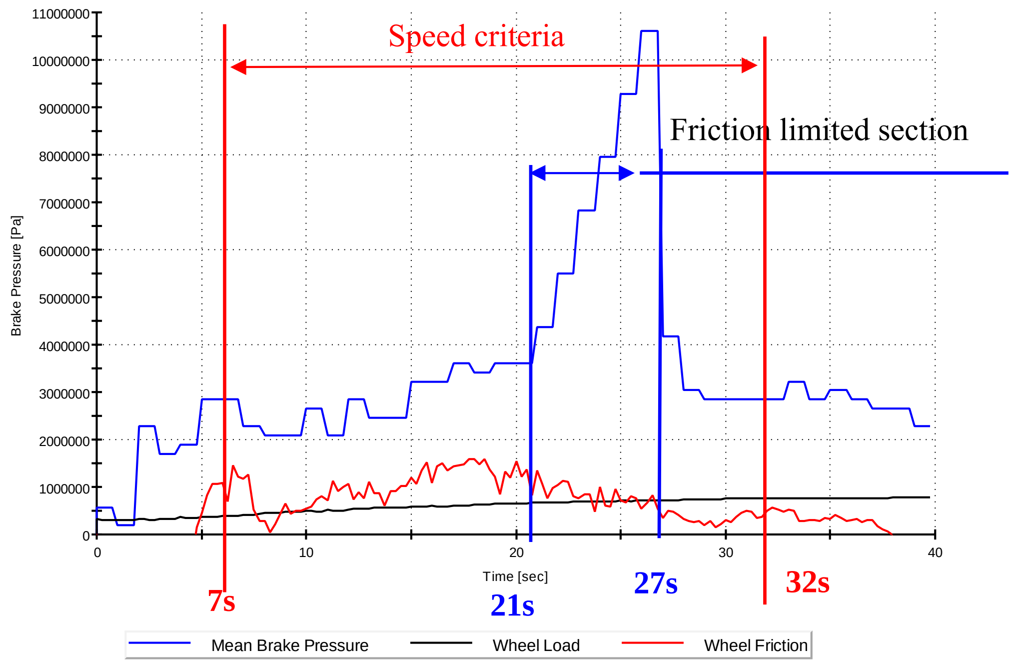

Figure 47 S12.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

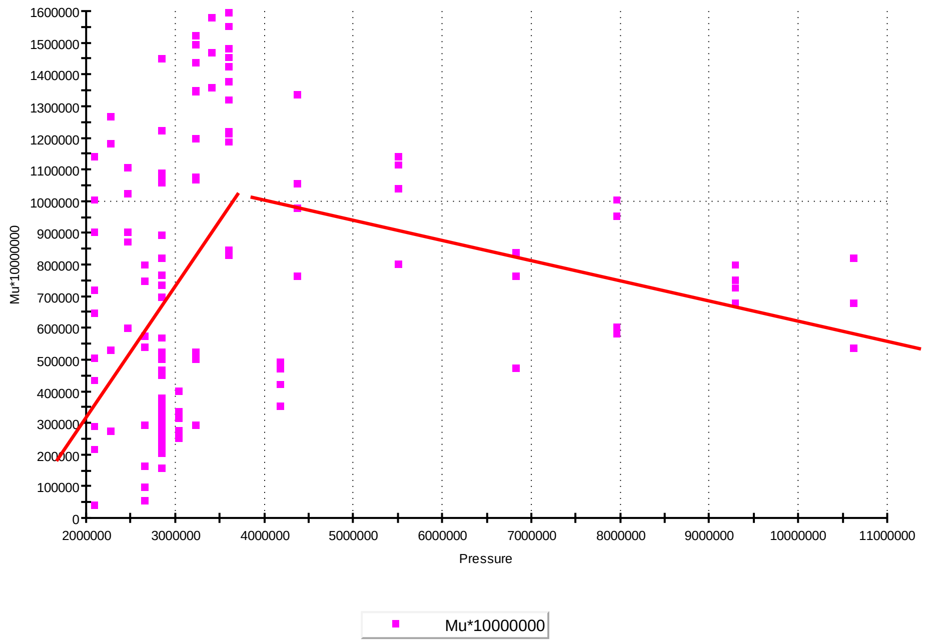

Figure 48 S12.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S13.txt

Flight No:F877 Landing Date/Time: JAN29_03/18:37

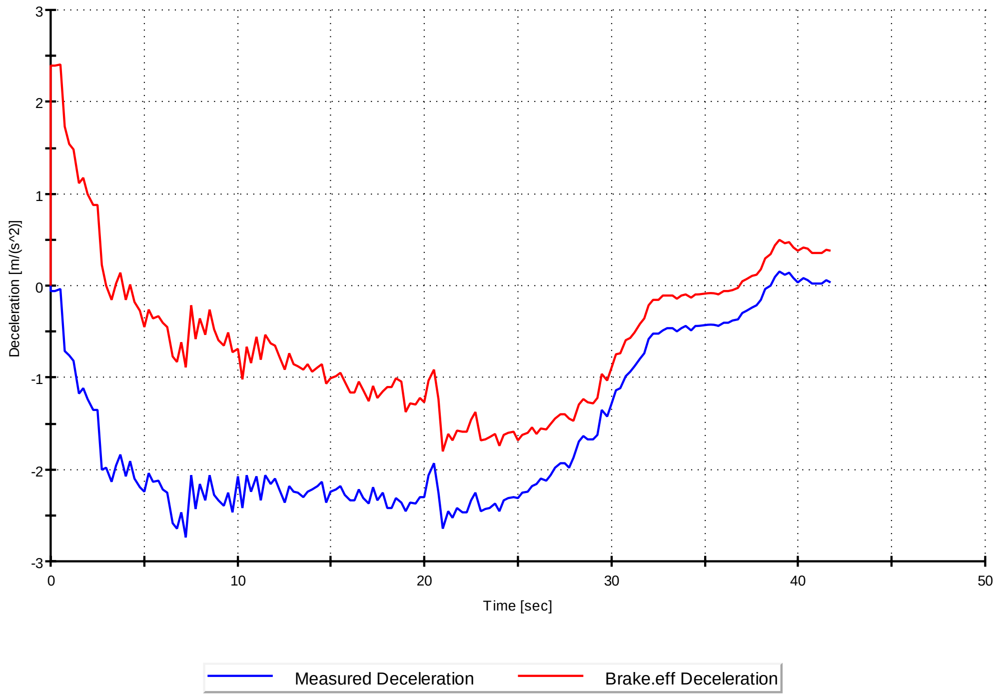

Figure 49 S13.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

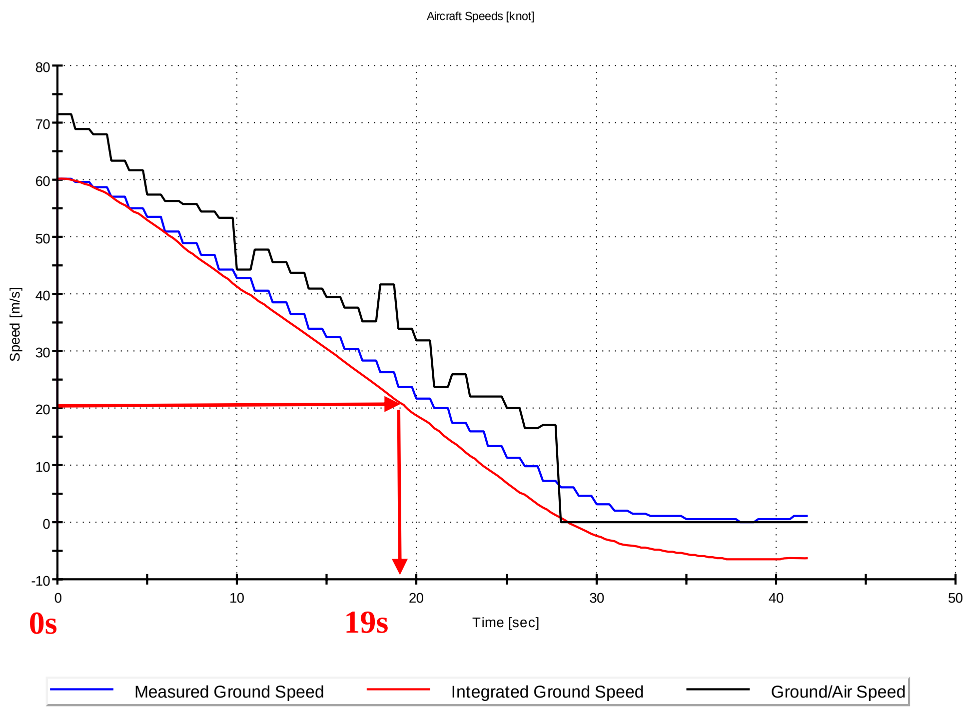

Figure 50 S13.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S13.txt

Flight No:F877 Landing Date/Time: JAN29_03/18:37

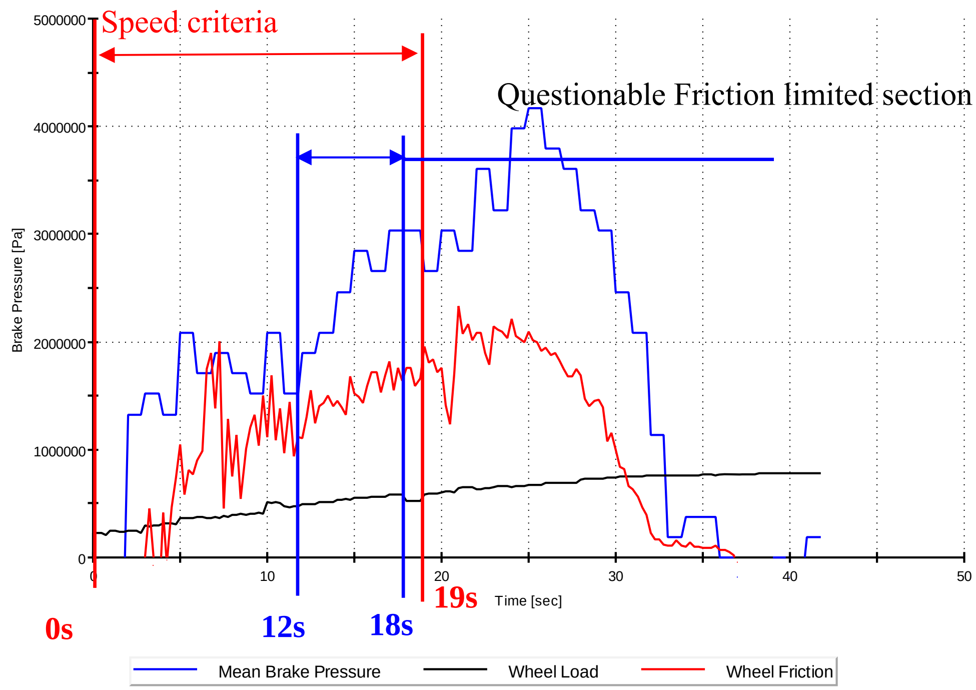

Figure 51 S13.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

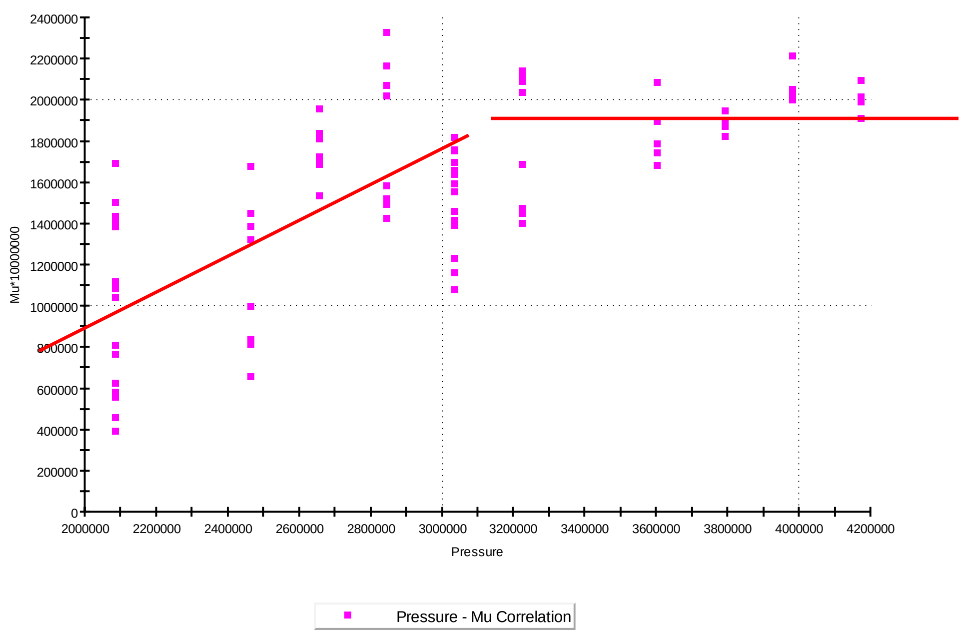

Figure 52 S13.txt Pressure vs. Mu Correlation

THIS LANDING HAS A QUESTIONABLE FRICTION LIMITED BRAKING.

S14.txt

Flight No:F879 Landing Date/Time: JAN30_03/21:01

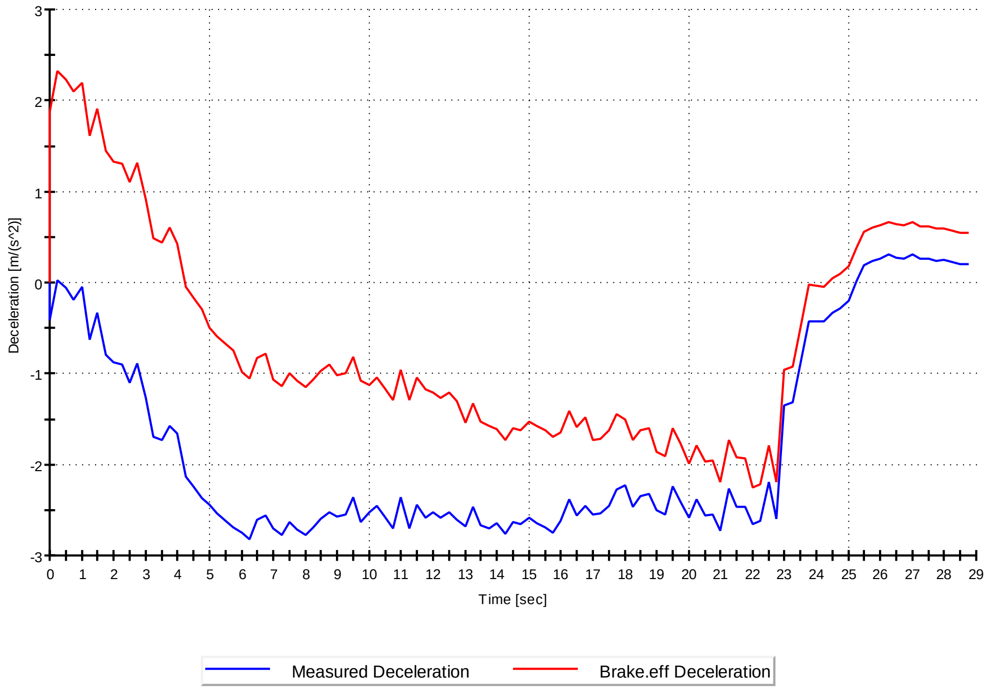

Figure 53 S14.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

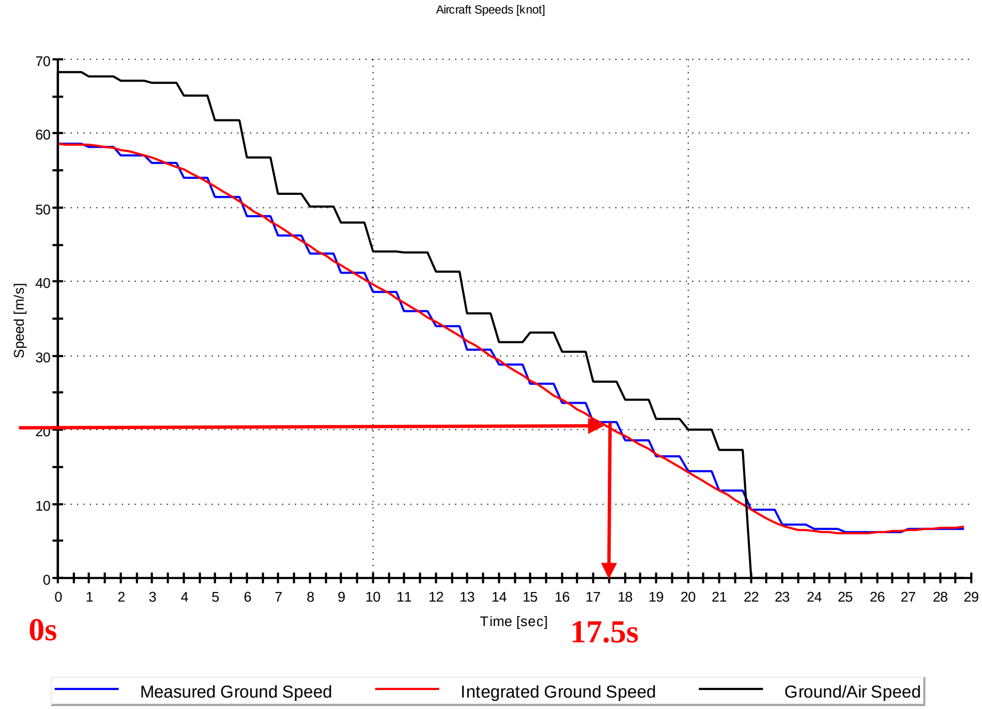

Figure 54 S14.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S14.txt

Flight No:F879 Landing Date/Time: JAN30_03/21:01

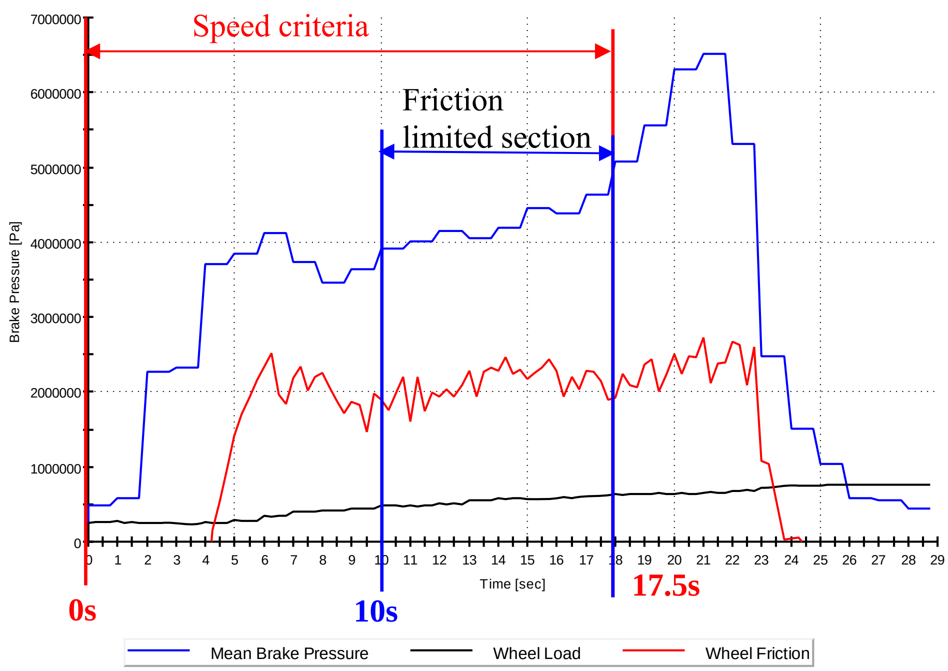

Figure 55 S14.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

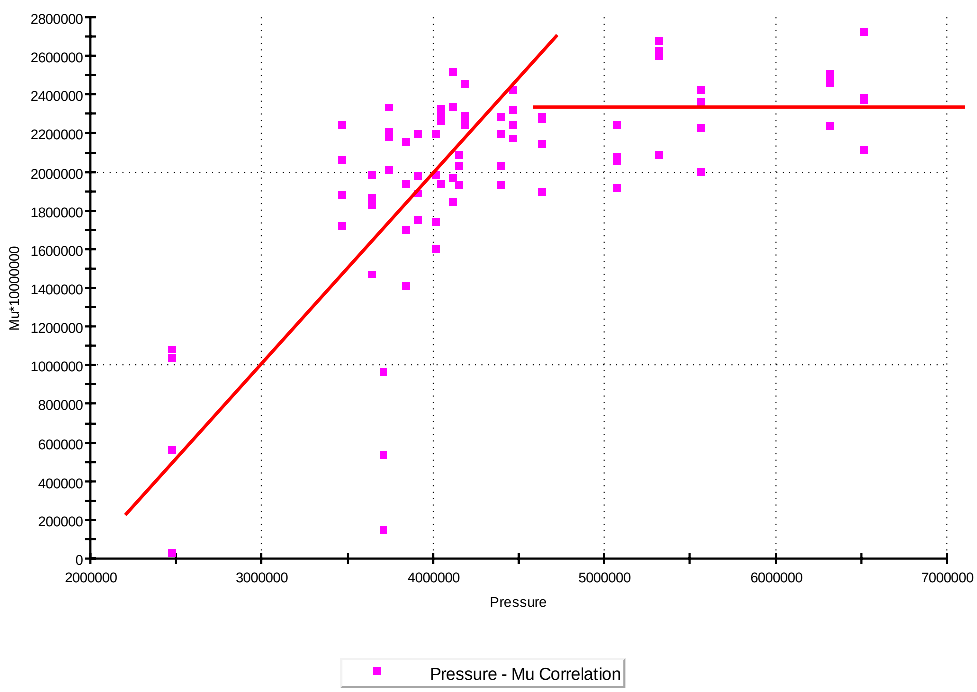

Figure 56 S14.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S15.txt

Flight No:F879 Landing Date/Time: JAN29_03/21:30

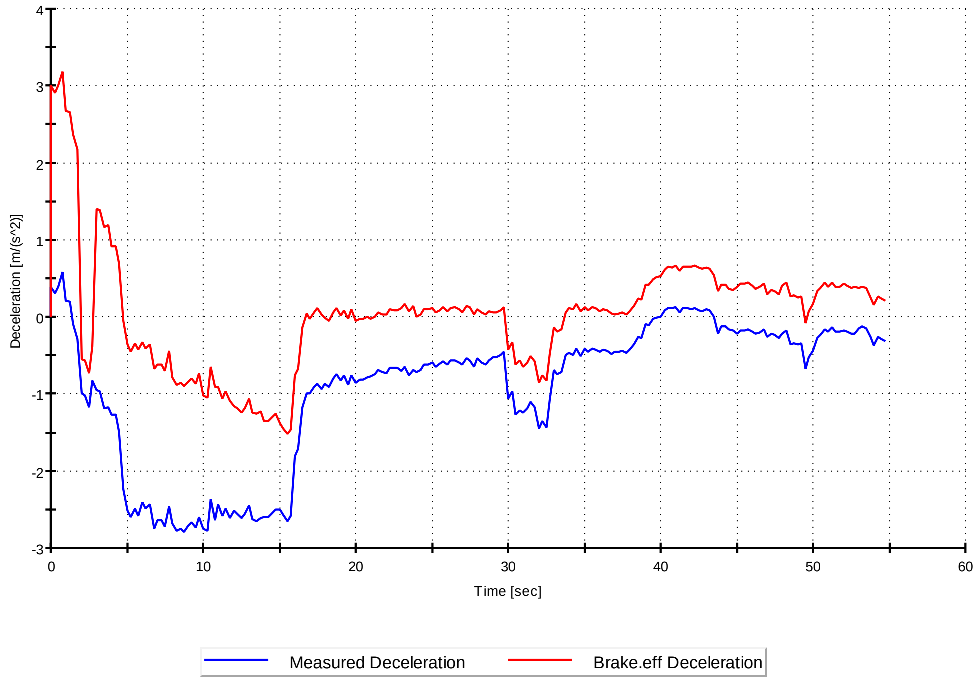

Figure 57 S15.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

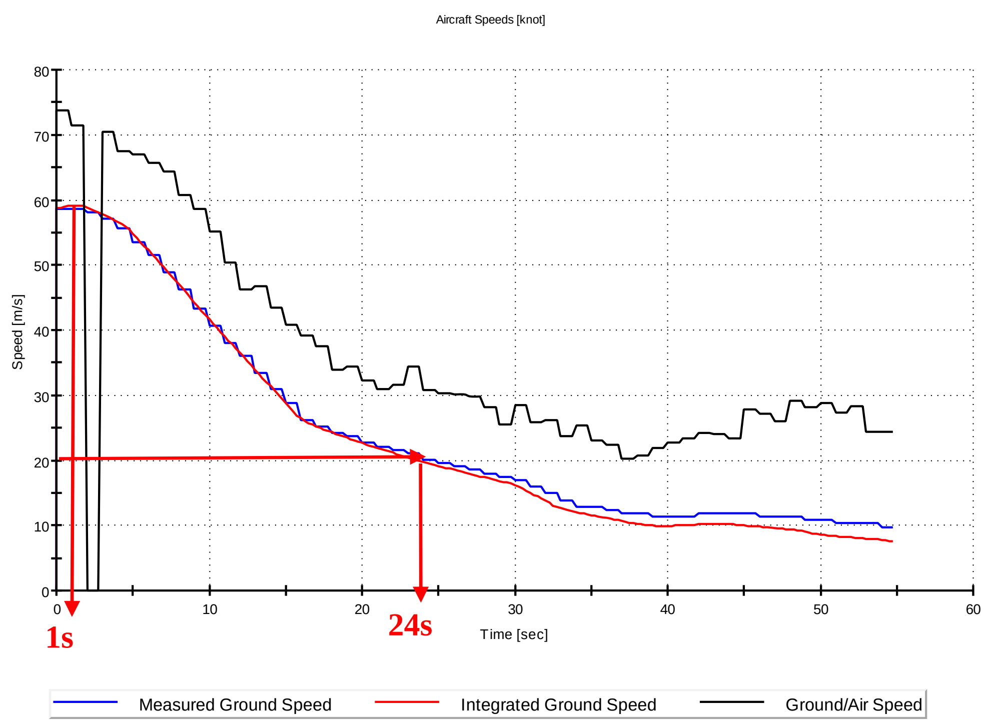

Figure 58 S15.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S15.txt

Flight No:F879 Landing Date/Time: JAN29_03/21:30

Figure 59 S15.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

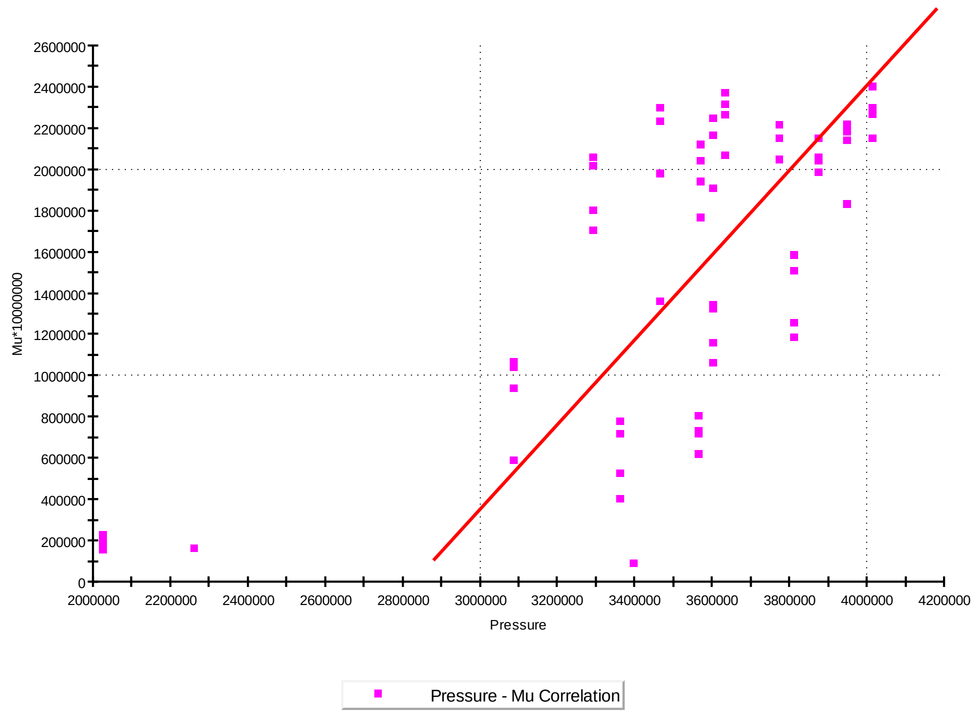

Figure 60 S15.txt Pressure vs. Mu Correlation

THIS LANDING DOES NOT HAVE A FRICTION LIMITED BRAKING.

S16.txt

Flight No:F879 Landing Date/Time: JAN31_03/20:55

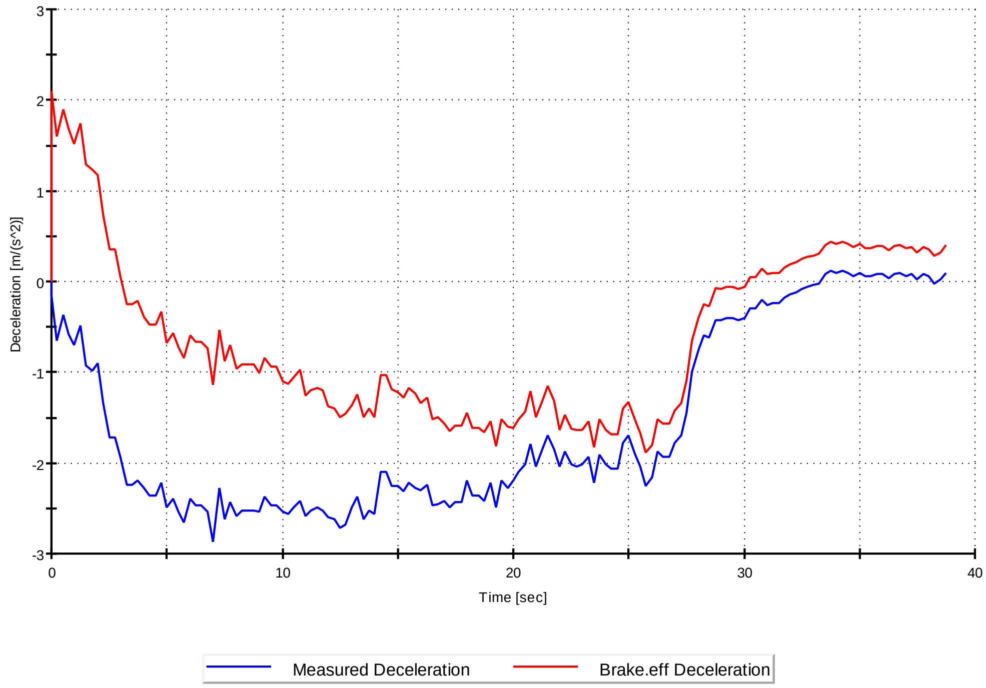

Figure 61 S16.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

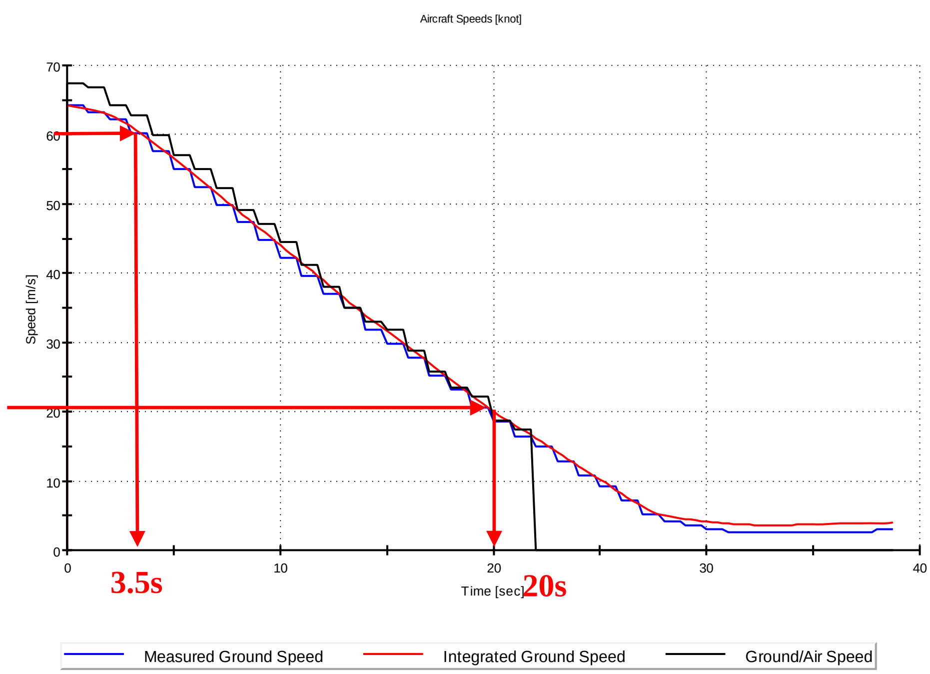

Figure 62 S16.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S16.txt

Flight No:F879 Landing Date/Time: JAN31_03/20:55

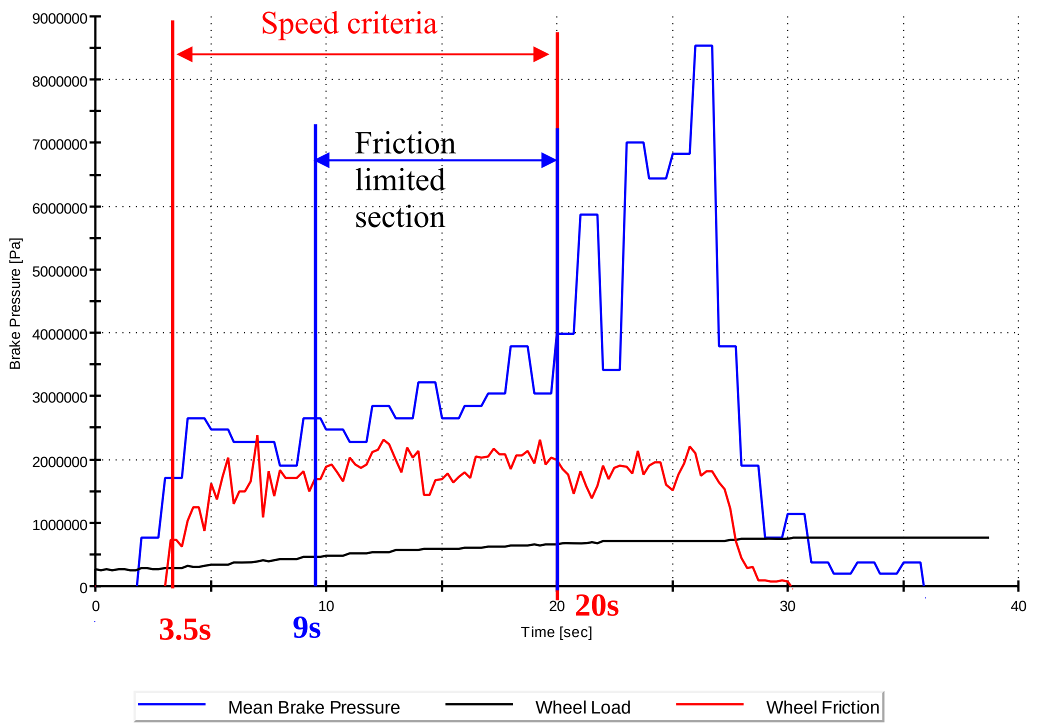

Figure 63 S16.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

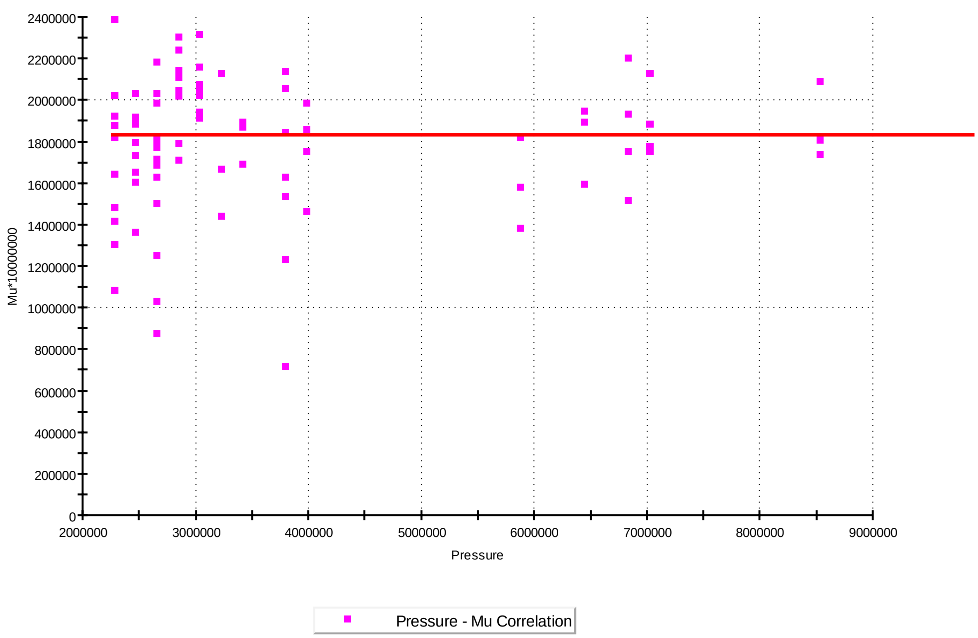

Figure 64 S16.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

S17.txt

Flight No:F879 Landing Date/Time: JAN23_03/21:14

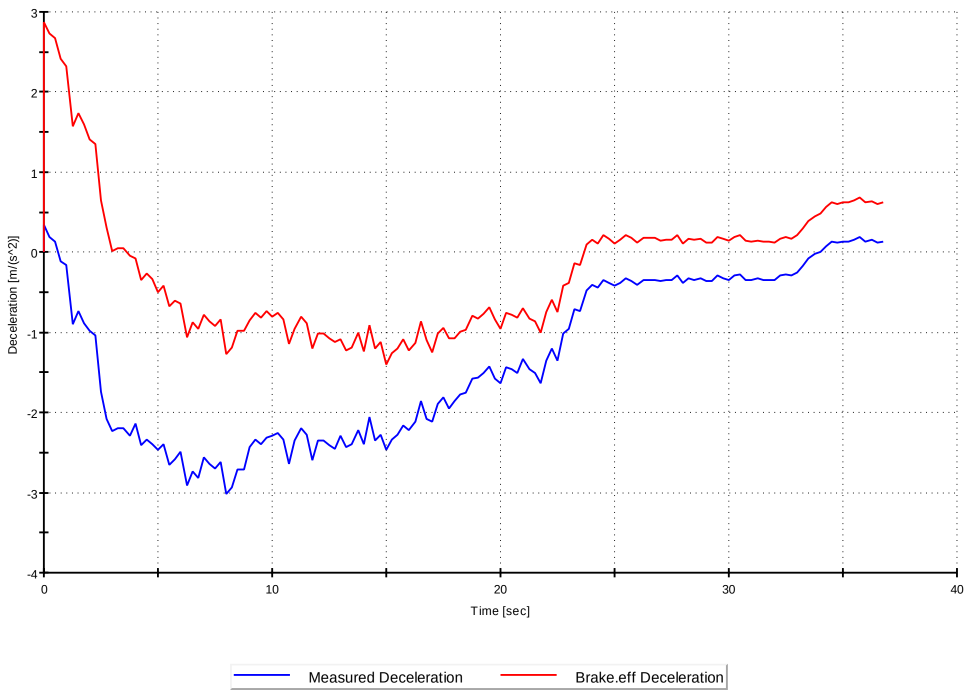

Figure 65 S17.txt Measured Deceleration and Brake Eff. Deceleration vs. Time

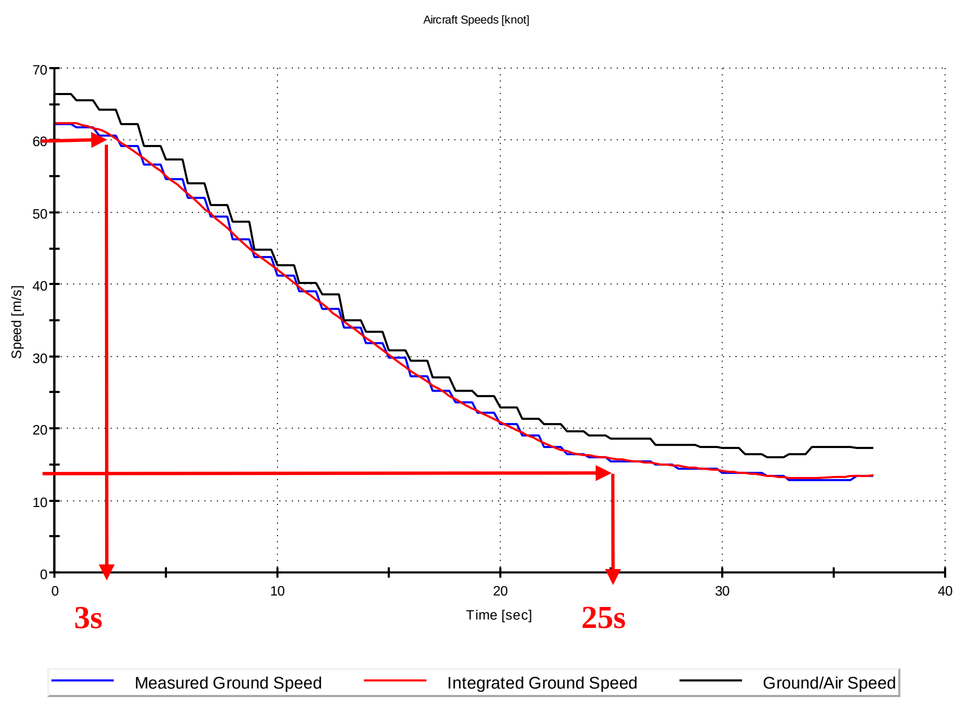

Figure 66 S17.txt Measured Ground Speed, Integrated Ground Speed and Ground/Air Speed vs. Time

S17.txt

Flight No:F879 Landing Date/Time: JAN23_03/21:14

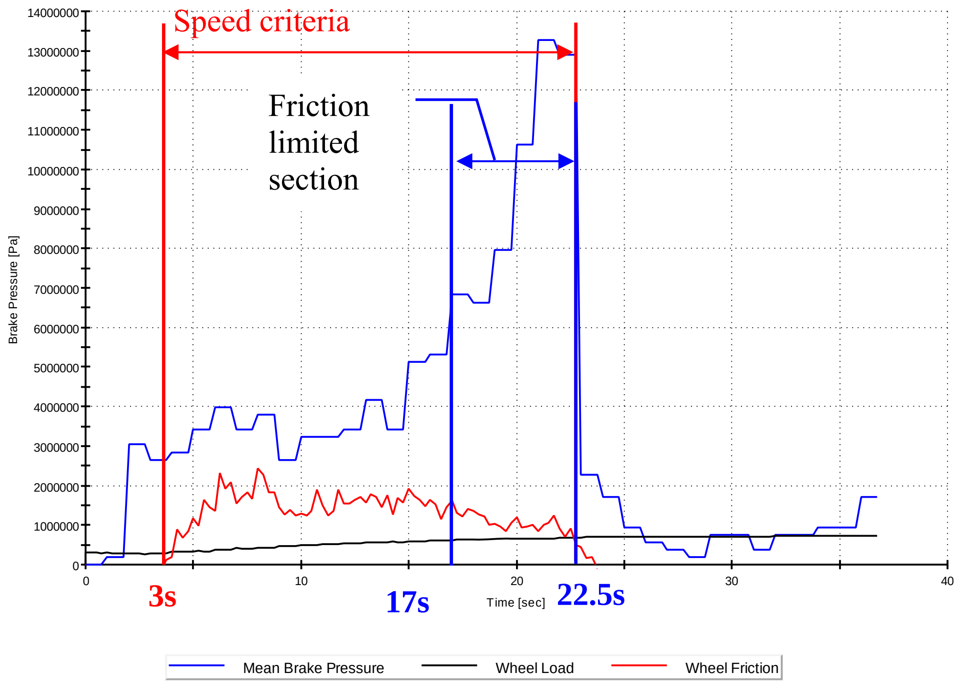

Figure 67 S17.txt Mean Brake Pressure, Wheel Load and Wheel Friction vs. Time

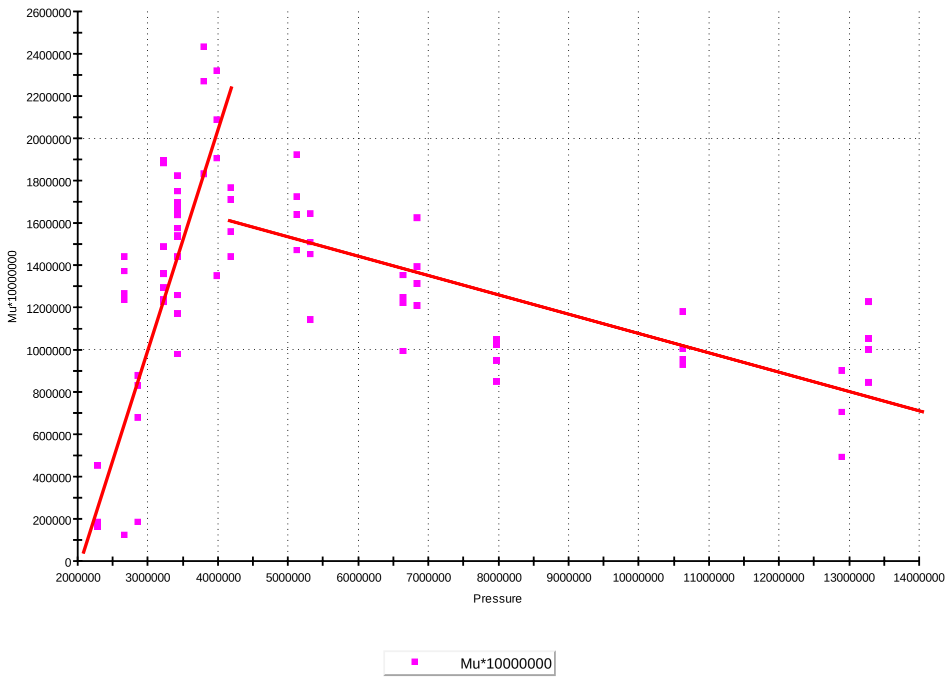

Figure 68 S17.txt Pressure vs. Mu Correlation

THIS LANDING HAS A FRICTION LIMITED BRAKING.

The Table 5 shows a summary of the analyses until this point.

Table 5 Time Window and Friction Limited Sections for Each Run

Flight No.	Date/Time	File Name	Speed criteria time window (s)	Friction limited section time window (s)
F875	01.29.03/12:45	S1.txt	5-26	-
F875	01.22.03/12:23	S2.txt	5-28	15-21
F877	01.24.03/18:46	S3.txt	3-20.5	9-20.5
F879	01.20.03/20:53	S4.txt	3-18	11-18
F877	01.21.03/19:05	S5.txt	1-17	-
F873	01.22.03/10:55	S6.txt	-	-
F873	01.29.03/10:27	S7.txt	2-19	10-19
F879	01.24.03/21:11	S8.txt	4-22	-
F873	01.20.03/13:24	S9.txt	2-17	9-17
F873	01.24.03/10:43	S10.txt	2-30	10-17
F875	01.30.03/12:30	S11.txt	0-22	-
F877	01.23.03/19:03	S12.txt	7-32	21-27
F877	01.29.03/18:37	S13.txt	0-19	12-18
F879	01.30.03/21:30	S14.txt	0-17.5	10 - 17.5
F879	01.29.03/21:30	S15.txt	1-24	-
F879	01.31.03/21:14	S16.txt	3.5-20	9-20
F879	01.23.03/21:14	S17.txt	3-25	16 - 20

8.2 Identifying Average Available Friction for Friction Limited Runs

For the friction limited landing, the available average friction was calculated by averaging the brake generated wheel friction in the friction limited time window.

The brake generated wheel friction graphs for each friction limited landing with the average available friction are shown in Figures 69 through 79.

S2.txt

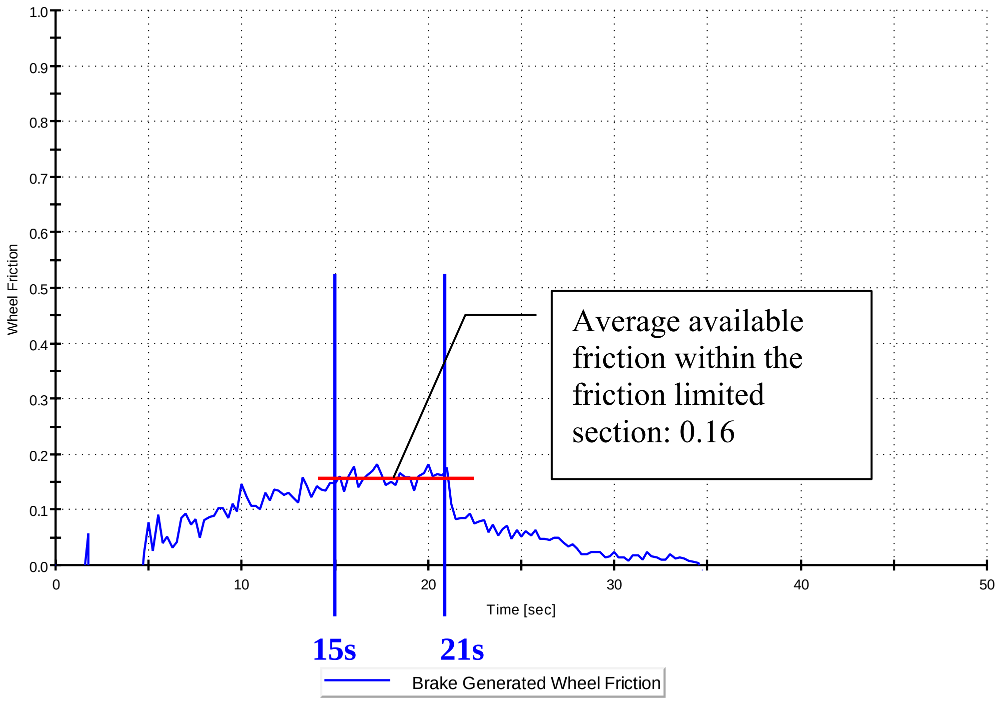

Figure 69 S2.txt Average Available Friction

S3.txt

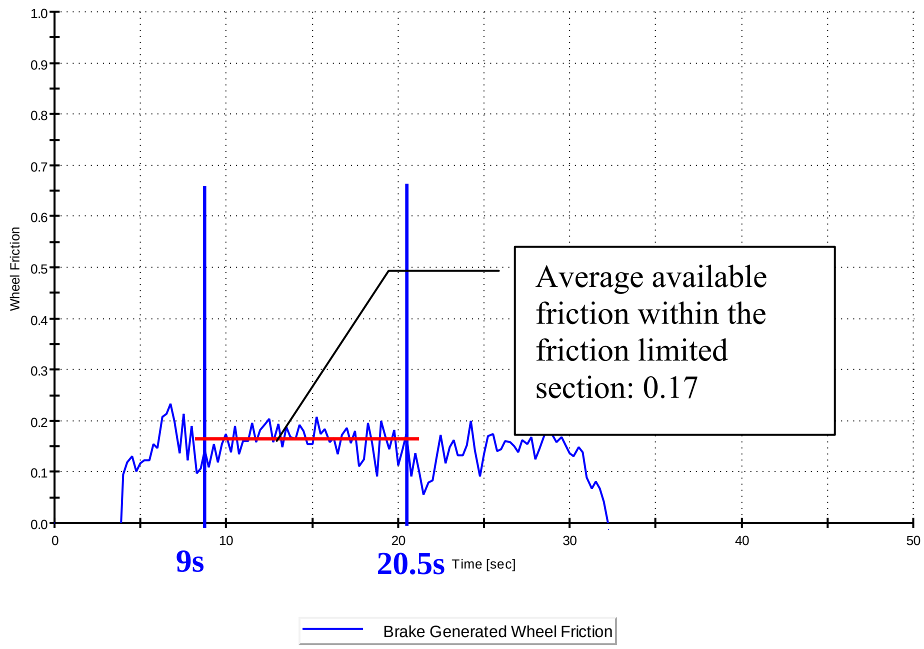

Figure 70 S3.txt Average Available Friction

S4.txt

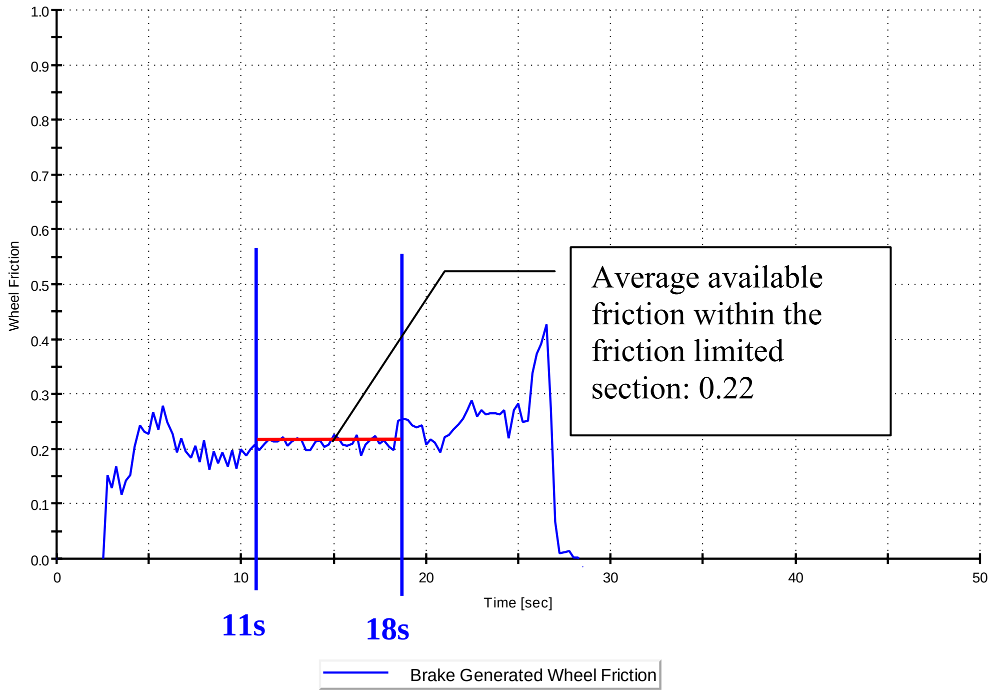

Figure 71 S4.txt Average Available Friction

S7.txt

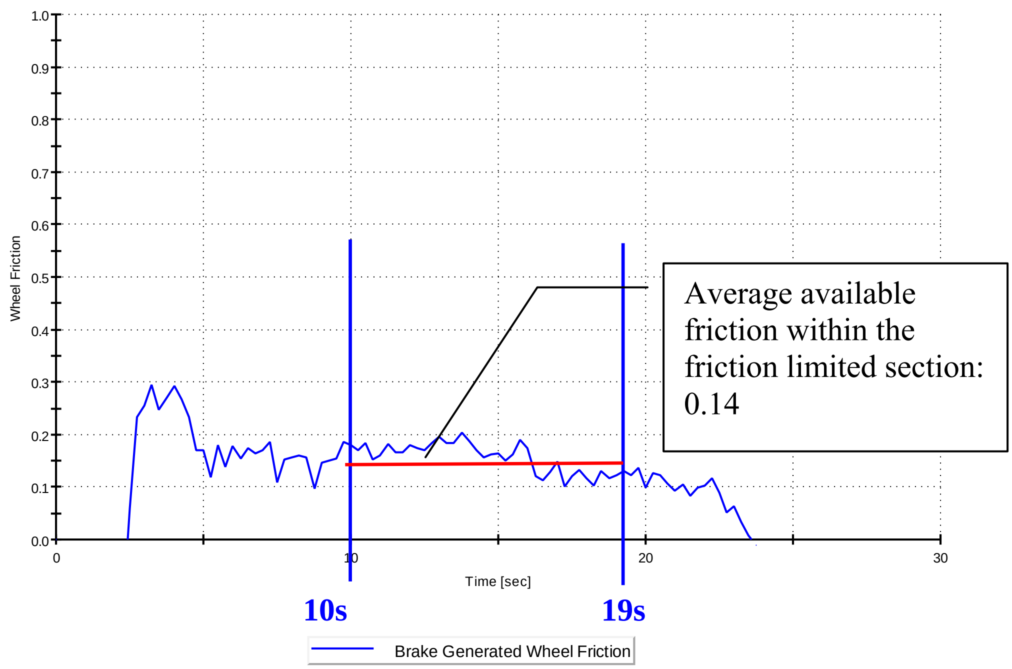

Figure 72 S7.txt Average Available Friction

S9.txt

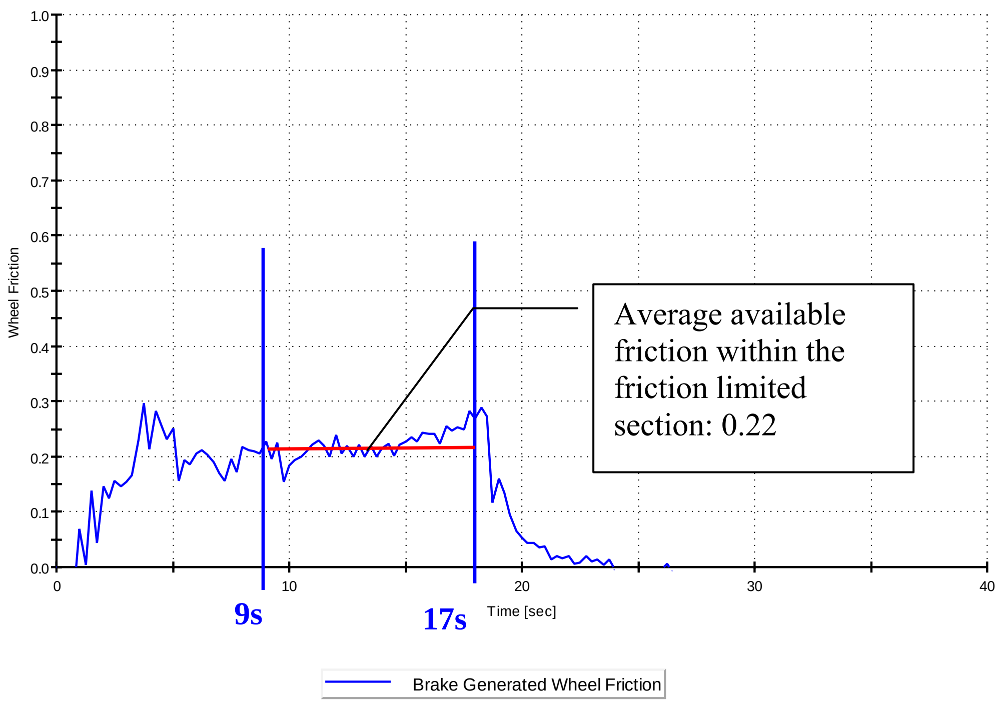

Figure 73 S9.txt Average Available Friction

S10.txt

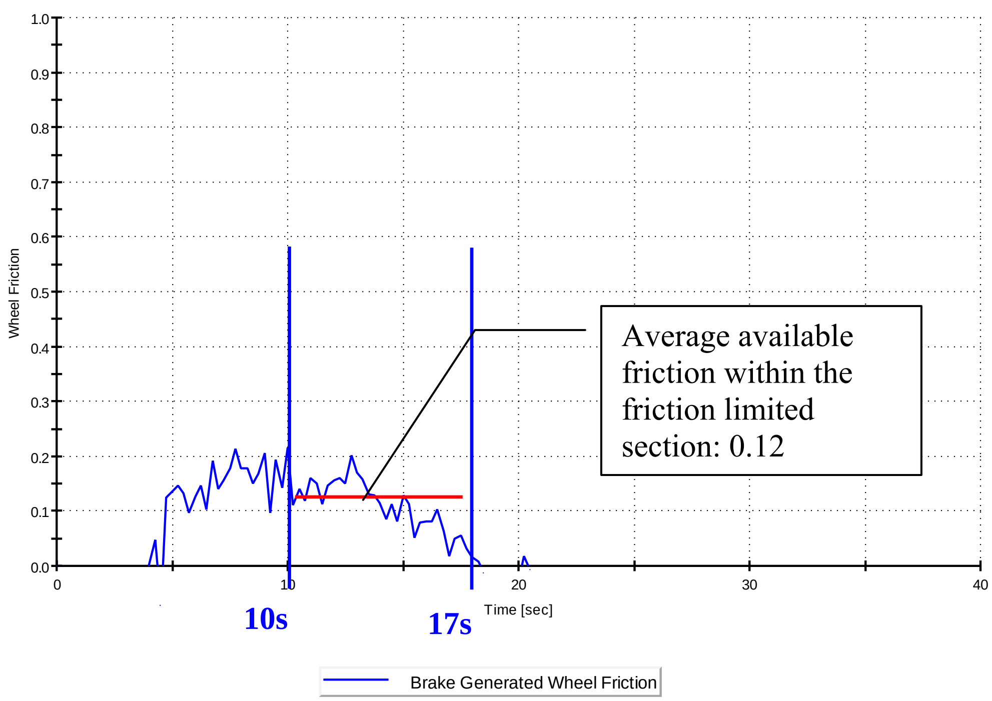

Figure 74 S10.txt Average Available Friction

S12.txt

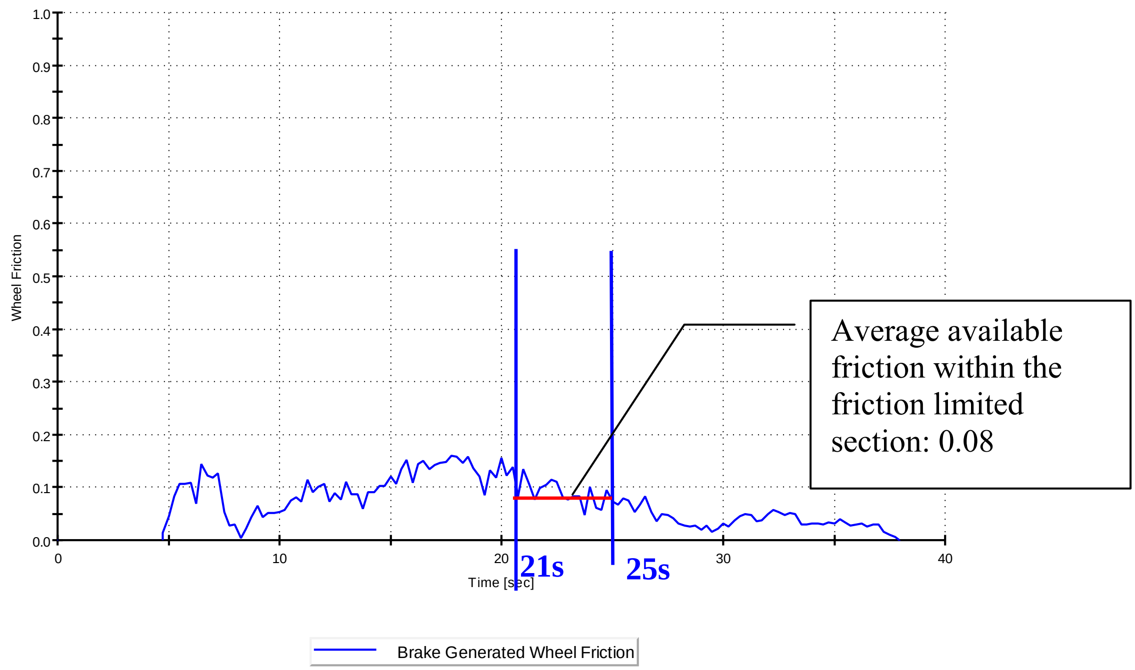

Figure 75 S12.txt Average Available Friction

S13.txt

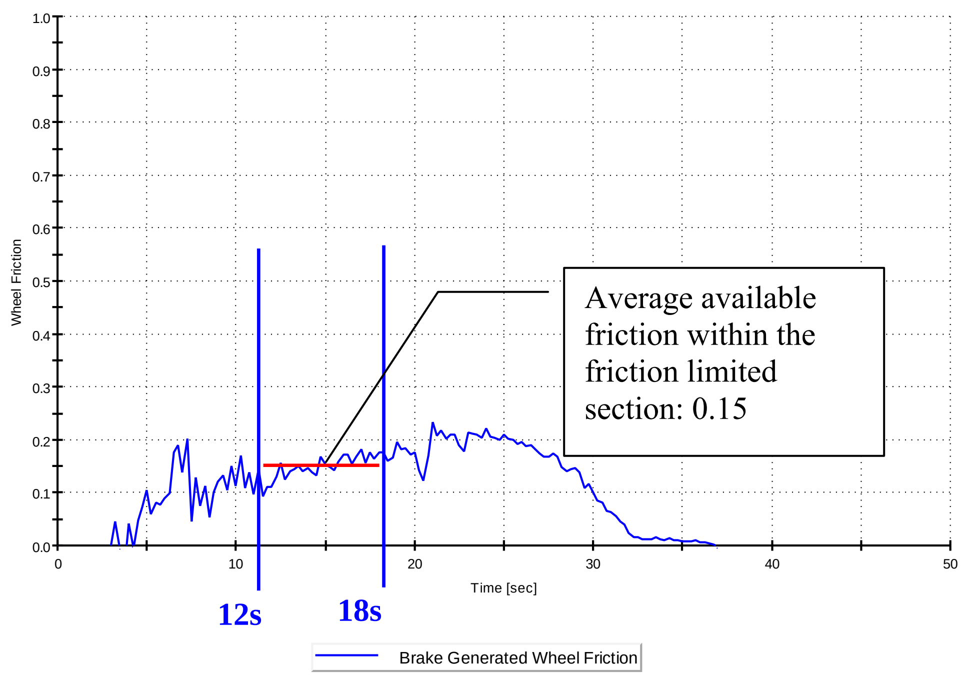

Figure 76 S13.txt Average Available Friction

S14.txt

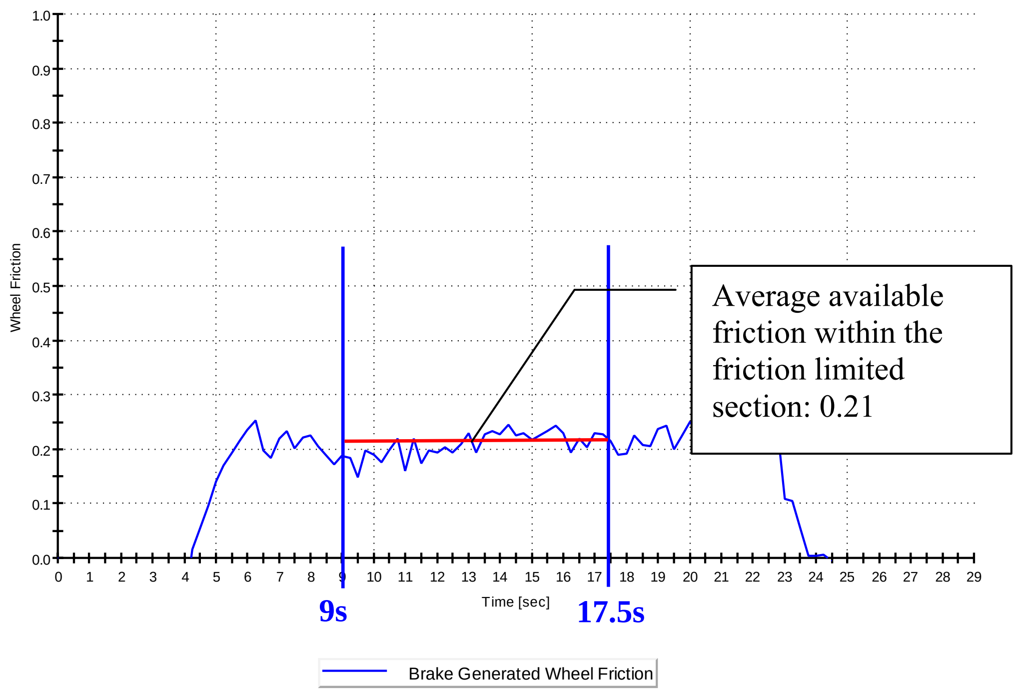

Figure 77 S14.txt Average Available Friction

S16.txt

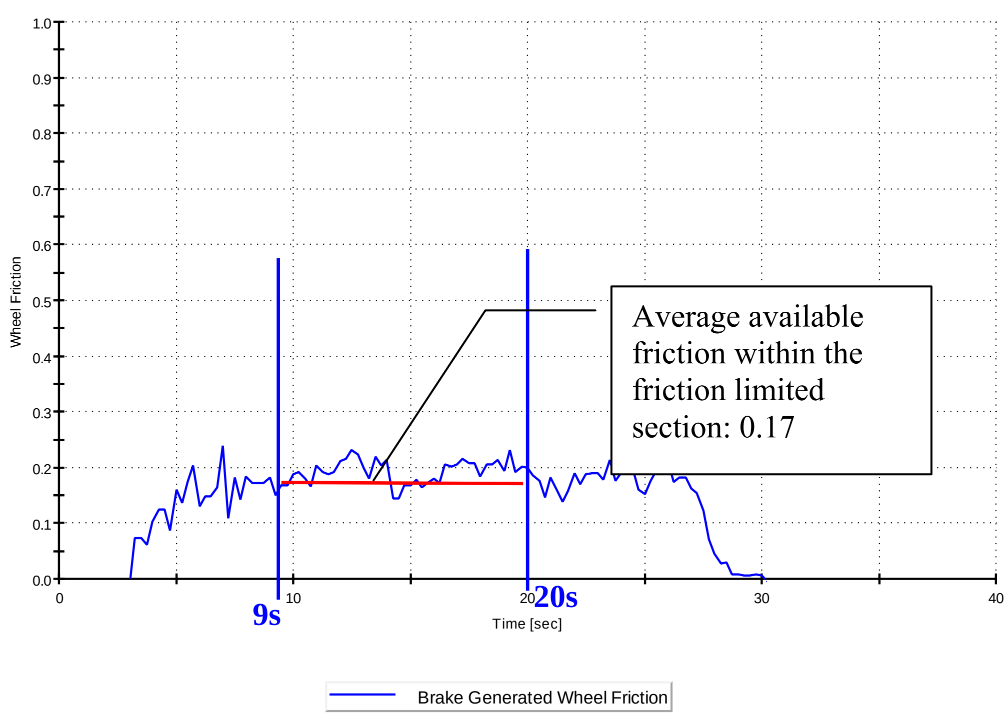

Figure 78 S16.txt Average Available Friction

S17.txt

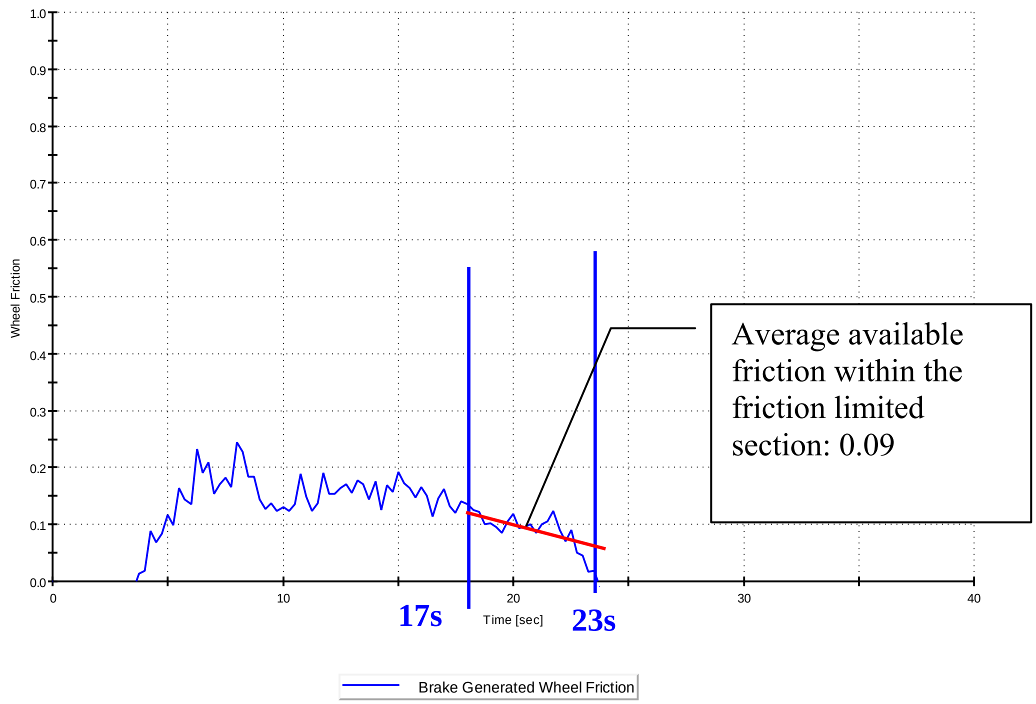

Figure 79 S17.txt Average Available Friction

For the friction limited runs, the average available friction is shown in Table 6.

Table 6 Average Available Friction for the Friction Limited Runs

Flight No.	Date/Time	File Name	Aircraft friction
F875	01.22.03/12:23	S2.txt	0.16
F877	01.24.03/18:46	S3.txt	0.17
F879	01.20.03/20:53	S4.txt	0.22
F873	01.29.03/10:27	S7.txt	0.14
F873	01.20.03/13:24	S9.txt	0.22
F873	01.24.03/10:43	S10.txt	0.12
F877	01.23.03/19:03	S12.txt	0.08
F877	01.29.03/18:37	S13.txt	0.15
F879	01.30.03/21:30	S14.txt	0.21
F879	01.31.03/21:14	S16.txt	0.17
F879	01.23.03/21:14	S17.txt	0.09

8.3 Identifying the Maximum Used Friction Within the Speed Criteria for NON Friction Limited Runs

For the non friction limited landing, the maximum used friction within the speed criteria was calculated by averaging the brake generated wheel friction in the speed criteria time window.

The brake generated wheel friction graphs for each friction limited landing with the maximum used friction are shown in Figures 80 through 84.

S1.txt

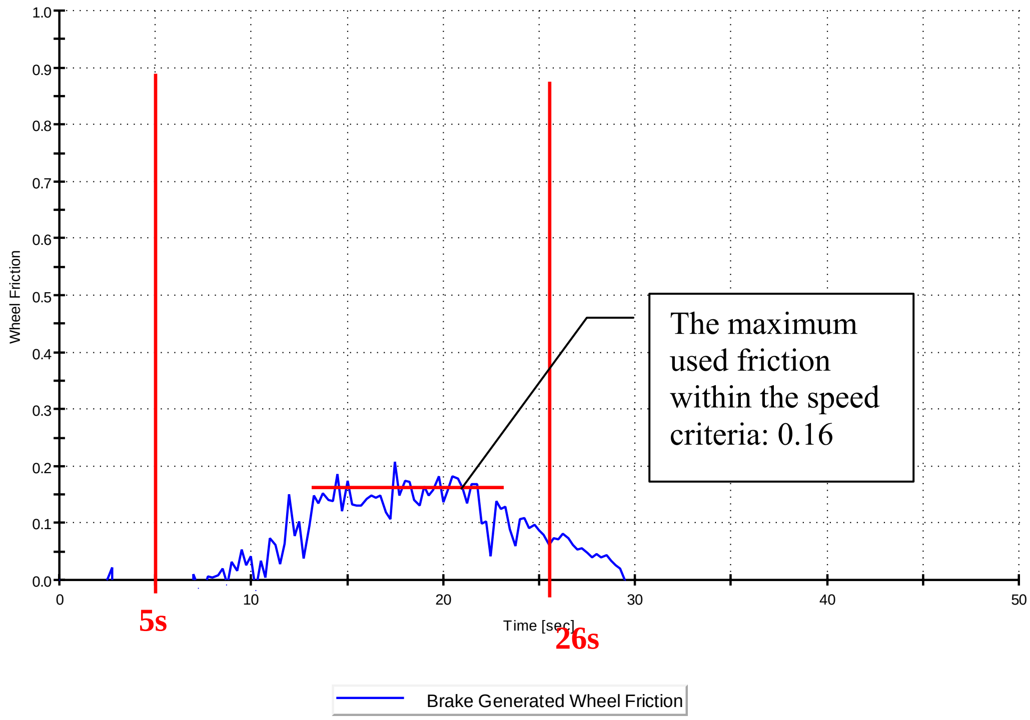

Figure 80 S1.txt Maximum Used Friction

S5.txt

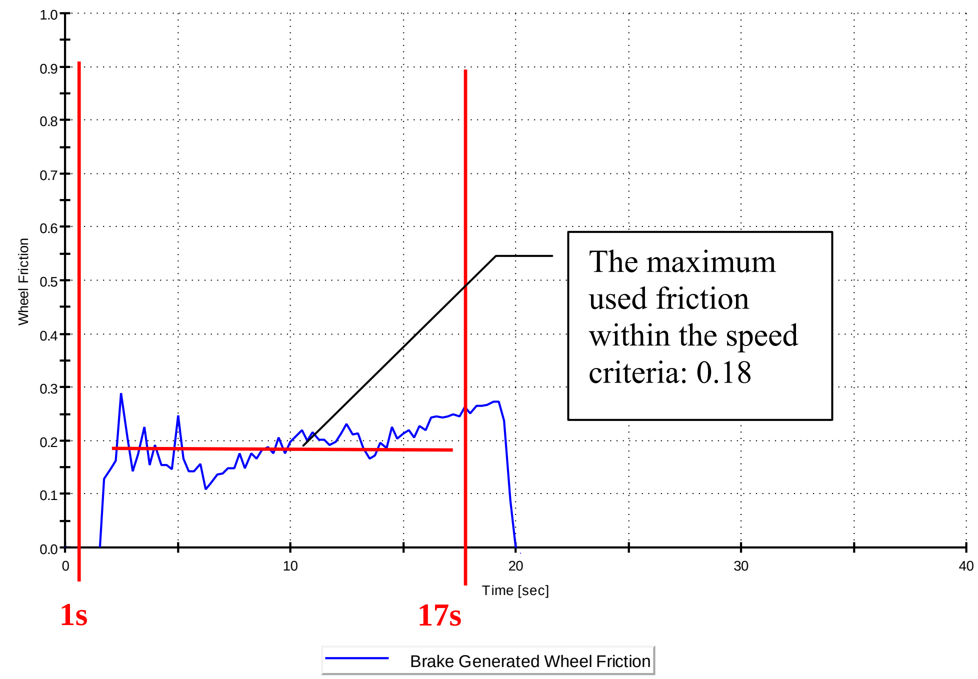

Figure 81 S5.txt Maximum Used Friction

S8.txt

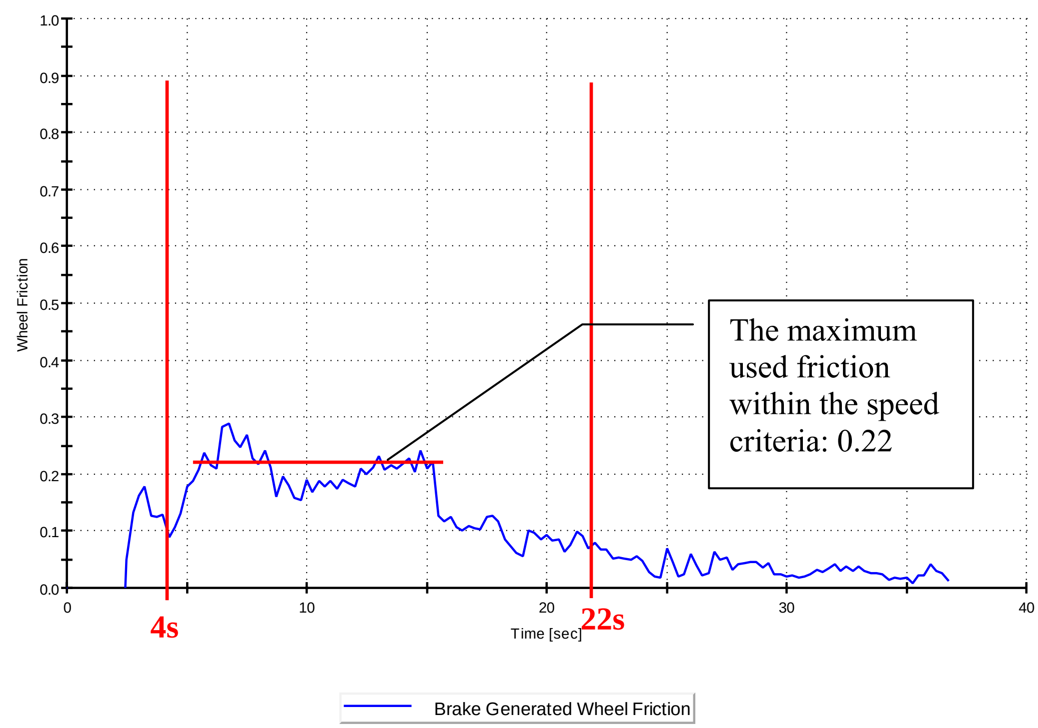

Figure 82 S8.txt Maximum Used Friction

S11.txt

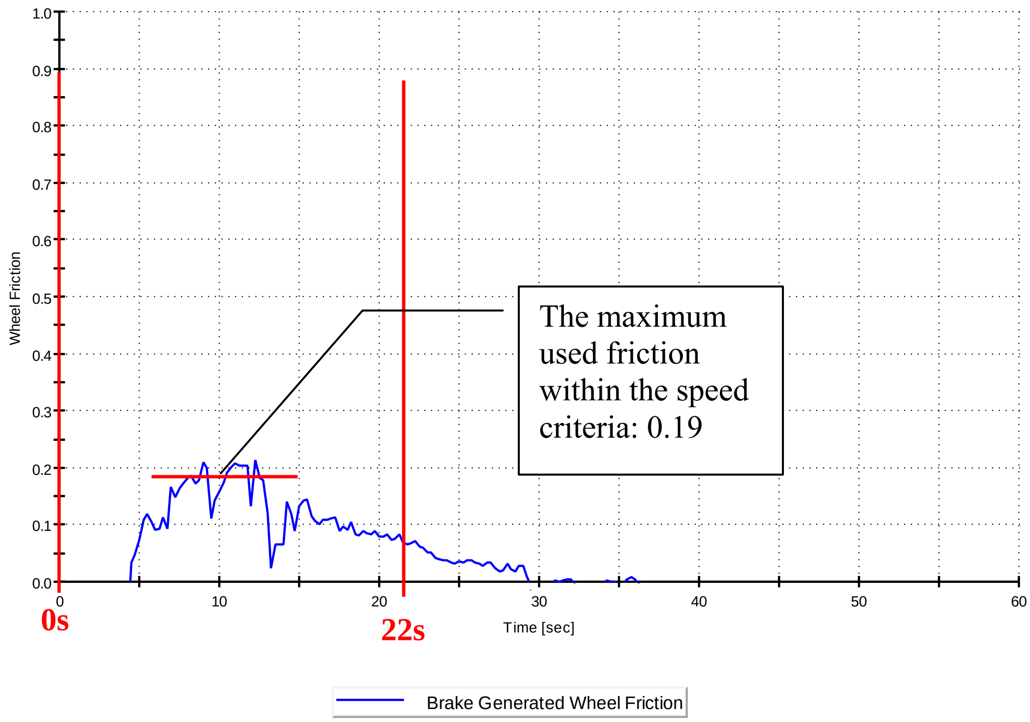

Figure 83 S11.txt Maximum Used Friction

S15.txt

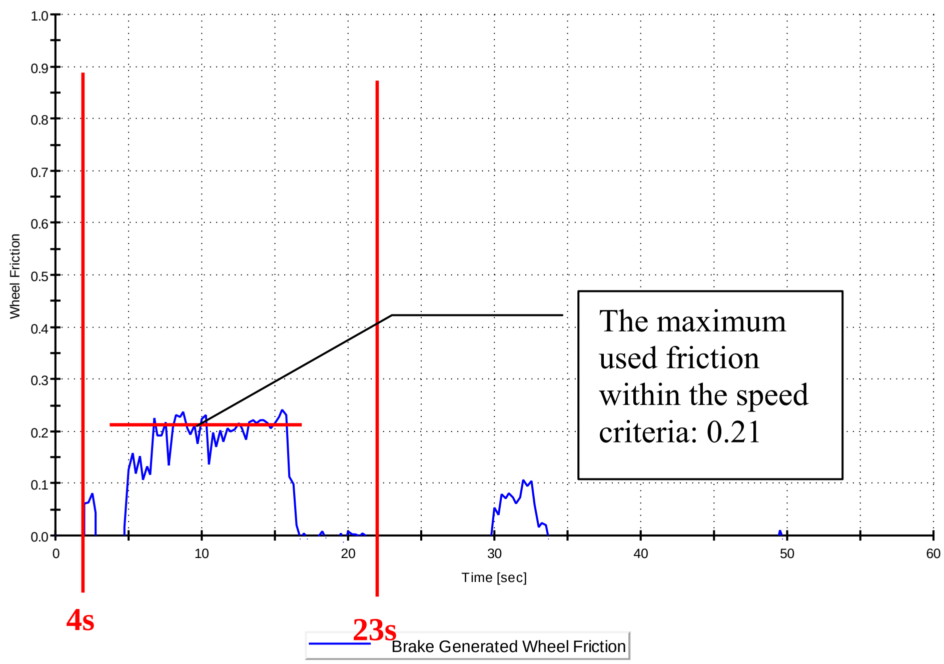

Figure 84 S15.txt Maximum Used Friction

The maximum used friction within the speed criteria for non friction limited runs is shown in Table 7.

Table 7 Summary of the Maximum Used Friction for the Non Friction Limited Runs

Flight No	Date/Time	File Name	Aircraft friction
F875	01.29.03/12:45	S1.txt	0.16
F877	01.21.03/19:05	S5.txt	0.18
F879	01.24.03/21:11	S8.txt	0.22
F875	01.30.03/12:30	S11.txt	0.19
F879	01.29.03/21:30	S15.txt	0.21

8.4 Comparing Aircraft Friction with the Ground Friction Measuring Device Measurements

Based on the aircraft data simulation, the data sets shown in Table 8 were identified as friction limited braking. These data sets then could be cross checked with the measured ground friction measurement data for further analysis.

Table 8 Summary of Aircraft Braking Friction with the Ground Friction Measuring Device Measurement for the Friction Limited Runs

Flight No.	Date/Time	File Name	Aircraft friction	AutoBrake setting	Saab Friction	Temp
F875	01.22.03/12:23	S2.txt	0.16	3	0.95-0.32*	-1
F877	01.24.03/18:46	S3.txt	0.17	4	0.33	-1
F879	01.20.03/20:53	S4.txt	0.22	4	0.95-0.39*	-2
F873	01.29.03/10:27	S7.txt	0.14	4	0.286	-4
F873	01.20.03/13:24	S9.txt	0.22	4	0.95	-3
F873	01.24.03/10:43	S10.txt	0.12	4	0.295	+0.5
F877	01.23.03/19:03	S12.txt	0.08	3	0.26	0
F877	01.29.03/18:37	S13.txt	0.15	3	0.296	-5
F879	01.30.03/21:30	S14.txt	0.21	4	0.36	+2.5
F879	01.31.03/21:14	S16.txt	0.17	4	0.30	-4
F879	01.23.03/21:14	S17.txt	0.09	4	0.24	0

* For these two data sets, NOT the last SNOWTAM released before the aircraft landing but the previous SNOWTAM data were used (see explanation below).

For both the S2 and S4 data sets, the last SNOWTAM released before the aircraft landing reported 0.95 SAAB friction values. During the analysis, these data sets produced data pairs that were outliers by an enormous margin. Upon closer inspection of the released SNOWTAM data sets prior to the one corresponding to the landing, a very significant discrepancy was discovered. For the S4 data set, the SNOWTAM released one hour prior to the aircraft landing contained 10mm/12mm/10mm 100% dry snow coverage for runway sections A/B/C with SAAB friction reading 0.39/0.39/0.39, respectively. The METAR and SNOWTAM both called for deteriorating conditions. The SNOWTAM released 10 minutes before the aircraft landing reported basically the same conditions with 10mm/12mm/10mm 100% dry snow coverage for runway sections A/B/C with SAAB friction reading 0.95/0.95/0.95, respectively, also with still deteriorating conditions. Based on these data, it can be concluded that the 0.95 friction coefficient was reported erroneously. The aircraft data strongly supports the hypothesis of an error in the

SAAB data. In the data analysis the earlier SAAB friction data of 0.39 was used instead of the last reported 0.95 friction coefficient.

The same reasoning can be applied for data set S2. One hour before the aircraft landing, a SNOWTAM released contained 3mm/3mm/3mm 100% dry snow coverage for runway sections A/B/C with generally deteriorating conditions, and 0.32/0.32/0.34 for corresponding SAAB friction coefficients. The SNOWTAM released prior to aircraft landing again contained basically the same conditions: 4mm/4mm/4mm 80% dry snow coverage with 0.95/0.95/0.95 friction readings. In this case as well as in the previous, the aircraft data strongly supports the hypothesis of wrongly reported friction coefficient. In this case also, not the last reported friction reading but instead the previously reported SAAB friction values were used.

For the S9 data set, very much the same observations apply. The SNOWTAM released prior to aircraft landing contains data than can lead to the same conclusion as above. The reported conditions and SAAB friction readings are contradictory. Unfortunately, in this case only one SNOWTAM was received prior to the aircraft landing. Consequently, cross checking and data correction was not possible. This data set was therefore excluded from further analysis.

9 RESULT – CORRELATION TO THE AKITA SAAB GFMD

From the data in Table 8, the following data sets proved to produce true friction limited braking data: S2, S3, S4, S7, S10, S12, S13, S14, S16, and S17. The obtained final results are collected in Table 9.

Table 9 Real Friction Limited Braking

File Name	Saab Friction	Aircraft friction
S2.txt	0.327	0.16
S3.txt	0.333	0.17
S4.txt	0.39	0.22
S7.txt	0.286	0.14
S10.txt	0.295	0.12
S12.txt	0.26	0.08
S13.txt	0.296	0.15
S14.txt	0.36	0.21
S16.txt	0.30	0.19
S17.txt	0.24	0.09

The obtained friction values were compared to the measured friction from the Saab Friction Tester used by Akita Airport. The paired data can be observed in Figure 85. The correlation of the measured ground friction to the effective braking friction data provided by the simulation is convincing. The obtained correlation coefficient shows a strong dependence of the aircraft braking friction on the reported ground friction measurements.

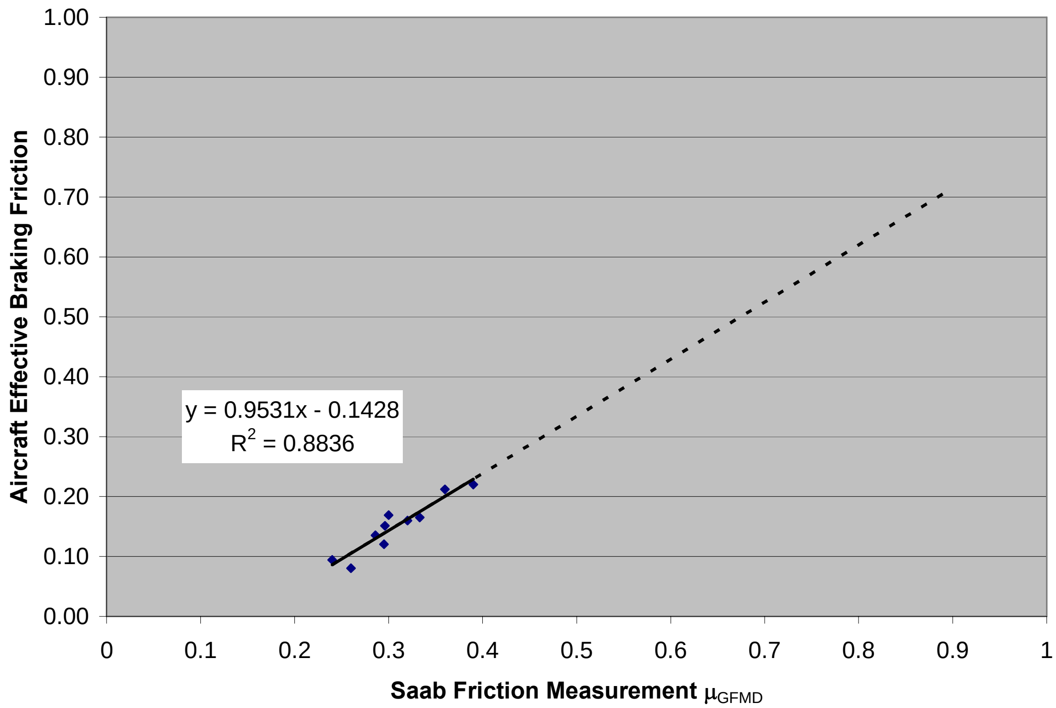

Figure 85 Saab Friction Measurement and Aircraft Effective Braking Friction Correlation

10 RESULT – CORRELATION TO THE IRFI

Because the International Reference Device (IRD) was only available at New Chitose Airport, Akita Airport's SAAB friction measuring device was not calibrated to report the IRFI. Therefore, this report includes only a correlation between the B767-300 and Akita Airport's SAAB friction measurement device.

However, it is anticipated that the difference in the result would only be the difference of the correlation values, but that the quality of the correlation (R^2) would be similar or improved.

11 CONCLUSIONS

According to the original test plan, measurements were to be taken at two different locations: New Chitose Airport and Akita Airport. Unfortunately, because of a lack of winter weather conditions, there were no aircraft measurements taken at New Chitose

Airport. Almost at the same time, due to the availability of the desired winter weather conditions at Akita Airport, several aircraft landing QAR data sets were recorded together with measurements taken with Akita Airport's SAAB friction measuring device.

A total of 43 flights were identified as candidates to be included in the study where the requested procedures were followed on winter surfaces. The flight data recorded in the QAR systems were saved and paired with the additional airport data for future analysis. The data validation, checking of actual runway conditions, inspection of the ground friction measurement data, and other consistency assessments eliminated a number of landing data sets.

Of the 43 flights, 10 flights proved to be valid friction limited landings. For these landings, a correlation between the B767-300 and Akita Airport's SAAB friction measuring device was developed, and the obtained correlation coefficient (R^2= 0.88) shows a strong dependence of the aircraft braking friction on the reported ground friction measurements.

Akita Airport's SAAB friction measuring device was not calibrated to report the IRFI. However, it is anticipated that the difference in the result would be only the difference of the correlation values, but that the quality of the correlation (R^2) would be similar or improved.

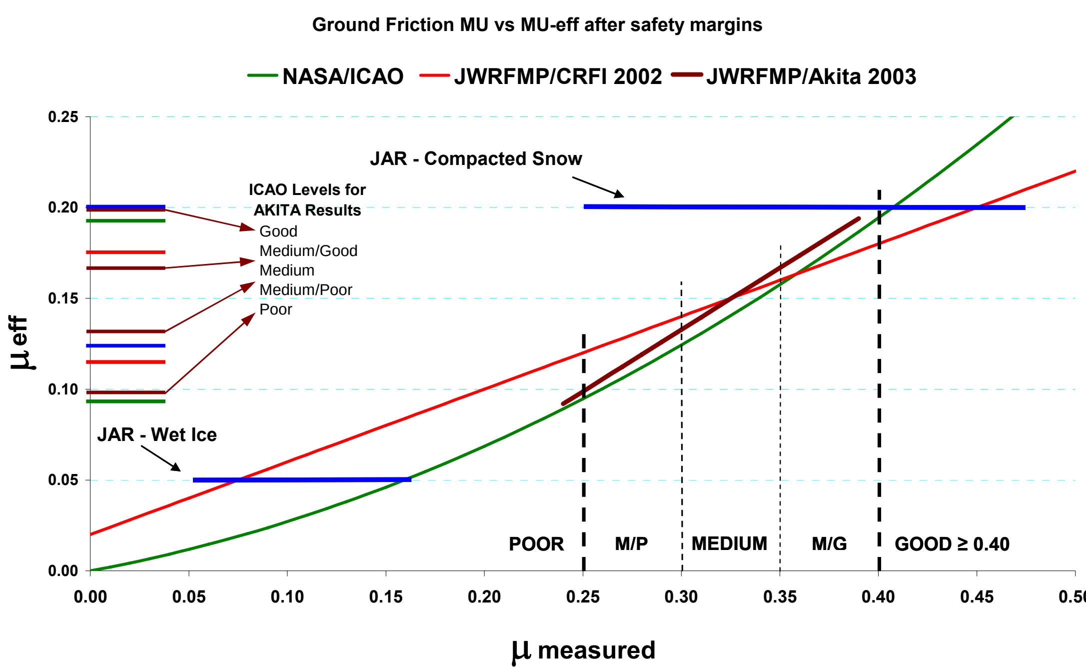

Figure 86 Comparison of New Results to Currently Used Values

The computed measurement results depicted in Figure 85 were adjusted with the ICAO recommended 5/7 and 0.5 safety rules and plotted against the currently used values in Figure 86. The graph shows the relative agreement of the newly obtained results to those of the adopted ICAO and new JAR regulatory numbers as well as the previously obtained JWRFMP results used by the CRFI index.

APPENDIX A - SNOWTAM DATA

FLIGHT :1/20/03 F879 20 53

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/20 11:44Z	20:44	20:53	9 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 10 mm	DRY SNOW	100%
-B - 12 mm	DRY SNOW	100%
-C - 10 mm	DRY SNOW	100%

W: COND SLIGHTLY DETERIORATING, BUT OPERATION WILL NOT BE AFFECTED

FLIGHT :1/20/03 F877 18:51

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/20 09:36Z	18:36	18:51	15 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	less 80%
-B - 1 mm	DRY SNOW	less 80%
-C - 1 mm	DRY SNOW	less 80%

W: CHANGE NOT EXPECTED

FLIGHT :1/20/03 F875 12:12

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/20 05:26Z	11:26	12:12	46 min

RMKS
3.) - SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - CLEAR		
-B - CLEAR		
-C - CLEAR		

W: CHANGE NOT EXPECTED

FLIGHT :1/20/03 F873 10:24

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/20 01:30Z	10:30	10:24	6 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 5 mm	DRY SNOW	100%
-B - 3 mm	DRY SNOW	LESS 80 %

FLIGHT :1/21/03 F879 21:21

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/21 11:24Z	20:24	21:02	13 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	100%
-B - 1 mm	DRY SNOW	100%
-C - 1 mm	DRY SNOW	100%

W: COND SLIGHTLY DETERIORATING, BUT OPERATION WILL NOT BE AFFECTED

FLIGHT :1/21/03 F877 19:05

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/21 09:50Z	18:50	19:05	15 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	100%
-B - 1 mm	DRY SNOW	100%
-C - 1 mm	DRY SNOW	100%

W: COND SLIGHTLY DETERIORATING, BUT OPERATION WILL NOT BE AFFECTED

FLIGHT :1/21/03 F875 12:21

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/21 02:38Z	11:38	12:21	43 min

RMKS
3.) 37/37/95- SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 5 mm	WET SNOW	100%
-B - 5 mm	WET SNOW	100%
-C - 3 mm	WET SNOW	100%

W: COND SLIGHTLY DETERIORATING, BUT OPERATION WILL NOT BE AFFECTED

FLIGHT :1/21/03 F873 10:29

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/21 00:47Z	9:47	10:29	42 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	WET SNOW	100%
-B - 1 mm	WET SNOW	100%

FLIGHT :1/22/03 F877 18:42

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/22 10:11Z	19:11	18:42	29 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	WET SNOW	100%
-B - 1 mm	WET SNOW	100%
-C - 1 mm	WET SNOW	100%

W: CHANGE NOT EXPECTED

FLIGHT :1/22/03 F875 12:23

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/22 02:59Z	11:59	12:23	24 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 4 mm	DRY SNOW	100%
-B - 4 mm	DRY SNOW	100%
-C - 4 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/22/03 F873 10:55

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/22 02:04Z	11:04	10:55	9 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 4 mm	DRY SNOW	LESS 80 %
-B - 4 mm	DRY SNOW	LESS 80 %
-C - 4 mm	DRY SNOW	LESS 80 %

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/23/03 F879 21:14

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/23 12:03Z	21:03	21:14	11 min

RMKS
3.) 24/24/24 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 5 mm	DRY SNOW	100%
-B - 8 mm	DRY SNOW	100%
-C - 10 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/23/03 F877 19:03

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/23 10:33Z	19:33	19:03	30 min

RMKS
3.) 26/26/26 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 26 mm	DRY SNOW	100%
-B - 26 mm	DRY SNOW	100%
-C - 26 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/23/03 F875 12:15

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/23 02:32Z	11:32	12:15	43 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	LESS 60%
-B - 1mm	DRY SNOW	LESS 60%
-C - 1mm	DRY SNOW	LESS 20%

W: CHANGE NOT EXPECTED

FLIGHT :1/23/03 F873 10:36

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/23 02:32Z	11:32	10:36	56 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	LESS 60%
-B - 1mm	DRY SNOW	LESS 60%

FLIGHT :1/24/03 F879 21:11

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/24 11:40Z	20:40	21:11	31 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 2 mm	WET SNOW	100%
-B - 2 mm	WET SNOW	100%
-C - 2 mm	WET SNOW	100%

W: CHANGE NOT EXPECTED

FLIGHT :1/24/03 F877 18:46

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/24 09:38Z	18:38	18:46	8 min

RMKS
3.) 33/32/35 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 5 mm	DRY SNOW	100%
-B - 5 mm	DRY SNOW	100%
-C - 5 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/24/03 F875 12:47

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/24 03:15Z	12:15	12:47	32 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 2 mm	WET SNOW	LESS 60%
-B - 2 mm	WET SNOW	LESS 60%
-C - 2 mm	WET SNOW	LESS 60%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/24/03 F873 10:43

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/24 01:21Z	10:21	10:43	22 min

RMKS
3.) 95/32/27 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 15 mm	DRY SNOW	100%
-B - 15 mm	DRY SNOW	100%

FLIGHT :1/29/03 F879 21:30

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/29 12:01Z	21:01	21:30	29 min

RMKS
3.) 35/35/35 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 2 mm	DRY SNOW	100%
-B - 2 mm	DRY SNOW	100%
-C - 2 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/29/03 F877 18:37

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/29 09:09Z	18:09	18:37	29 min

RMKS
3.) 34/26/29 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 5 mm	DRY SNOW	less 80%
-B - 5 mm	DRY SNOW	less 80%
-C - 3 mm	DRY SNOW	less 80%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/29/03 F875 12:45

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/29 03:52Z	12:52	12:45	7 min

RMKS
3.) 34/35/35 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 7 mm	DRY SNOW	100%
-B - 7 mm	DRY SNOW	100%
-C - 7 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/29/03 F873 10:27

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/29 01:12Z	10:12	10:27	15 min

RMKS
3.) 28/29/29 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 12 mm	DRY SNOW	100%
-B - 12 mm	DRY SNOW	100%

FLIGHT :1/30/03 F879 21:01

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/30 11:20Z	20:20	21:01	41 min

RMKS
3.) 39/36/34 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 10 mm	DRY SNOW	100%
-B - 10 mm	DRY SNOW	100%
-C - 12 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/30/03 F877 18:53

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/30 09:27Z	18:27	18:53	26 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 2 mm	DRY SNOW	100%
-B - 2 mm	DRY SNOW	100%
-C - 2 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/30/03 F875 12:30

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/30 03:51Z	12:51	12:30	21 min

RMKS
3.) 27/29/27 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 20 mm	DRY SNOW	100%
-B - 10 mm	DRY SNOW	100%
-C - 20 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/30/03 F873 10:39

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/30 01:26Z	10:26	10:39	13 min

RMKS
3.) 30/31/31 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 8 mm	DRY SNOW	100%
-B - 8 mm	DRY SNOW	100%

FLIGHT :1/31/03 F879 20:55

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/31 11:31Z	20:31	20:55	16 min

RMKS
3.) 95/31/29 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 10 mm	DRY SNOW	100%
-B - 10 mm	DRY SNOW	100%
-C - 7 mm	DRY SNOW	100%

W: GENERALLY DETERIORATING COND EXPECTED

FLIGHT :1/31/03 F877 18:47

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/31 09:307Z	18:30	18:47	17 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 2 mm	DRY SNOW	100%
-B - 2 mm	DRY SNOW	100%
-C - 2 mm	DRY SNOW	100%

W: CHANGE NOT EXPECTED

FLIGHT :1/31/03 F875 12:12

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/31 04:53Z	13:53	12:12	101 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	WET SNOW	LESS 40%
-B - 1 mm	WET SNOW	LESS 40%
-C - 1 mm	WET SNOW	LESS 40%

W: CHANGE NOT EXPECTED

FLIGHT :1/31/03 F873 10:21

Date / Time of SNOTAM	Japan standard time	Aircraft landing	Time to/after aircraft landing
S/I cond as of 03/01/31 01:48Z	10:48	10:21	27 min

RMKS
3.) 95/95/95 SAAB TYPE CONTINUOUS MEASURING DEVICE

Area /Snow	Depth-class of snow	Coverage
-A - 1 mm	DRY SNOW	LESS 60%
-B - 1 mm	DRY SNOW	LESS 60%

APPENDIX B – WEIGHT & BALANCE DATA

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 20JAN03 09:17 NH0873

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	186100	+	50	11. Z.F. WT	=	209300	12.00%	33.00%
3. ADNL	=	200	-	1	MAC	=	19.40%	>---V	------<
4. (2)+(3)	=	186300	+	49	12. TAXI WT	=	239300	11.40%	33.50%
5. FUEL	=	30000			MAC	=	18.60%	>---V	------<
6. WQBF	=	216300			STAB	=	3.3		
7. A.C.L.	=	72400			14. L/D WT	=	230500		
8. PAX 120	=	18000							
9. BCM-TTL	=	5000							
10. PAYLOAD	=	23000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 20JAN03 11:04 NH0875

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	185300	+	49	11. Z.F. WT	=	218200	11.90%	33.20%
3. ADNL	=	0	-	0	MAC	=	23.50%	>-----V	----<
4. (2)+(3)	=	185300	+	49	12. TAXI WT	=	251200	11.20%	33.70%
5. FUEL	=	33000			MAC	=	22.20%	>---V	------<
6. WQBF	=	218300			STAB	=	2.9		
7. A.C.L.	=	70400			14. L/D WT	=	242100		
8. PAX 120	=	29100							
9. BCM-TTL	=	3800							
10. PAYLOAD	=	32900							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 20JAN03 17:31 NH0877

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	192600	+	46	11. Z.F. WT	=	219900	11.80%	33.20%
3. ADNL	=	0	-	0	MAC	=	21.00%	>----V	-----<
4. (2)+(3)	=	192600	+	46	12. TAXI WT	=	253000	11.20%	33.70%
5. FUEL	=	33100			MAC	=	20.10%	>---V	------<
6. WQBF	=	225700			STAB		MAX=2.5	D1=3.0	D2=3.5
7. A.C.L.	=	63000			14. L/D WT	=	244100		
8. PAX 120	=	21200							
9. BCM-TTL	=	6100							
10. PAYLOAD	=	27300							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 20JAN03 19:53 NH0879

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	186300	+	48	11. Z.F. WT	=	210800	12.00%	33.00%
3. ADNL	=	0	-	0	MAC	=	19.20%	>---V	------<
4. (2)+(3)	=	186300	+	48	12. TAXI WT	=	244100	11.30%	33.60%
5. FUEL	=	33300			MAC	=	18.50%	>---V	------<
6. WQBF	=	219600			STAB	=	3.4		
7. A.C.L.	=	69100			14. L/D WT	=	235200		
8. PAX 120	=	21800							
9. BCM-TTL	=	2700							
10. PAYLOAD	=	24500							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 21JAN03 19:50 NH0879

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	185800	+	49	11. Z.F. WT	=	216600	11.90%	33.20%
3. ADNL	=	0	-	0	MAC	=	19.20%	>---V ------<	
4. (2)+(3)	=	185800	+	49	12. TAXI WT	=	252700	11.20%	33.70%
5. FUEL	=	36100			MAC	=	18.60%	>---V ------<	
6. WQBF	=	221900			STAB	=	3.5		
7. A.C.L.	=	66800			14. L/D WT	=	243500		
8. PAX 120	=	25300							
9. BCM-TTL	=	5500							
10. PAYLOAD	=	30800							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 21JAN03 17:32 NH0877

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	185900	+	50	11. Z.F. WT	=	205300	12.10%	32.90%
3. ADNL	=	200	-	1	MAC	=	16.40%	>--V -------<	
4. (2)+(3)	=	186100	+	49	12. TAXI WT	=	240000	11.40%	33.50%
5. FUEL	=	34700			MAC	=	16.10%	>--V -------<	
6. WQBF	=	220800			STAB	=	3.7		
7. A.C.L.	=	67900			14. L/D WT	=	231000		
8. PAX 120	=	17300							
9. BCM-TTL	=	1900							
10. PAYLOAD	=	19200							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 21JAN03 11:06 NH0875

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	186100	+	50	11. Z.F. WT	=	213500	11.90%	33.10%
3. ADNL	=	0	-	0	MAC	=	16.40%	>------V ---<	
4. (2)+(3)	=	186100	+	50	12. TAXI WT	=	249600	11.20%	33.70%
5. FUEL	=	36100			MAC	=	23.30%	>-----V ----<	
6. WQBF	=	222200			STAB	=	2.7		
7. A.C.L.	=	66500			14. L/D WT	=	240500		
8. PAX 120	=	25800							
9. BCM-TTL	=	1600							
10. PAYLOAD	=	27400							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 21JAN03 09:19 NH0873

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	185700	+	49	11. Z.F. WT	=	210300	12.00%	33.00%
3. ADNL	=	0	-	0	MAC	=	17.40%	>--V -------<	
4. (2)+(3)	=	185700	+	49	12. TAXI WT	=	245600	11.30%	33.60%
5. FUEL	=	35300			MAC	=	17.70%	>--V -------<	
6. WQBF	=	221000			STAB	=	3.7		
7. A.C.L.	=	67700			14. L/D WT	=	236800		
8. PAX 120	=	23300							
9. BCM-TTL	=	1300							
10. PAYLOAD	=	24600							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 22JAN03 19:52 NH0879

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185900	+	49	11. Z.F. WT	=	228400	11.60%	33.30%
3. ADNL	=	0	-	0	MAC	=	23.30%	>-----V ----<	
4. (2)+(3)	=	185900	+	49	12. TAXI WT	=	266200	11.00%	33.90%
5. FUEL	=	37800			MAC	=	22.20%	>----V -----<	
6. WQBF	=	223700			STAB	=	3.2		
7. A.C.L.	=	65000			14. L/D WT	=	256800		
8. PAX 120	=	34900							
9. BCM-TTL	=	7600							
10. PAYLOAD	=	42500							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 22JAN03 17:36 NH0877

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185800	+	49	11. Z.F. WT	=	231400	11.60%	33.40%
3. ADNL	=	0	-	0	MAC	=	22.90%	>-----V ----<	
4. (2)+(3)	=	185800	+	49	12. TAXI WT	=	269100	11.00%	33.90%
5. FUEL	=	37700			MAC	=	21.80%	>----V -----<	
6. WQBF	=	223500			STAB	=	3.3		
7. A.C.L.	=	65200			14. L/D WT	=	259600		
8. PAX 120	=	38800							
9. BCM-TTL	=	6800							
10. PAYLOAD	=	45600							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 22JAN03 11:06 NH0875

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185700	+	49	11. Z.F. WT	=	216400	11.90%	33.20%
3. ADNL	=	0	-	0	MAC	=	24.40%	>----V -----<	
4. (2)+(3)	=	185700	+	49	12. TAXI WT	=	252300	11.20%	33.70%
5. FUEL	=	35900			MAC	=	23.00%	>-----V ----<	
6. WQBF	=	221600			STAB	=	2.8		
7. A.C.L.	=	67100			14. L/D WT	=	242800		
8. PAX 120	=	25900							
9. BCM-TTL	=	4800							
10. PAYLOAD	=	30700							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 22JAN03 09:24 NH0873

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	187000	+	49	11. Z.F. WT	=	213700	11.90%	33.10%
3. ADNL	=	0	-	0	MAC	=	17.60%	>--V -------<	
4. (2)+(3)	=	187000	+	49	12. TAXI WT	=	249500	11.20%	33.70%
5. FUEL	=	35800			MAC	=	17.10%	>--V -------<	
6. WQBF	=	222800			STAB	=	3.7		
7. A.C.L.	=	65900			14. L/D WT	=	239900		
8. PAX 120	=	22400							
9. BCM-TTL	=	4300							
10. PAYLOAD	=	26700							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 23JAN03 09:21 NH0873

		WT		IU				FL	AL
1. ATOW(1)	=	288700							
2. Q.E.W.	=	185900	+	48	11. Z.F. WT	=	220500	11.80%	33.20%
3. ADNL	=	300	-	1	MAC	=	18.30%	>---V	------<
4. (2)+(3)	=	186200	+	47	12. TAXI WT	=	254700	11.20%	33.70%
5. FUEL	=	34200			MAC	=	17.70%	>--V	-------<
6. WQBF	=	220400			STAB	=	3.7		
7. A.C.L.	=	68300			14. L/D WT	=	246000		
8. PAX 120	=	32900							
9. BCM-TTL	=	1400							
10. PAYLOAD	=	34300							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 23JAN03 11:04 NH0875

		WT		IU				FL	AL
1. ATOW(1)	=	288600							
2. Q.E.W.	=	187000	+	49	11. Z.F. WT	=	214100	12.00%	33.10%
3. ADNL	=	0	-	0	MAC	=	20.30%	>---V	------<
4. (2)+(3)	=	187000	+	49	12. TAXI WT	=	248100	11.30%	33.70%
5. FUEL	=	34000			MAC	=	19.40%	>---V	------<
6. WQBF	=	221000			STAB	=	3.3		
7. A.C.L.	=	67600			14. L/D WT	=	239500		
8. PAX 120	=	25900							
9. BCM-TTL	=	1200							
10. PAYLOAD	=	27100							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 23JAN03 17:39 NH0877

		WT		IU				FL	AL
1. ATOW(1)	=	288600							
2. Q.E.W.	=	186000	+	48	11. Z.F. WT	=	221200	11.80%	33.20%
3. ADNL	=	200	-	1	MAC	=	22.10%	>----V	-----<
4. (2)+(3)	=	186200	+	47	12. TAXI WT	=	258200	11.10%	33.80%
5. FUEL	=	37000			MAC	=	19.40%	>----V	-----<
6. WQBF	=	223200			STAB	=	3.2		
7. A.C.L.	=	65400			14. L/D WT	=	249600		
8. PAX 120	=	32200							
9. BCM-TTL	=	2800							
10. PAYLOAD	=	35000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 23JAN03 19:51 NH0879

		WT		IU				FL	AL
1. ATOW(1)	=	288600							
2. Q.E.W.	=	185700	+	48	11. Z.F. WT	=	214700	11.90%	33.10%
3. ADNL	=	0	-	0	MAC	=	20.50%	>----V	-----<
4. (2)+(3)	=	185700	+	48	12. TAXI WT	=	250700	11.20%	33.70%
5. FUEL	=	36000			MAC	=	19.60%	>---V	-----<
6. WQBF	=	221700			STAB	=	3.3		
7. A.C.L.	=	66900			14. L/D WT	=	242100		
8. PAX 120	=	21800							
9. BCM-TTL	=	7200							
10. PAYLOAD	=	29000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 24JAN03 09:23 NH0873

```
                    WT          IU
1. ATOW(1)   =    288700                                                FL        AL
2. Q.E.W.    =    185900  +     49        11. Z.F.  WT    =     207900  12.10%    33.00%
3. ADNL      =       200  -      1                  MAC =       19.80%  >---V ------<
4. (2)+(3)   =    186100  +     48        12. TAXI  WT    =     241800  11.40%    33.60%
5. FUEL      =     33900                            MAC =       19.00%  >---V ------<
6. WQBF      =    220000                           STAB =          3.3
7. A.C.L.    =     68700                  14. L/D  WT     =     232900
8. PAX 120   =     18200
9. BCM-TTL   =      3600
10. PAYLOAD  =     21800
```

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 24JAN03 11:05 NH0875

```
                    WT          IU
1. ATOW(1)   =    288700                                                FL        AL
2. Q.E.W.    =    186300  +     48        11. Z.F.  WT    =     211900  12.00%    33.00%
3. ADNL      =       200  -      1                  MAC =       20.50%  >----V -----<
4. (2)+(3)   =    186500  +     47        12. TAXI  WT    =     246800  11.30%    33.60%
5. FUEL      =     34900                            MAC =       19.60%  >---V ------<
6. WQBF      =    221400                           STAB =          3.3
7. A.C.L.    =     67300                  14. L/D  WT     =     237700
8. PAX 120   =     22900
9. BCM-TTL   =      2500
10. PAYLOAD  =     25400
```

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 24JAN03 17:34 NH0877

```
                    WT          IU
1. ATOW(1)   =    288700                                                FL        AL
2. Q.E.W.    =    184500  +     47        11. Z.F.  WT    =     218900  11.80%    33.20%
3. ADNL      =         0  -      0                  MAC =       20.50%  >-V --------<
4. (2)+(3)   =    184500  +     47        12. TAXI  WT    =     255200  11.10%    33.70%
5. FUEL      =     36300                            MAC =       15.50%  >-V --------<
6. WQBF      =    220800                           STAB =          4.1
7. A.C.L.    =     67900                  14. L/D  WT     =     245800
8. PAX 120   =     28300
9. BCM-TTL   =      6100
10. PAYLOAD  =     34400
```

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 24JAN03 20:00 NH0879

```
                    WT          IU
1. ATOW(1)   =    288700                                                FL        AL
2. Q.E.W.    =    185300  +     49        11. Z.F.  WT    =     227800  11.60%    33.30%
3. ADNL      =         0  -      0                  MAC =       20.50%  >----V -----<
4. (2)+(3)   =    185300  +     49        12. TAXI  WT    =     265600  11.00%    33.80%
5. FUEL      =     37800                            MAC =       21.00%  >----V -----<
6. WQBF      =    223100                           STAB =          3.4
7. A.C.L.    =     65600                  14. L/D  WT     =     255800
8. PAX 120   =     36800
9. BCM-TTL   =      5700
10. PAYLOAD  =     42500
```

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 29JAN03 09:19 NH0873

		WT		IU					
1. ATOW(1)	=	288600						FL	AL
2. Q.E.W.	=	185800	+	49	11. Z.F. WT	=	209100	12.10%	33.00%
3. ADNL	=	0	-	0	MAC	=	20.50%	>---V ------<	
4. (2)+(3)	=	185800	+	49	12. TAXI WT	=	244700	11.30%	33.60%
5. FUEL	=	35600			MAC	=	18.00%	>---V ------<	
6. WQBF	=	221400			STAB	=	3.5		
7. A.C.L.	=	67200			14. L/D WT	=	236100		
8. PAX 120	=	18200							
9. BCM-TTL	=	5100							
10. PAYLOAD	=	23300							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 29JAN03 11:07 NH0875

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185400	+	49	11. Z.F. WT	=	207500	12.10%	33.00%
3. ADNL	=	0	-	0	MAC	=	19.00%	>---V ------<	
4. (2)+(3)	=	185400	+	49	12. TAXI WT	=	247500	11.30%	33.60%
5. FUEL	=	40000			MAC	=	18.50%	>---V ------<	
6. WQBF	=	225400			STAB	=	3.5		
7. A.C.L.	=	63300			14. L/D WT	=	238700		
8. PAX 120	=	21100							
9. BCM-TTL	=	1000							
10. PAYLOAD	=	22100							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 29JAN03 17:37 NH0877

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185700	+	49	11. Z.F. WT	=	220000	11.80%	33.20%
3. ADNL	=	0	-	0	MAC	=	19.10%	>---V ------<	
4. (2)+(3)	=	185700	+	49	12. TAXI WT	=	256400	11.20%	33.70%
5. FUEL	=	36400			MAC	=	18.50%	>---V ------<	
6. WQBF	=	222100			STAB	=	3.6		
7. A.C.L.	=	66600			14. L/D WT	=	247400		
8. PAX 120	=	30700							
9. BCM-TTL	=	3600							
10. PAYLOAD	=	34300							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 29JAN03 19:52 NH0879

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185900	+	49	11. Z.F. WT	=	225500	11.70%	33.30%
3. ADNL	=	0	-	0	MAC	=	19.10%	>------V ---<	
4. (2)+(3)	=	185900	+	49	12. TAXI WT	=	262800	11.00%	33.80%
5. FUEL	=	37300			MAC	=	23.40%	>-----V ----<	
6. WQBF	=	223200			STAB	=	2.9		
7. A.C.L.	=	65500			14. L/D WT	=	253400		
8. PAX 120	=	33700							
9. BCM-TTL	=	5900							
10. PAYLOAD	=	39600							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 30JAN03 09:17 NH0873

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185500	+	48	11. Z.F. WT	=	205900	12.10%	33.00%
3. ADNL	=	0	-	0	MAC	=	19.50%	>---V ------<	
4. (2)+(3)	=	185500	+	48	12. TAXI WT	=	240700	11.40%	33.60%
5. FUEL	=	34800			MAC	=	18.70%	>---V ------<	
6. WQBF	=	220300			STAB	=	3.3		
7. A.C.L.	=	68400			14. L/D WT	=	231600		
8. PAX 120	=	18200							
9. BCM-TTL	=	2200							
10. PAYLOAD	=	20400							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 30JAN03 11:06 NH0875

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185700	+	49	11. Z.F. WT	=	210000	12.00%	33.10%
3. ADNL	=	200	-	1	MAC	=	19.10%	>---V ------<	
4. (2)+(3)	=	185900	+	48	12. TAXI WT	=	250000	11.30%	33.60%
5. FUEL	=	40000			MAC	=	18.50%	>---V ------<	
6. WQBF	=	225900			STAB	=	3.5		
7. A.C.L.	=	62800			14. L/D WT	=	240500		
8. PAX 120	=	23000							
9. BCM-TTL	=	1100							
10. PAYLOAD	=	24100							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 30JAN03 17:33 NH0877

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185700	+	49	11. Z.F. WT	=	211900	12.00%	33.00%
3. ADNL	=	200	-	1	MAC	=	17.50%	>--V -------<	
4. (2)+(3)	=	185900	+	48	12. TAXI WT	=	247500	11.30%	33.60%
5. FUEL	=	35600			MAC	=	17.10%	>--V -------<	
6. WQBF	=	221500			STAB	=	3.7		
7. A.C.L.	=	67200			14. L/D WT	=	238100		
8. PAX 120	=	23700							
9. BCM-TTL	=	2300							
10. PAYLOAD	=	26000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 30JAN03 19:50 NH0879

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	186200	+	49	11. Z.F. WT	=	213200	12.00%	33.10%
3. ADNL	=	0	-	0	MAC	=	20.10%	>---V ------<	
4. (2)+(3)	=	186200	+	49	12. TAXI WT	=	249500	11.30%	33.70%
5. FUEL	=	36300			MAC	=	19.30%	>---V ------<	
6. WQBF	=	222500			STAB	=	3.4		
7. A.C.L.	=	66200			14. L/D WT	=	240000		
8. PAX 120	=	22000							
9. BCM-TTL	=	5000							
10. PAYLOAD	=	27000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 31JAN03 09:15 NH0873

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185300	+	49	11. Z.F. WT	=	201300	12.30%	32.80%
3. ADNL	=	0	-	0	MAC	=	19.40%	>---V	------<
4. (2)+(3)	=	185300	+	49	12. TAXI WT	=	236200	11.50%	33.40%
5. FUEL	=	34900			MAC	=	18.60%	>---V	------<
6. WQBF	=	220200			STAB	=	3.3		
7. A.C.L.	=	68500			14. L/D WT	=	227200		
8. PAX 120	=	13800							
9. BCM-TTL	=	2200							
10. PAYLOAD	=	16000							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 31JAN03 11:04 NH0875

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185500	+	48	11. Z.F. WT	=	202100	12.20%	32.90%
3. ADNL	=	0	-	0	MAC	=	16.80%	>--V	-------<
4. (2)+(3)	=	185500	+	48	12. TAXI WT	=	236700	11.50%	33.50%
5. FUEL	=	34600			MAC	=	16.40%	>--V	-------<
6. WQBF	=	220100			STAB	=	3.6		
7. A.C.L.	=	68600			14. L/D WT	=	227700		
8. PAX 120	=	15500							
9. BCM-TTL	=	1100							
10. PAYLOAD	=	16600							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 31JAN03 17:34 NH0877

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	186300	+	48	11. Z.F. WT	=	217500	11.90%	33.20%
3. ADNL	=	0	-	0	MAC	=	19.50%	>---V	------<
4. (2)+(3)	=	186300	+	48	12. TAXI WT	=	254300	11.20%	33.70%
5. FUEL	=	36800			MAC	=	18.80%	>---V	------<
6. WQBF	=	223100			STAB	=	3.5		
7. A.C.L.	=	65600			14. L/D WT	=	244800		
8. PAX 120	=	28200							
9. BCM-TTL	=	3000							
10. PAYLOAD	=	31200							

FINAL COMPUTERIZED WEIGHT & BALANCE MANIFEST 31JAN03 19:48 NH0879

		WT		IU					
1. ATOW(1)	=	288700						FL	AL
2. Q.E.W.	=	185700	+	48	11. Z.F. WT	=	219300	11.90%	33.20%
3. ADNL	=	0	-	0	MAC	=	18.00%	>--V	-------<
4. (2)+(3)	=	185700	+	48	12. TAXI WT	=	252600	11.20%	33.70%
5. FUEL	=	33300			MAC	=	17.40%	>--V	-------<
6. WQBF	=	219000			STAB	=	3.7		
7. A.C.L.	=	69700			14. L/D WT	=	243300		
8. PAX 120	=	25800							
9. BCM-TTL	=	7800							
10. PAYLOAD	=	33600							

APPENDIX C – METAR DATA

1/20/2003

1200/20	RJSK	201200Z	VRB02KT	6000	-SHSN	FEW005	SCT010	BKN020	M02/M03
	Q1008	RMK	1ST005	4ST010	7CU020	A2978=			
20:53 F879									
1142/20	RJSK	201142Z	VRB01KT	3500	-SHSN	FEW008	BKN015	BKN025	M02/M04
	Q1008	RMK	1ST008	5ST015	7CU025	A2978=			
0953/20	RJSK	200953Z	VRB03KT	2500	-SHSN	FEW010	SCT020	BKN030	M01/M03
	Q1008	RMK	1ST010	4CU020	7CU030	A2979=			
18:51 F877									
0900/20	RJSK	200900Z	28006KT	250V340	8000	-SHSN	FEW020	BKN035	M01/M07
	Q1008	RMK	2CU020	7CU035	A2979	4000W-NW=			
0321/20	RJSK	200321Z	VRB01KT	6000	-SHSN	FEW007	BKN020	BKN030	M01/M03
	Q1008	RMK	1ST007	5CU020	7CU030	A2978=			
03:12 F875									
0300/20	RJSK	200300Z	00000KT	4000	-SHSN	BR FEW007	SCT010	BKN020	M02/M03
	Q1008	RMK	1ST007	3ST010	6CU020	A2979=			
0138/20	RJSK	200138Z	VRB02KT	2000	-SHSN	BR SCT1010	BKN020	BKN030	M03/M04
	Q1009	3ST010	5CU020	7CU030	A2981=				
01:24 F873									
0100/20	RJSK	200100Z	VRB03KT	4000	-SHSN	BR FEW010	SCT020	BKN030	M03/M04
	Q1009	RMK	1ST010	3CU020	7CU030	A2982=			

1/21/2003

1107/21	RJSK	211107Z	32010KT	3500	-SHSN	FEW010	SCT020	BKN030	M04/M06
	Q1012	RMK	1ST010	3CU020	7CU030	A2990=			
19:05 F877									
1000/21	RJSK	211000Z	32008KT	9999	-SHSN	FEW010	SCT020	BKN030	M04/M05
	Q1012	REBLSN	RMK	1ST010	3CU020	5CU030	A2990=		
0400/21	RJSK	210400Z	30019G30KT	9999	-BLSN	FEW020	SCT035	BKN050	M02/M12
	Q1007	RMK	1CU020	3CU035	6CU050	A2975=			
12:21 F875									
0303/21	RJSK	210303Z	30017G29KT	9999	-BLSN	-SHSN	FEW010	SCT020	BKN035
	M02/M10	Q1007	RMK	1ST010	3CU020	7CU035	A2974=		
0210/21	RJSK	210210Z	29018KT	0800	R28/1100	VP1800U	BLSN	SHSN	FEW003
	SCT008	BKN025	M04/M05	Q1007	RMK	1ST003	3ST008	7CU025	A2976=
10:29 F873									
0100/21	RJSK	210100Z	28012KT	9999	-SHSN	FEW005	SCT010	BKN030	M03/M06
	Q1008	RMK	1ST005	3ST010	7CU030	A2977=			

1/22/2003

0200/22	RJSK	220200Z	26013KT	600	R28/P1800N	BLSN	SHSN	VV003	M02/M04
	Q1014	REGS	RMK	A2995=					
10:55 F873									
0152/22	RJSK	220152Z	26014KT	3500	-SHSN	FEW005	SCT010	BKN020	M02/M04
	Q1014	REBLSN	REGS	RMK	1ST005	3ST010	7CU020	A2995=	
0330/22	RJSK	220330Z	30013KT	5000	-SHSN	FEW005	SCT010	BKN030	M01/M05
	Q1013	RMK	1ST005	3ST010	7CU030	A2992=			
12:23 F875									
0317/22	RJSK	220317Z	29018KT	2800	-BLSN	-SHSN	FEW005	SCT010	BKN030
	M01/M05	Q1013	RMK	1ST005	3ST010	7CU030	A2992=		
1000/22	RJSK	221000Z	29010KT	9999	-SHSN	FEW020	SCT030	BKN040	M00/M06
	Q1013	RMK	1CU020	3CU030	7CU040	A2992=			
18:42 F877									
0900/22	RJSK	220900Z	30005KT	260V330	9999	FEW020	SCT030	BKN045	M01/M07
	Q1013	RMK	1CU020	3CU030	7CU045	A2994=			
1200/22	RJSK	221200Z	30004KT	9999	FEW020	SCT030	BKN040	M01/M05	
	Q1012	RMK	1CU020	4CU030	7CU040	A2991=			
20:50 F879									

1/23/2003

0200/23	RJSK	230200Z	12005KT	9999	SCT035	BKN060	M02/M05		
	Q1005	RMK	3CU035	7SC060	A2970=				
10:36 F783									
0100/23	RJSK	230100Z	14006KT	9999	SCT035	BKN050	M03/M05		
	Q1007	RMK	3CU035	7SC050	A2974=				
0329/23	RJSK	230329Z	11004KT	080V140	4000	-SN	SCT015	BKN035	M00/M03
	Q1002	RMK	4ST015	7SC035	A2961 P/RF=				
12:15 F875									
0300/23	RJSK	230300Z	14004KT	100V190	9999	-SN	FEW030	BKN045	BKN070
	M00/M04	Q1004	RMK	2CU030	6SC045	7AC070	A2965=		
0800/23	RJSK	230800Z	VRB01KT	1000	R28/P1800N	-SN BR	FEW003	BKN005	BKN015
	00/M00	Q0998	RMK	1ST003	5ST005	7ST015	A2949=		
21:14 F879									
1200/23	RJSK	231200Z	30004KT	1000	R28/P1800N	-SN BR	FEW003	BKN005	BKN012
	00/M00	Q0997	RMK	1ST003	5ST005	7ST012	A2946=		
1100/23	RJSK	231100Z	VRB02KT	1000	R28/P1800N	-SN BR	FEW003	BKN005	BKN012
	00/M00	Q0997	RMK	1ST003	5ST005	7ST012	A2947=		
19:03 F877									
1000/23	RJSK	231000Z	00000KT	1000	R28/P1800N	-SN BR	FEW003	BKN005	BKN012
	00/M00	Q0998	RMK	1ST003	5ST005	7ST012	A2948=		

1/24/2003

0200/24	RJSK	240200Z	29017KT	9999	-SHSN	FEW010	SCT020	BKN035	01/M02
	Q1003	RMK	1ST010	3CU020	7SU035	A2964=			
10:43 F783									
0128/24	RJSK	2400128Z	30012KT	8000	-SHSN	FEW005	SCT010	BKN025	01/M01
	Q1003	RMK	1ST005	3ST010	7CU025	A2964=			
0400/24	RJSK	240400Z	31013KT	9999	-SHSN	FEW010	SCT030	BKN040	01/M03
	Q1003	RMK	1ST010	4CU030	6CU040	A2963=			
12:47 F875									
0325/24	RJSK	240325Z	28022KT	6000	-SHSN	FEW010	SCT025	BKN040	M00/M02
	Q1003	RMK	1ST010	3CU025	7CU040	A2963=			
1000/24	241000Z	33015G25KT	290V350	200	R28/0900	VP1800D	+BLSN	SHSN	VV002
	M01/M02	Q1007	RETS	RMK	A2975=				
18:46 F877									
0944/24	RJSK	240944Z	29019KT	5000	-TSSN	FEW005	BKN008	BKN020	FEW020CB
	M01/M02	Q1007	RMK	1ST005	5ST008	7CU020	1CB020	A2974	FBL TS
	20KM NW	MON	SE=						
0932/24	RJSK	240932Z	29019KT	800	R28/1400VP1800N	BLSN	SHSN	FEW005	BKN008
	BKN015	M01/M02	Q1007	RMK	1ST005	5ST008	7ST015	A2974=	
21:11 F879									
1200/24	RJSK	241200Z	33009KT	300V360	9999	-SHSN	FEW010	BKN020	BKN030
	M01/M04	Q1008	RMK	1ST010	5CU020	7CU030	A2979=		

1/29/2003

0135/29	RJSK	290135Z	30013KT	300	R28/1500N	SHSN	VV003	M03/M05	
	Q0995	RMK	A2940=						
10:27 F783									
0300/29	RJSK	290300Z	32013KT	290V350	1000	R28/P1800N	-SHSN	FEW003	BKN008
	BKN015	M04/M06	Q0995	RMK	1ST003	7ST015	A2940=		
0351/29	RJSK	290351Z	32008KT	270V350	2500	-SHSN	FEW005	SCT010	BKN015
	M04/M06	Q0996	RMK	1ST008	4ST010	7ST015	A2942=		
12:45 F875									
0338/29	RJSK	290338Z	32011KT	290V360	4000	-SHSN	FEW005	BKN010	BKN015
	M05/M06	Q0996	RMK	1ST005	5ST010	7ST015	A2941=		

1/30/2003

0150/30	RJSK	300150Z	29017KT	1400	R28/1000V1700D	-BLSN	-SHSN	FEW004	BKN007
	BKN015	M04/M05	Q1010	RMK	1ST003	5ST005	7ST010	A2986=	
10:39 F783									
0138/30	RJSK	300138Z	30021G31KT	400	R28/P1800N	BLSN	SHSN	VV005	M04/M06
	Q1011	RMK	A2986=						
0330/30	RJSK	300330Z	28021G31KT	2500	R28/0900VP1800U	-BLSN	-SHSN	FEW004	SCT008
	BKN020	M03/M06	Q1010	RMK	1ST004	4ST008	6CU020	A2985=	
12:30 F875									
0329/30	RJSK	300329Z	28022KT	2500	R28/0900VB1800U	-BLSN	-SHSN	FEW004	SCT008
	BKN020	M03/M06	Q1010	RMK	1ST004	4ST008	6CU020	A2985=	
1000/30	RJSK	301000Z	28018KT	3000	-BLSN	-SHSN	FEW005	SCT008	BKN025
	M03/M05	Q1014	RMK	1ST005	3ST008	7CU025	A2994=		
18:53 F877									
0950/30	RJSK	300950Z	28017KT	3500	-BLSN	-SHSN	FEW004	SCT008	BKN015
	M03/M04	Q1014	RMK	1ST004	3ST008	7CU015	A2994=		
1215/30	RJSK	301215Z	26020KT	1600	R28/P1800N	-BLSN	-SHSN	FEW005	BKN010
	BKN025	M02/M06	Q1014	RMK	1ST005	5ST010	7CU025	A2997=	
21:11 F879									
1200/30	RJSK	301200Z	29019KT	6000	-BLSN	-SHSN	FEW005	SCT010	BKN025
	M03/M06	Q1014	RMK	1ST005	3ST010	7CU025	A2997=		

1/31/2003

0131/31	RJSK	310131Z	33008KT	8000	-SHSN	FEW010	SCT020	BKN030	M02/M06
	Q1015	RMK	1ST010	4CU020	7CU030	A2997=			
10:21 F783									
0114/31	RJSK	310114Z	30015KT	2500	-BLSN	-SHSN	FEW008	BKN015	BKN025
	M01/M07	Q1015	RMK	1ST008	5ST015	7CU025	A2997=		
0342/31	RJSK	310342Z	30013KT	2500	-SHSN	FEW010	BKN020	BKN030	M02/M05
	Q1014	RMK	1ST010	5CU020	7CU030	A2995=			
12:12 F875									
0300/31	RJSK	310300Z	32008KT	4000	-SHSN	FEW010	BKN020	BKN030	M03/M05
	Q1014	RMK	1ST010	5CU020	7CU030	A2996=			
1000/31	RJSK	311000Z	33007KT	280V360	8000	-SHSN	FEW010	BKN015	BKN025
	M04/M06	Q1016	RMK	1ST010	5ST015	7CU025	A3001=		
18:47 F877									
0933/31	RJSK	310933Z	33006KT	7000	-SHSN	FEW008	SCT015	BKN030	M03/M05
	Q1015	RMK	1ST008	3ST015	7CU030	A3000=			
1200/31	RJSK	311200Z	29006KT	9999	-SHSN	FEW010	SCT015	BKN035	M04/M06
	Q1016	RMK	1ST010	3ST015	7CU035	A3003=			
20:55 F879									
1140/31	RJSK	311140Z	32010KT	6000	-SHSN	FEW008	SCT015	BKN030	M04/M05
	Q1016	RMK	1ST008	3ST015	7CU030	A3002=			