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A Dornier DU328 Aircraft Braking Performance on Winter Contaminated Runways

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16. Abstract

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The aircraft performed 13 full anti-skid braking runs on four different test surfaces. In addition to the test aircraft, two ground vehicles measured the surface friction: the Electronic Recording Decelerometer (ERD) and the International Reference Vehicle (IRV). The aircraft braking coefficient was determined for each test run and compared against the two vehicles. Both test vehicles compared very well with the aircraft, obtaining a correlation of 94 percent for the ERD and 82 percent for the IRV. Aircraft brake pressures and wheel speeds were also examined to determine the effectiveness of the anti-skid system of the aircraft. The anti-skid system was found to work very well and was able to maintain an overall slip ratio of 7 percent.

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Treize courses en freinage avec antidérapage ont été réalisées dans quatre états de contamination de piste différents. Outre l'avion d'essai, deux véhicules au sol mesuraient le coefficient de frottement : le décéléromètre électronique (ERD) et le véhicule de référence international (IRV). À chaque essai, le coefficient de freinage de l'avion était déterminé et comparé aux valeurs obtenues à l'aide des deux appareils de mesure au sol. Les résultats obtenus avec l'un et l'autre véhicules affichent une étroite corrélation avec les valeurs mesurées avec l'avion, soit des coefficients de 0,94, dans le cas de l'ERD, et de 0,82, dans le cas de l'IRV. La pression de freinage et la vitesse de rotation des roues de l'avion ont également été mesurées, afin de déterminer l'efficacité du système antidérapage. Celui-ci a été jugé très efficace, puisque le taux de glissement pour l'ensemble des essais n'a pas dépassé 7 p. 100.

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RÉSUMÉ

Le comportement à l'atterrissage d'un avion Dornier DU328 à turbopropulseurs a été évalué au cours des hivers 1999-2000 et 2000-2001, à l'Aéroport international de Munich et à la base aérienne militaire de Erding, en Allemagne. Les essais ont été menés dans le cadre du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver, un programme coopératif auquel participent Transports Canada, la U.S. National Aeronautics & Space Administration, le Conseil national de recherches du Canada et la U.S. Federal Aviation Administration.

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1.0 Introduction

1.1 Background

In 1995 the Joint Winter Runways Friction Measurement Program (JWRFMP) was established to study aircraft performance on winter contaminated runways. The JWRFMP is comprised of Transport Canada, the National Research Council of Canada, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA). As part of the JWRFMP, a Fairchild Dornier 328-130 Turboprop prototype aircraft was tested at the Munich International airport in Germany during the winter of 1999/2000 and at the Erding military base in Germany during the winter of 2000/2001.

This report presents the results of this flight test program performed on the DU328.

1.2 Objectives

The overall objectives of the JWRFMP were many fold, however, there were two primary objectives as they related to aircraft. The first was to determine the aircraft braking performance on winter contaminated runway surfaces. Secondly, to find a means of correlating aircraft braking performance with that of ground vehicle friction measurement devices.

1.3 Scope

The scope of this report is limited to presenting the results obtained for the aircraft testing. The analytical work and equations used to derive these results are simply presented. Their detailed development can be found in Reference 1. A number of aircraft have participated in the JWRFMP program over its five-year mandate. The results from the DU328 test program will not be compared to that of other aircraft. For an in depth comparison of all the aircraft that have participated in the program, including the DU328, see Reference 2. Unfortunately the 1999/2000 Munich data could not be processed due to insufficient engine thrust information. For these tests, the throttle levers were placed in flight-idle for testing, which is a governed engine setting, and could not be modeled as a simple function of airspeed.

2.0 Test Equipment

The test equipment suite consisted of the test aircraft, ground test vehicles, and large number of support personnel.

2.1 Test Aircraft

The Fairchild Dornier 328-130 Turboprop prototype aircraft (S/N 3003) is a developmental flight test aircraft operated by Fairchild Dornier, fitted with Pratt and Whitney PW119B engines. The maximum takeoff weight is 30,840 lbs, and maximum landing weight is 29,160 lbs. All tests were performed in the landing configuration, which consists of a flap setting of 32 degrees and with the ground spoilers manually deployed. The throttle levers were placed into the ground-idle position. The ground-idle throttle position is a non-governed engine setting and therefore the engine thrust would be repeatable from run to run.

The aircraft was fitted with an instrumentation system which recorded flight control surface positions, brake system performance, engine speed and throttle settings, individual wheel speeds, and aircraft acceleration, heading, attitude and forward speed. A minimum data sample rate of 16 samples/sec was available for all recorded parameters. A Honeywell Inertial Reference System and a differential GPS position reference system were also used for these tests.

The following is the list of parameters recorded along with the units.

Time	Local time
Tas (kts)	True air speed
Gs (kts)	Ground speed
Lat (deg)	Latitude
Lon (deg)	Longitude
Height (m)	Geoid height
Prop Speed L (%)	Propeller speed, left
Prop Speed R (%)	Propeller speed, right
Prop Torq L (%)	Propeller Torque, left
Prop Torq R (%)	Propeller Torque, right
Elevator (deg)	Elevator deflection
Rudder (deg)	Rudder deflection
Aileron L (deg)	Aileron, left deflection
Aileron R (deg)	Aileron, right deflection
Ax (g)	Longitudinal acceleration
Ay (g)	Lateral acceleration
Az (g)	Vertical acceleration
Pitch (deg)	Pitch attitude
Heading (deg)	Aircraft heading
Grnd Spoil (deg)	Ground spoiler deflection
Brake Left (bar)	Brake pressure, left
Brake Right (bar)	Brake pressure, right
Wspd LI (rpm)	Wheel speed, left inner
Wspd LO (rpm)	Wheel speed, left outer
Wspd RO (rpm)	Wheel speed, right outer
Wspd RI (rpm)	Wheel speed, right inner
Vtrack spd (m/s)	Vertical velocity
X (m)	Distance along runway

Y (m)	Lateral distance from runway center line
Z (m)	Vertical distance along runway
Vx (m/s)	Velocity along the runway
Vy (m/s)	Lateral velocity along the runway
Vz (m/s)	Vertical velocity along the runway

2.2 Ground Test Vehicles

There were two primary ground friction measuring test vehicles used. The Electronic Recording Device (ERD) and the International Reference Vehicle (IRV). The ERD is a device that is hard mounted inside a test vehicle (Chevy Blazer pickup truck) and will typically make three spot friction measurements along a runway surface. The friction value reported is called the Canadian Runway Friction Index (CRFI). The IRV is a trailer towed device and is capable of a continuous measurement of the runway friction. The friction value reported by it is called the International Runway Friction Index (IRFI) as measured by the IRV. The CRFI has been standardized across all of Canada and is available to all pilots flying during winter operations. The IRFI is an international standard that is currently under development and as yet, has not been adopted internationally. The final reference vehicle for the IRFI has not yet been determined, however, a number of friction measuring devices have been calibrated to report the proposed IRFI standard. Thus, when referring to an IRFI measurement, the terminology of "as measured by...." is used. A third friction measuring vehicle was also used, the Saab Surface Friction Tester (SSFT). Its role was that of validation in the event of large discrepancies between the ERD and IRV.

2.3 Support Personnel

There were number of support personnel needed to run the test program. The foremost was the aircraft flight crew; this consisted of two pilots and two flight test engineers. The aircraft also had a ground test crew that run a portable weather and DGPS station. There was an overall test coordinator and a ground vehicle test coordinator. The ground vehicles required at least one operator per vehicle. There was a test surface inspector who recorded surface conditions. And finally, there was a film crew supporting the program.

3.0 Test Procedures

Each test series was started with a preflight briefing where test procedures and objectives were clearly stated. The test coordinator was responsible for: the overall testing, directing the various ground crews, coordinating with the aircraft crew, and ensuring safety. Each crew had radios and operated on the Dornier test frequency. The tower controller monitored this test frequency as well. Test sequences typically consisted of the ground vehicles making readings just prior the aircraft tests. Surfaces conditions were carefully noted and if applicable, measurements made (e.g. surface temperature, snow density. etc.). Once the coordinator ensured that the test section and runway were clear of all obstacles, the aircraft would make a test run and taxi back into position for the next test point. If the test section conditions were observed to be changing, the ground vehicles would make additional readings in between each aircraft test run. Otherwise the ground vehicle would only make readings at the start and end of each aircraft test series.

4.0 Summary of Test Surfaces

Four test surfaces were tested on:

A. Bare and Dry
B. Bare and Wet
C. Smooth ice
D. Smooth ice with one application of potassium acetate

The smooth ice surface was man-made and prepared the previous night using the airforce base fire trucks. The smooth ice with potassium acetate surface was the same man-made smooth ice surface with the chemicals applied to after the completion of the initial set of testing.

5.0 Analysis Methods

The analysis methods and equations used are fully developed in Reference 1 Appendix A. The final equations used are reproduced here for completeness.

It should be noted that in the development of these equations the aircraft weight is assumed to be entirely on the main wheels. This convention is consistent with the industry and with the other aircraft that have participated in the JWRFMP.

General equations of motion:

$$\frac{W}{g}\frac{dV}{dt} = -D - D_P - W\sin\varepsilon - D_F \qquad \textbf{(1)}$$

$$D_F = \mu_R (W\cos\varepsilon - L) \qquad \textbf{(2)}$$

$$L = \frac{1}{2}\rho_o V_{EAS}{}^2 SC_L$$

$$D = \frac{1}{2}\rho_o V_{EAS}{}^2 SC_D \qquad \textbf{(3)}$$

Where:

W	aircraft weight
G	gravitational constant
dV/dt	aircraft acceleration
$\mathbf{D_P}$	combined drag from the propellers and residual idle thrust
$\mathbf{D_F}$	wheel braking friction
D	aerodynamic drag
L	aerodynamic lift
	runway slope

μ_R	coefficient of rolling friction
μ_B	coefficient of braking friction
μ_S	wheel slip ratio coefficient
V_{EAS}	equivalent airspeed
S	wing surface area
Cl	coefficient of lift in ground effect
Cd	coefficient of drag in ground effect
V_{GS}	aircraft ground speed
V_W	wheel speed

For small angles of e, cos (ε) = 1, and sin (ε) = ε, the general equations (1,2 & 3) then become:

$$\frac{1}{g}\frac{dV}{dt} = -\frac{D}{W} - \frac{D_P}{W} - \varepsilon - \mu_R(1 - \frac{L}{W}) \quad \textbf{(4)}$$

Determination of flight idle and discing propeller drag:

Setting the rolling friction coefficient to 0.025 and solving for the propeller drag, the equation becomes:

$$\frac{D_P}{W} = -\frac{D}{W} - \varepsilon - \mu_R(1 - \frac{L}{W}) - \frac{1}{g}\frac{dV}{dt} \quad \textbf{(5)}$$

Determination of braking coefficient:

$$\mu_B = (-\frac{D}{W} - \frac{D_P}{W} - \varepsilon - \frac{1}{g}\frac{dV}{dt}) \Big/ (1 - \frac{L}{W}) \quad \textbf{(6)}$$

Determination of slip ratio:

$$\mu_S = (V_{GS} - V_W)/V_{GS} \quad \textbf{(7)}$$

6.0 Test Results and Discussion

6.1 Runway Slope

The runway slope was determined using the differential GPS system. The aircraft was slowly taxied down the entire length of the runway. Appendix A page A1 shows the results from this run, along with the straight line curve fit to the data. As can be seen from page A1, that although the runway as not entirely horizontal is was remarkable uniform in its slope. Thus a simple constant slope could be used for further reducing the data.

6.2 Propeller Drag

The propeller drag was modeled by performing a series of five accel/coasting runs. The aircraft was positioned at the button of the runway and accelerated to a target ground speed. The aircraft thrust levers were then placed into the ground-idle position and the aircraft allowed to coast, slowing down to a nominal speed. Equation number 5 was used to reduce this data and determine the propeller drag. The five accel/coasting runs were combined into one data set and a second order curve was then fit to the data. Appendix B page B1 shows the results of these runs. The term propeller drag as used is not strictly the propeller drag but also includes a small residual idle thrust term from the engines. The "propeller drag" is also a combined drag term for both of the propellers and engines. As can be seen from page B1 the data is very consistent and repeatable, giving a very high degree of confidence in the modeling of this data.

6.3 Slip Ratio

The slip ratio was determined using equation number 7. The slip ratio is essentially a percentage ratio between two speeds, the wheel speed and the ground speed of the aircraft. A value of zero indicates a non-braked, freewheeling tire. A value of one indicates a wheel lockup up condition. The table shown in appendix C page C1 summarizes all of the braked aircraft runs along with the average ground speed and slip ratios for each wheel. The graphs shown on pages C2 to C14 show all of the pertinent wheel slip information for each data run. The series of graphs down the left-hand side of the page show the braking parameters for the left-hand side of the aircraft and the series of graphs down the right-hand side of the page show all of right-hand aircraft braking parameters. For each column the top two graphs show the inner and outer wheel speeds, with the over plotted dashed line showing the ground speed of the aircraft. The third graph shows the brake pressure for that side of the aircraft. The bottom two graphs show the slip ratios, inner and outer, plotted against ground speed. The four wheel speeds were calibrated against the DGPS ground speed, using the data from one of the high speed taxi test.

Pages C2 and C3 show the data for a bare and dry runway, and pages C4 and C5 show the data for a bare and wet runway. Together these four cases represent surfaces with good braking action. This can be seen in the brake pressure traces, where the tire surface contact patch is capable of sustaining a larger braking torque before inducing a skid. The brake pressures show typical response, where the anti-skid system will apply a rapid increase of brake pressure until an impending skid is sensed. The brake pressure is then reduced until the skid recovers and the brake pressure is re applied and slowly ramped up over a one second period, until an other impending skid is sensed. The anti-skid system maintained an overall average slip ratio of 7%. The slip ratio also appears to have a minor speed effect. At higher speeds (~80 kts) the slip ratio is maintained at roughly 5% and at lower speed (~20 kts) the slip ratio is at roughly 9%. It is not clear if this is an artifact of the dynamics due to speed effects or of the anti-skid system design.

Pages C6 to C11 show the data for 100% smooth ice surface. The low friction of this test surface is evident in the brake pressures, which never get higher than 300 lbs. For safety considerations, the entry speeds into the test section were progressively increased form 40 kts. to 80 kts. The first test run (page C6) entered the test section at 40 kts and shows a considerable amount of scatter in the slip ratios at 20 kts and below. The anti-skid system for this aircraft is active down to speeds to as low as 10 kts. At low speeds the slip ratio becomes very erratic due to the extremely low surface friction and the long recovery time required by the wheels. Over all the slip ratios for this surface are much lower, on the order of 6% with negligible speed effects.

Pages C12 to C14 show the data for a 100% smooth ice surface with one application of potassium acetate. Initially the potassium acetate sat on top of the surface and acted more like grit, no tests were performed at this stage. The chemicals then started acting on the ice surface by boring small holes down through the ice to the underlying tarmac. The first test run was done at this point. The chemicals then started to melt the upper ice surface from below, creating a thin water layer between the tarmac and the ice. The subsequent two test runs were done at this stage. With each test run the aircraft progressively broke apart the ice surface and hence the surface friction value increased with each run.

An interesting observation is that the average slip ratios remain the same for the right and left hand brakes, however, the right outer and left inner brakes exhibit a consistently lower scatter in the slip ratios. This can be attributed to two possible causes. First, is the brake pressure modulator may be slightly worn, such a device would certainly have a poor frequency response and hence a larger scatter in the maintained slip ratios. Without the repair history on the brake modulator parts it is impossible to say with any certainty if this may be the cause. A second possible cause could be the presence of a significant crosswind effect. A careful review of the winds during the test periods do not show there to be a consistent strong cross wind present. Hence it is not known why the right outer and left inner brake pressures should show a marked reduction in data scatter.

Page C15 shows a graph of the average slip ratio plotted against the average ground speed for each test run. This graph shows clearly that there is no speed effect on the slip ratio and that the two are not correlated. The average slip ratio for all of the full anti-skid braking runs was 7%.

6.4 Braking Coefficient

The braking coefficient (μ_B) was calculated using equation number 6. For all of the full anti-skid braking runs, the brake pressure traces resembled that of a saw tooth pattern. The period of these saw tooth patterns are on the order of 1 second. The aircraft data acquisition system collected data at 16 Hz and the instantaneous braking coefficient was calculated at this same sample rate. However, the anti-skid system of the aircraft is continuously varying the brake pressures. As a result, the instantaneous unfiltered traces of μ_B contained noticeable variations due to the anti-skid action. It was decided therefore to use a 1.5-second moving window average on the data. This smoothed the data out over one and a half cycles of the saw tooth patterns. This was sufficient to average out the anti-skid cycles and still leave in the variations with ground speed and runway friction.

The data for the 13 braking runs are presented in Appendix D. The tabular data is presented on page Appendix D1 and the graphical data presented on pages D2 to D6. The relationship between the braking coefficient and the CRFI is presented on page D7 and on page D8 the relationship between the braking coefficient and the IRFI is presented.

The data shows no clear relationship between the braking coefficient (μ_B) and aircraft ground speed. This is most clearly evident on pages D2 and D3. Page D2 indicates a strong positive correlation with groundspeed; however, page D3 shows no correlation or perhaps a slightly negative correlation. With no clear correlation with aircraft ground speed the $\mu_{B,}$ further analysis reduced the data to a single run average value and compared this with the runway friction measured by the ground vehicles.

Page D7 shows the relationship between the braking coefficient and the CRFI. As is evident from the graph there is a very good correlation of 94% between the two parameters. The solid line is the best straight line fit through the data points. The dashed line shown is from the μ_B vs CRFI determined for all the aircraft that have participated in the JWRFMP program. These have been, a B757, B737, B727, Falcon 20, and Dash 8 aircrafts. See reference 2 for a detailed comparison of these aircraft, including the DU328. Page D8 shows the relationship between the braking coefficient and the IRFI. Here too, there is a very good correlation between the two parameters of 82% and compare very well with the other aircraft. With such strong correlations it is possible to use the ground vehicle friction measurements as a predictor for aircraft braking performance on winter contaminated surfaces.

7.0 Conclusions

1) The anti-skid system on the aircraft worked very well and was able to maintain an average slip-ratio of 7%.

2) Aircraft braking performance correlated well both the CRFI and the IRFI.

3) The CRFI and IRFI can be used as aircraft braking performance predictor.

4) Aircraft braking performance was very similar to that of other aircraft that were tested under the JWRFMP program.

8.0 Acknowledgements

The author is indebted to the flight test team at Fairchild-Dornier for their support throughout the program. For their professionalism and can-do approach during the flight test period and subsequently, for their prompt reply to my many questions and requests during the writing of this report.

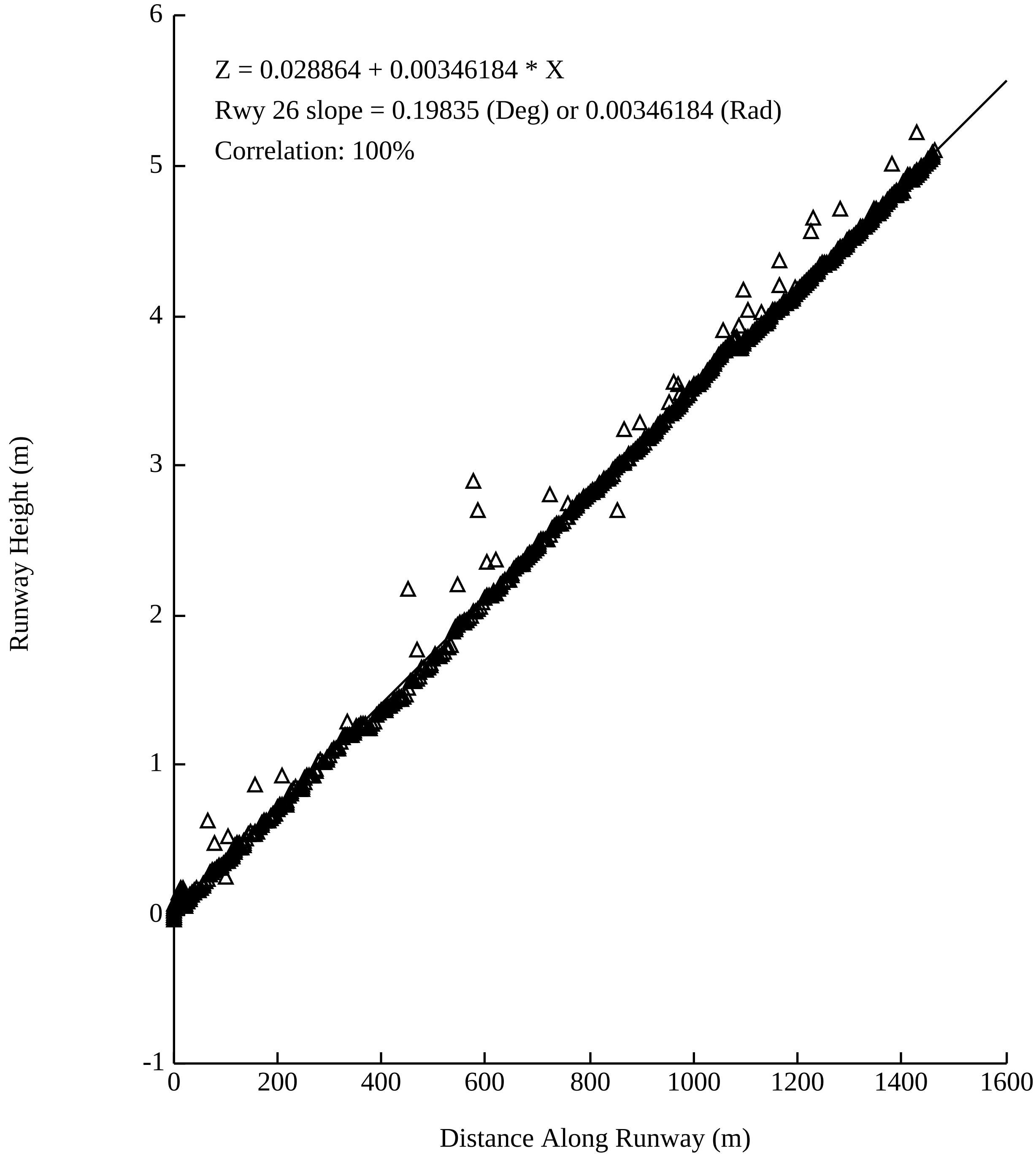
9.0 References

1. J.C.T. Martin, J.B. Croll, M. Bastian — Braking Friction Coefficient and Contamination Drag Obtained for a Falcon 20 Aircraft on Winter Contaminated Runway Surfaces. National Research Council Canada, LTR-FR-132, September

2. J.B.Croll, M. Bastian, J.C.T. Martin, P. Carson — Evaluation of Aircraft Braking Performance On Winter Contaminated Runways and Prediction of Aircraft Landing Distance Using the Canadian Runway Friction Index, National Research Council Canada, LTR-FR-183, TP 13943E, June 2002

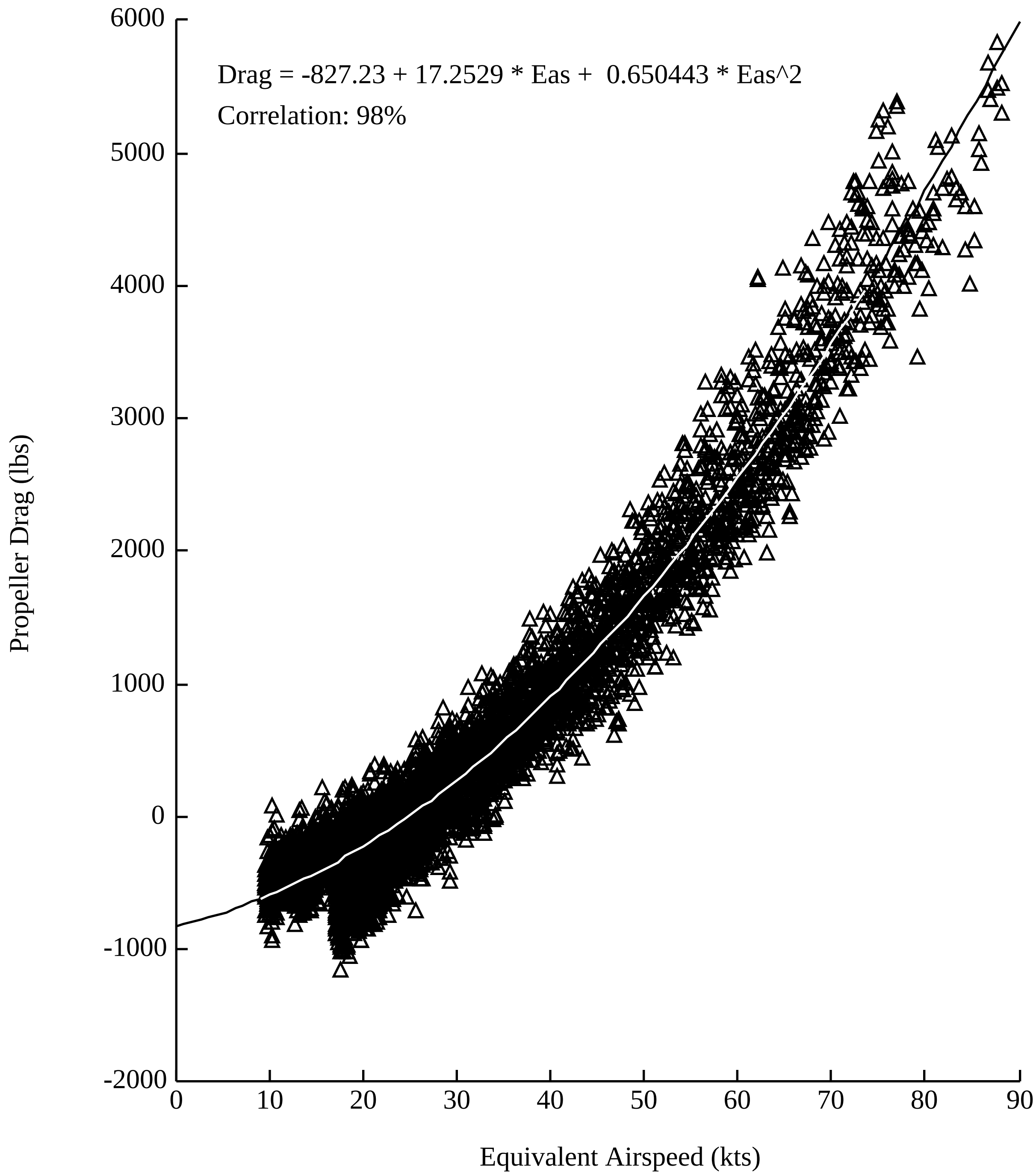
Runway 26 Slope Determination

Flight T30916 Run 31



Ground Idle Propeller Drag - Total Drag for Both Propellers

Flight T30916 Runs 33 to 36



TEST RUNS FOR ANTI-SKID BRAKING SLIP RATIO

The following table shows the test runs used to determine the anti-skid braking wheel slip ratio ($_S$). Pages C2 to C14 show time histories of all the brake related data. The series of graphs down the left-hand side of the page show the ground speed and the left-hand: inner and outer wheel speeds, inner and outer brake pressures, left and right brake pressures, and the inner and outer wheel slip ratios. The series of graphs down the right-hand side of the page show similar data both for the right-hand side of the aircraft. The average run value of ground speed and $_S$ for each wheel is shown in the table and on Page C15.

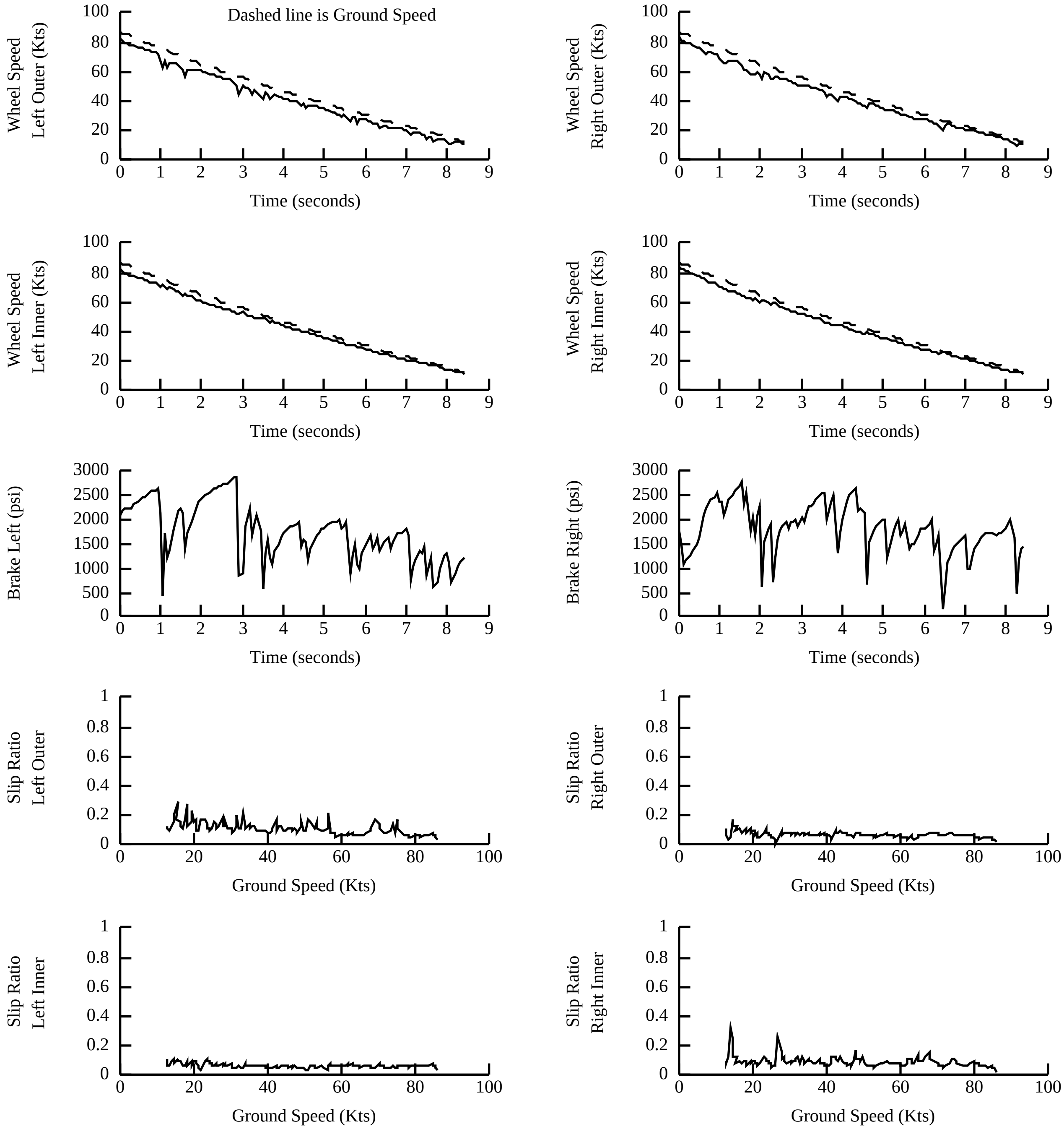
FLT/ Date	RUN/ Time	RW	TAXI/ RTO/ LAND	FLAP/PWR BRK	WEIGHT (LB)	MEAN SPEED (KTGS)	MEAN SLIP RATIO $_s$			
							LO	LI	RO	RI
T30916 28/02/01	41 14:12	26	RTO	32/IDLE/B	26500	44	0.120	0.069	0.074	0.099
	42 14:29	26	RTO	32/IDLE/B	26240	45	0.112	0.061	0.058	0.080
T30916 28/02/01	61 15:09	26			25700	45	0.078	0.047	0.039	0.074
	62 15:28	26	RTO	32/IDLE/B	25435	47	0.094	0.061	0.055	0.075
T30919 01/03/01	21 08:27	26	RTO	32/IDLE/B	27125	23	0.066	0.062	0.064	0.068
	22 08:32	26	RTO	32/IDLE/B	27060	44	0.072	0.038	0.051	0.063
	23 08:36	26	RTO	32/DISC/B	27000	59	0.091	0.044	0.070	0.082
	24 09:15	26	RTO	32/DISC/B	27033	46	0.045	0.054	0.032	0.053
	25 08:58	26	RTO	32/DISC/B	26750	40	0.071	0.021	0.037	0.053
	26 08:54	26	RTO	32/IDLE/B	26691	23	0.072	0.047	0.037	0.053
T30919 01/03/01	41 10:12	26	RTO	32/DISC/B	26837	20	0.098	0.075	0.084	0.087
	42 10:15	26	RTO	32/IDLE/B	26817	27	0.113	0.068	0.069	0.077
	43 10:26	26	RTO	32/IDLE/B	26640	37	0.118	0.067	0076	0.093

Surface: 100% Bare and Dry

Flight t30916, Run Number 41

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average Not Available, CRFI Average 0.92

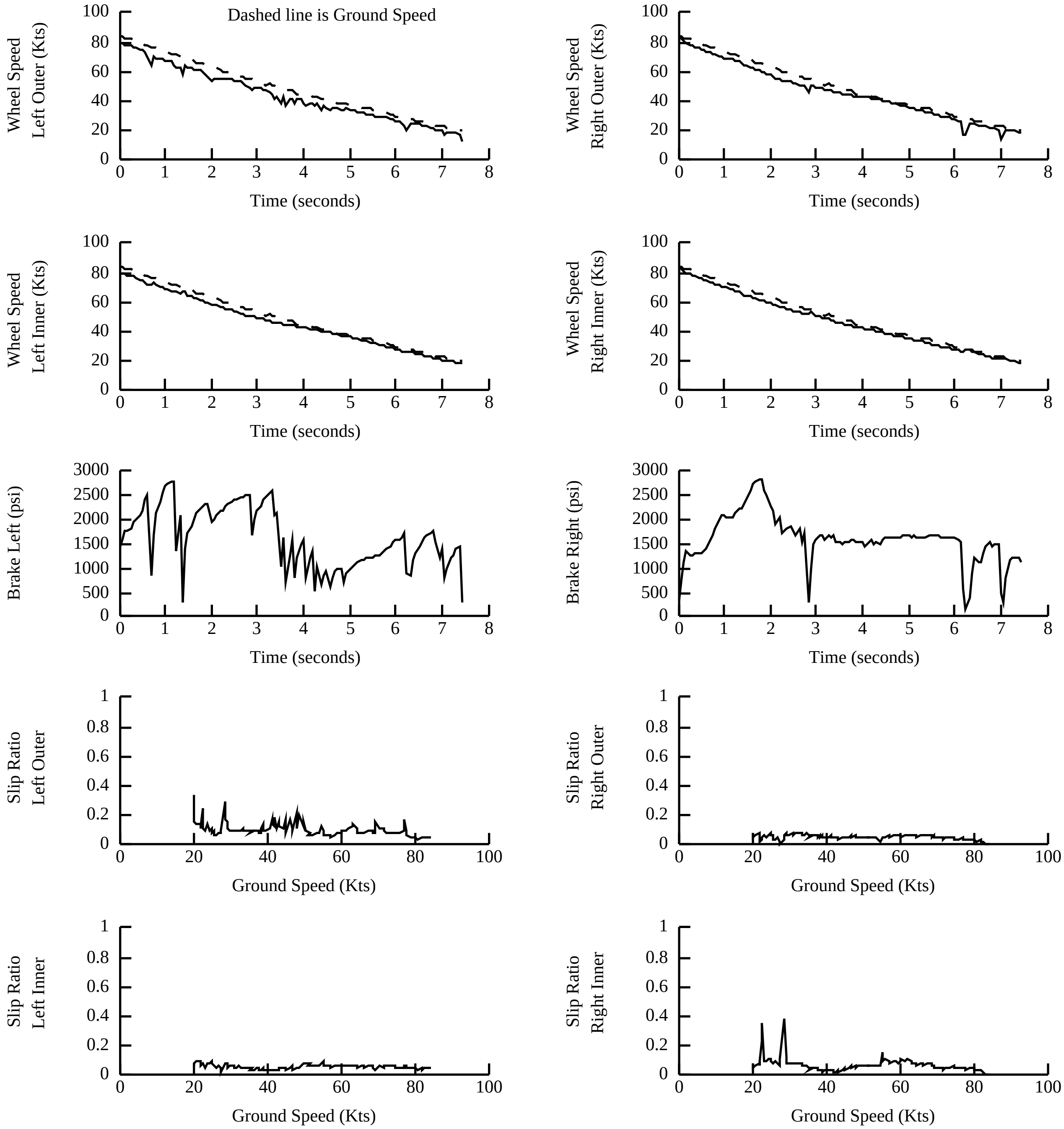


Surface: 100% Bare and Dry

Flight t30916, Run Number 42

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average Not Available, CRFI Average 0.92

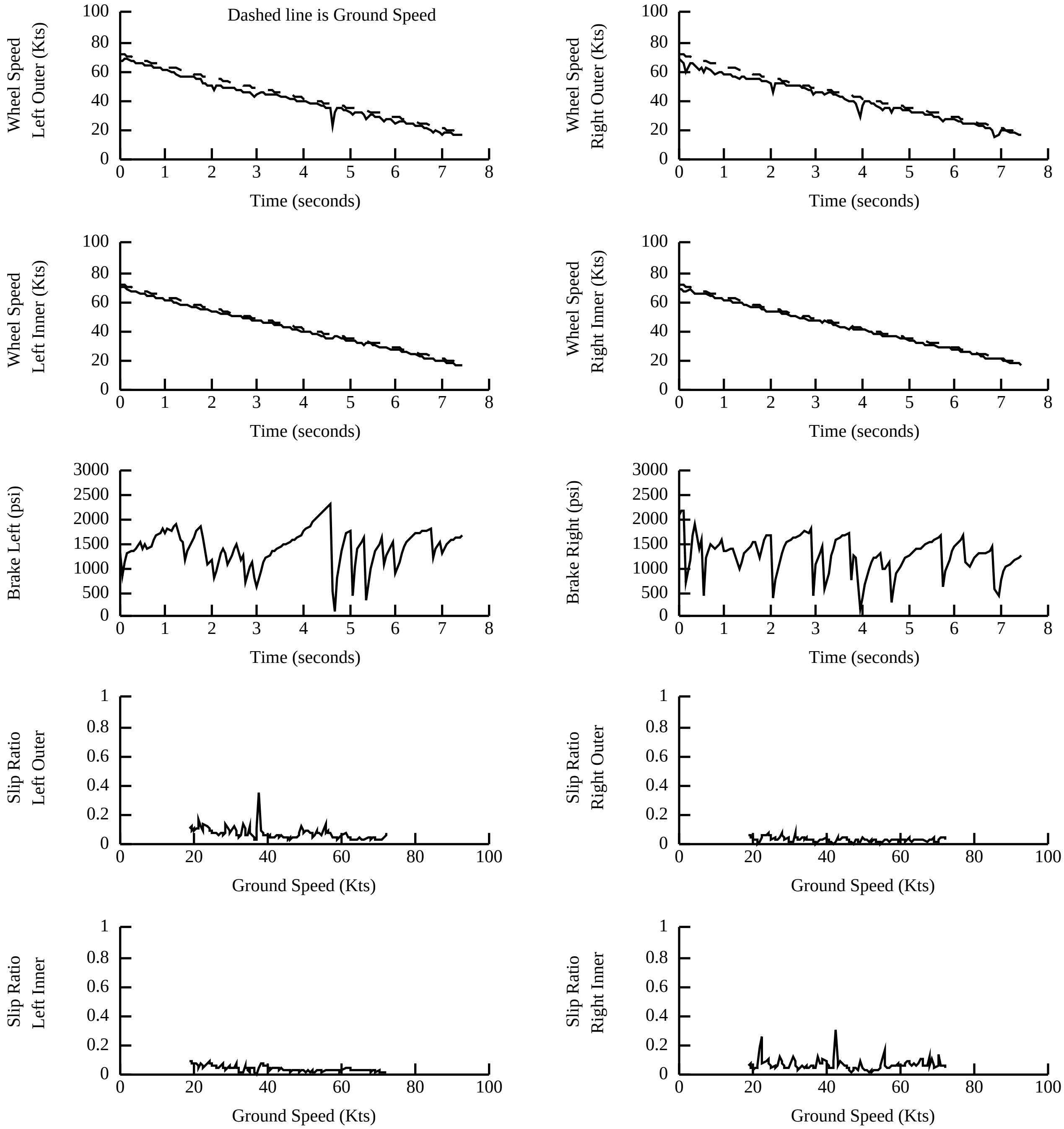


Surface: 100% Bare and Wet

Flight t30916, Run Number 61

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.80, CRFI Average 0.72

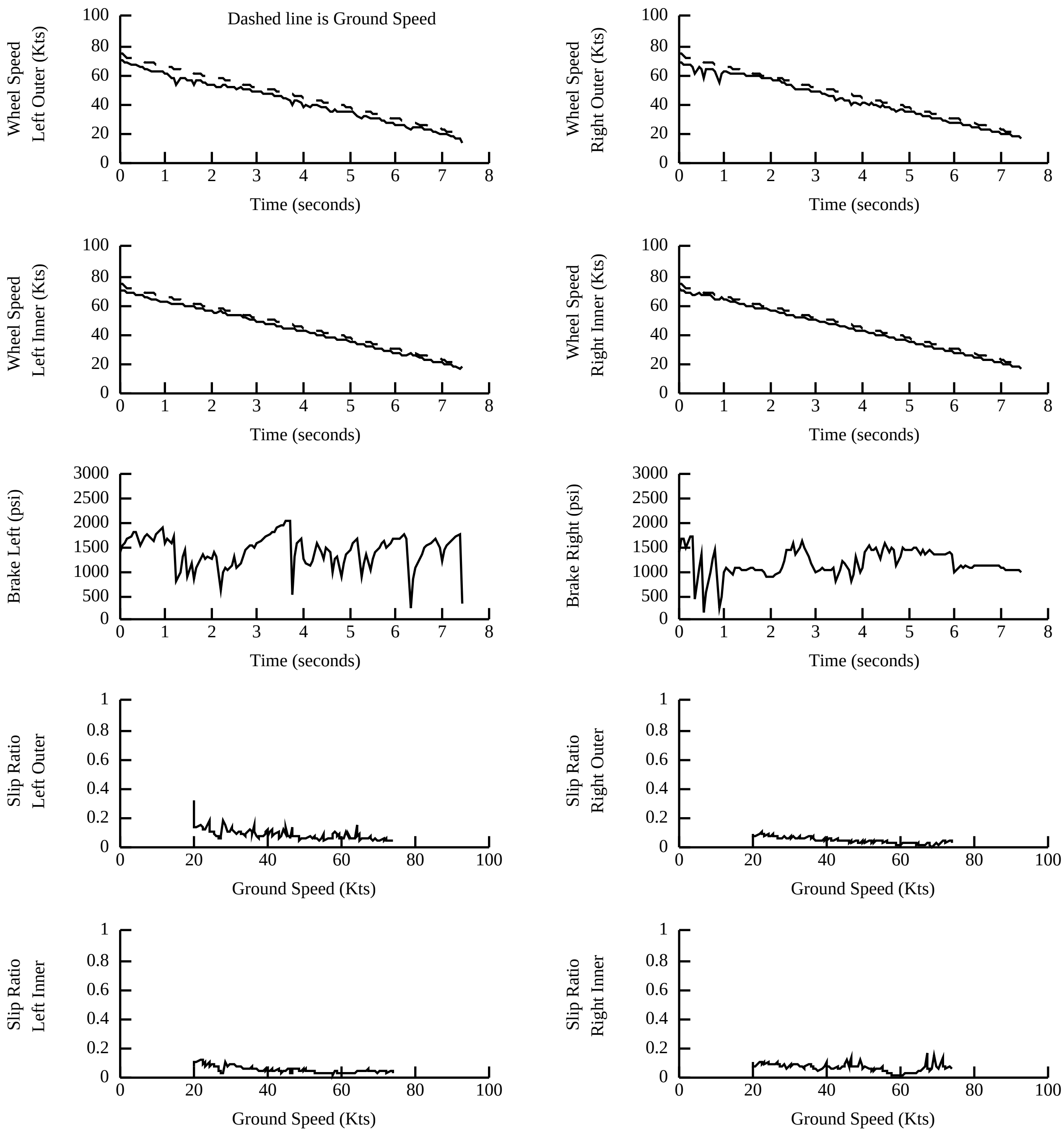


Surface: 100% Bare and Wet

Flight t30916, Run Number 62

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.78, CRFI Average 0.72

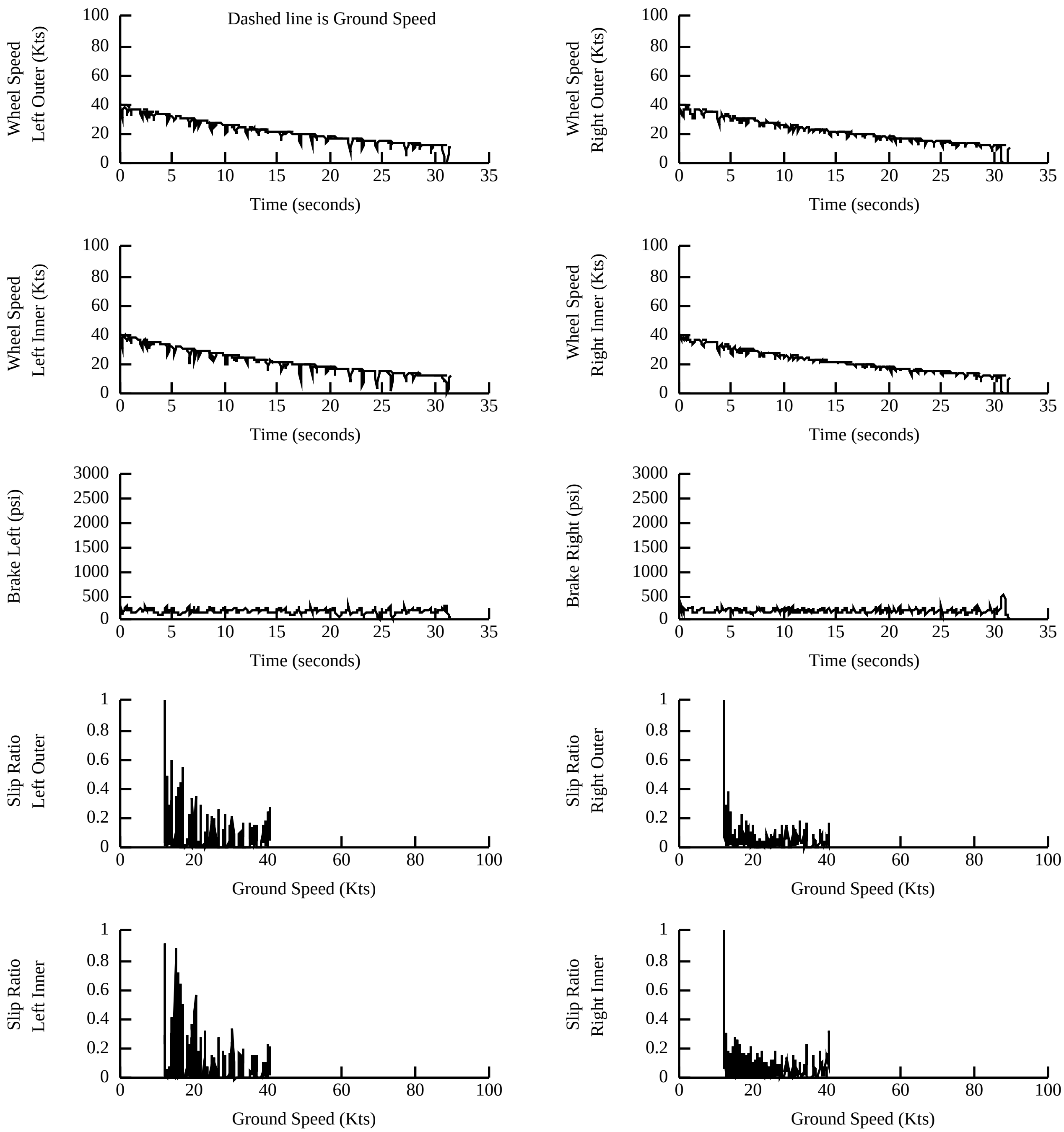


Surface: 100% Smooth Ice

Flight t30919, Run Number 21

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.17, CRFI Average 0.09

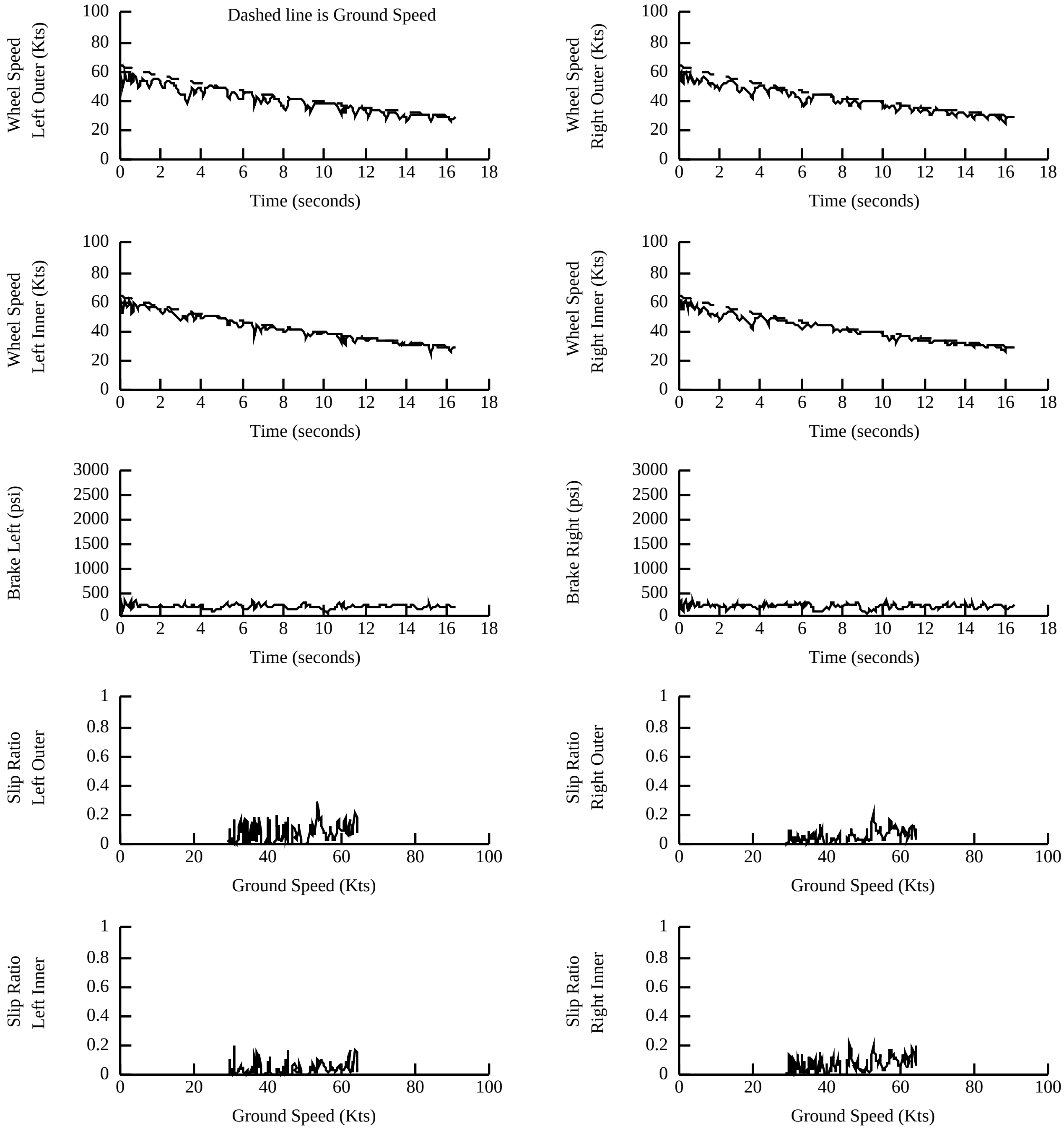


Surface: 100% Smooth Ice

Flight t30919, Run Number 22

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.17, CRFI Average 0.10

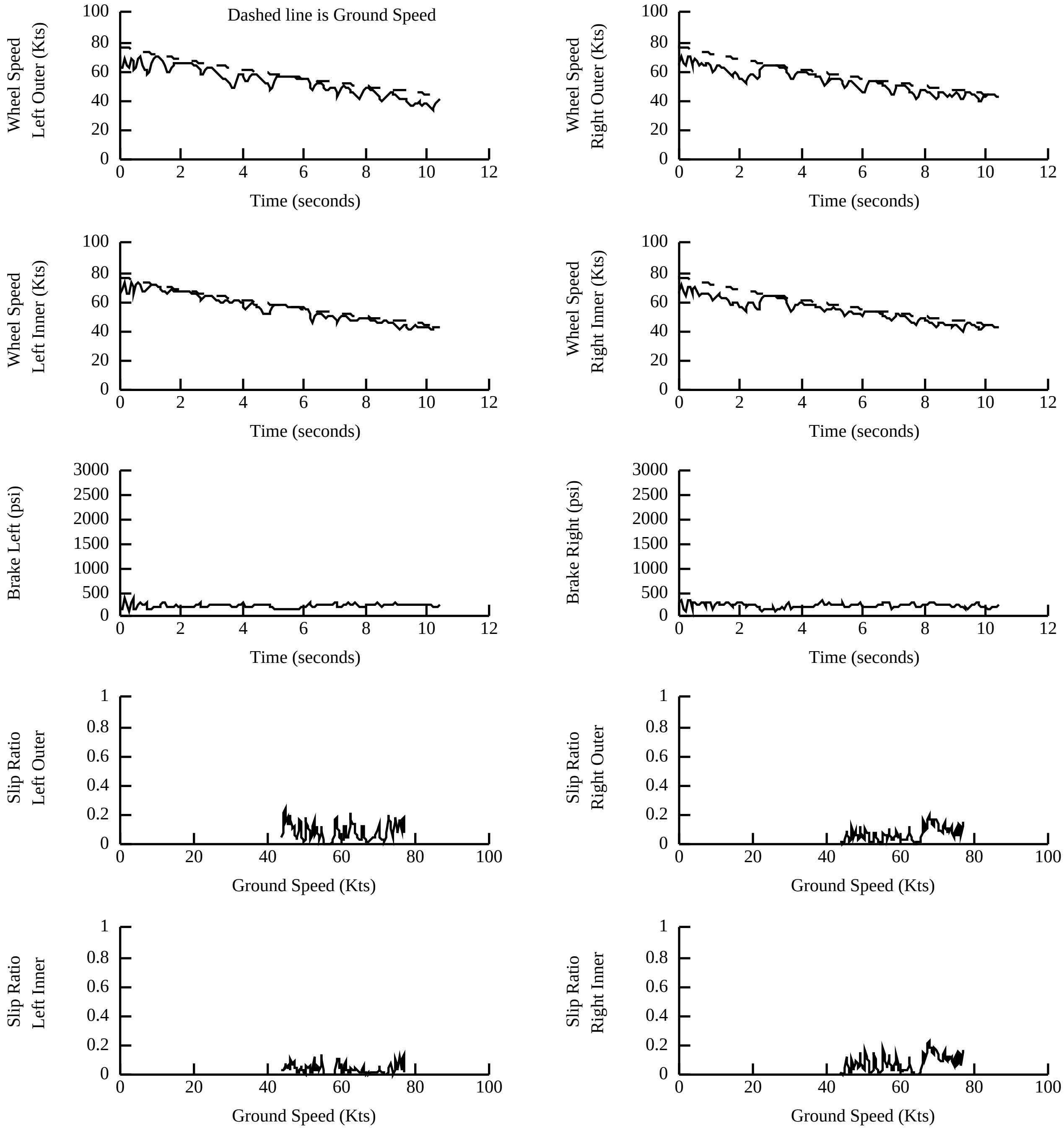


Surface: 100% Smooth Ice

Flight t30919, Run Number 23

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.17, CRFI Average 0.10

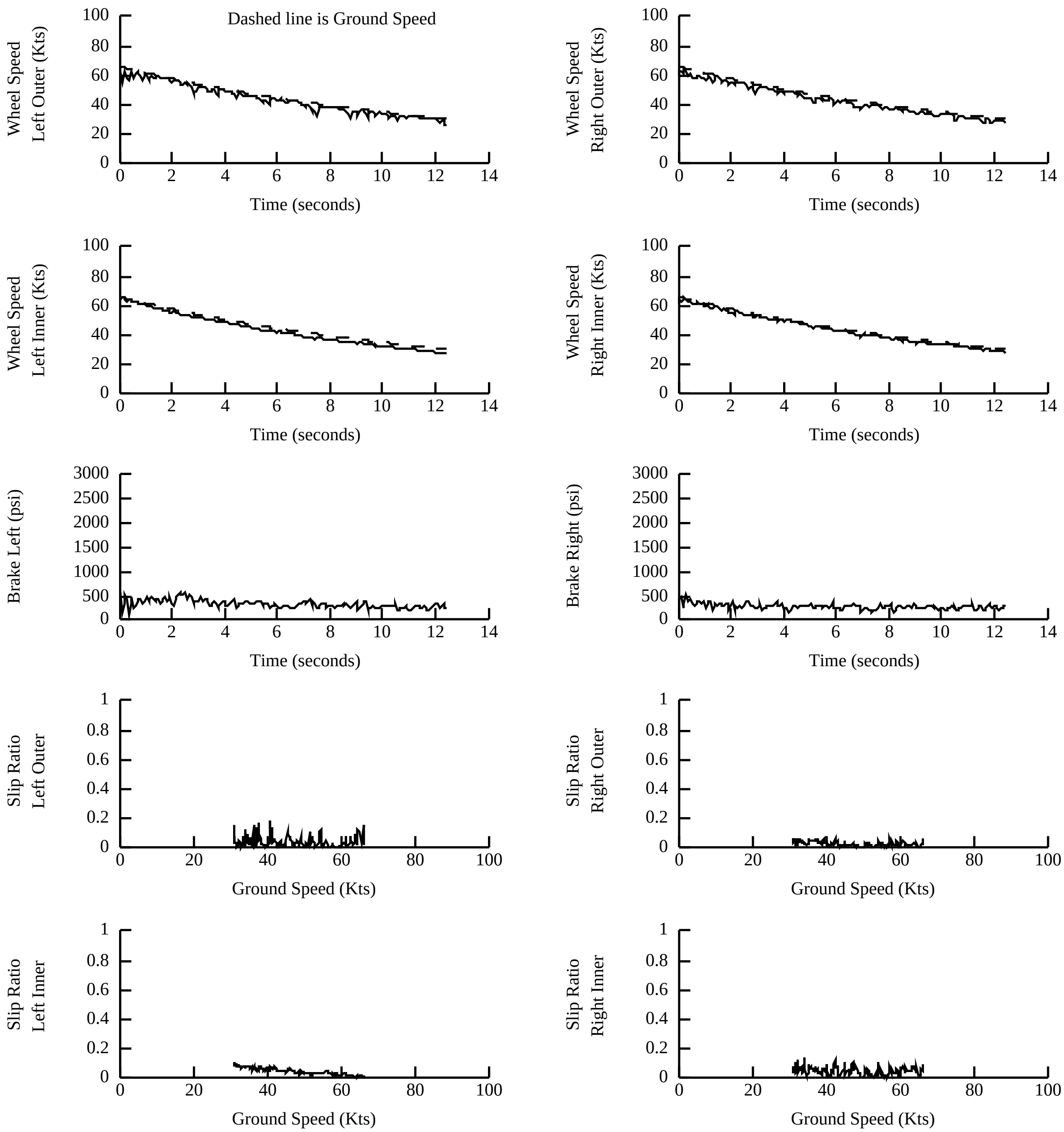


Surface: 100% Smooth Ice

Flight t30919, Run Number 24

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.16, CRFI Average 0.14

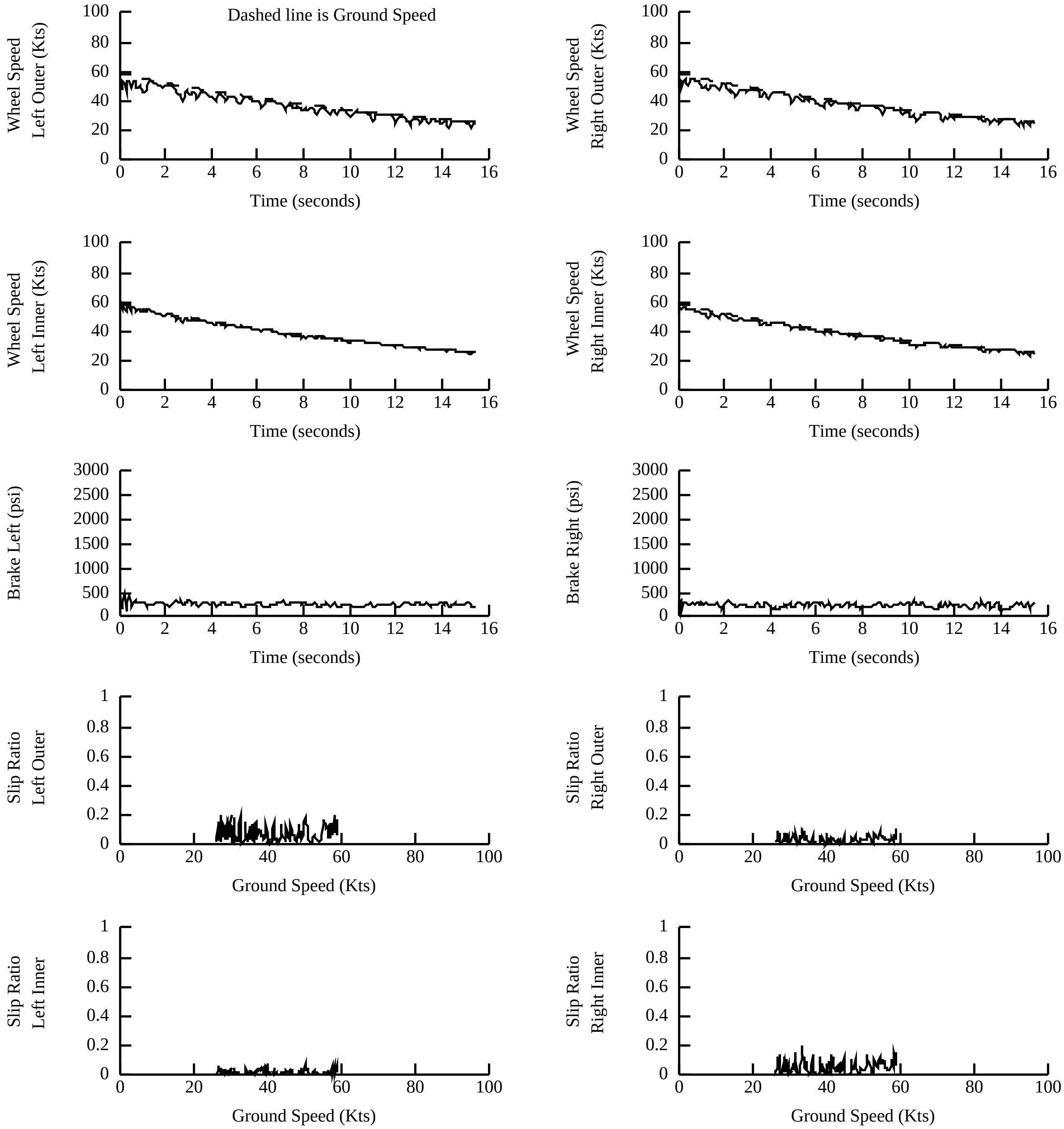


Surface: 100% Smooth Ice

Flight t30919, Run Number 25

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.14, CRFI Average 0.16

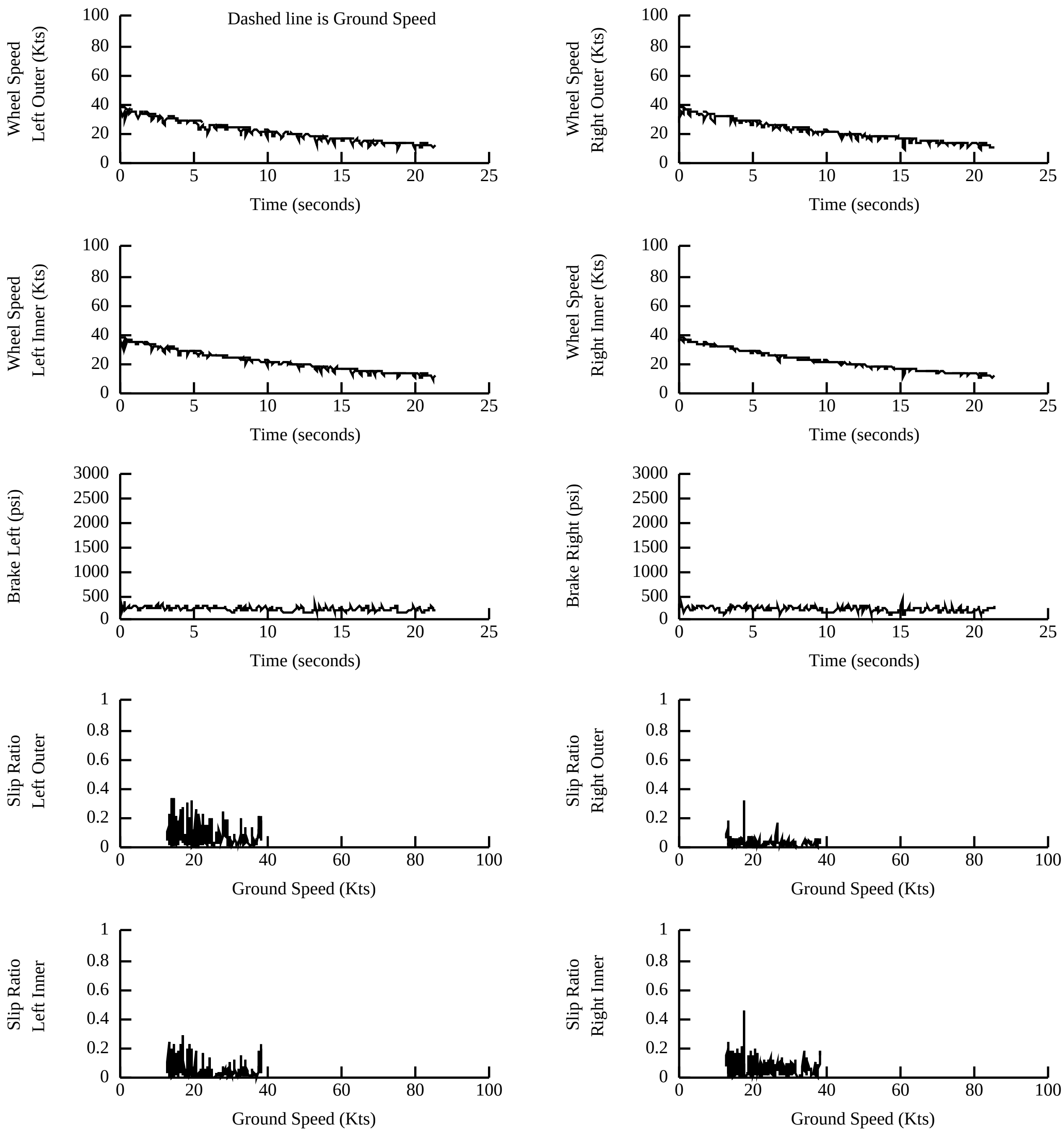


Surface: 100% Smooth Ice

Flight t30919, Run Number 26

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average ?.??, CRFI Average ?.??

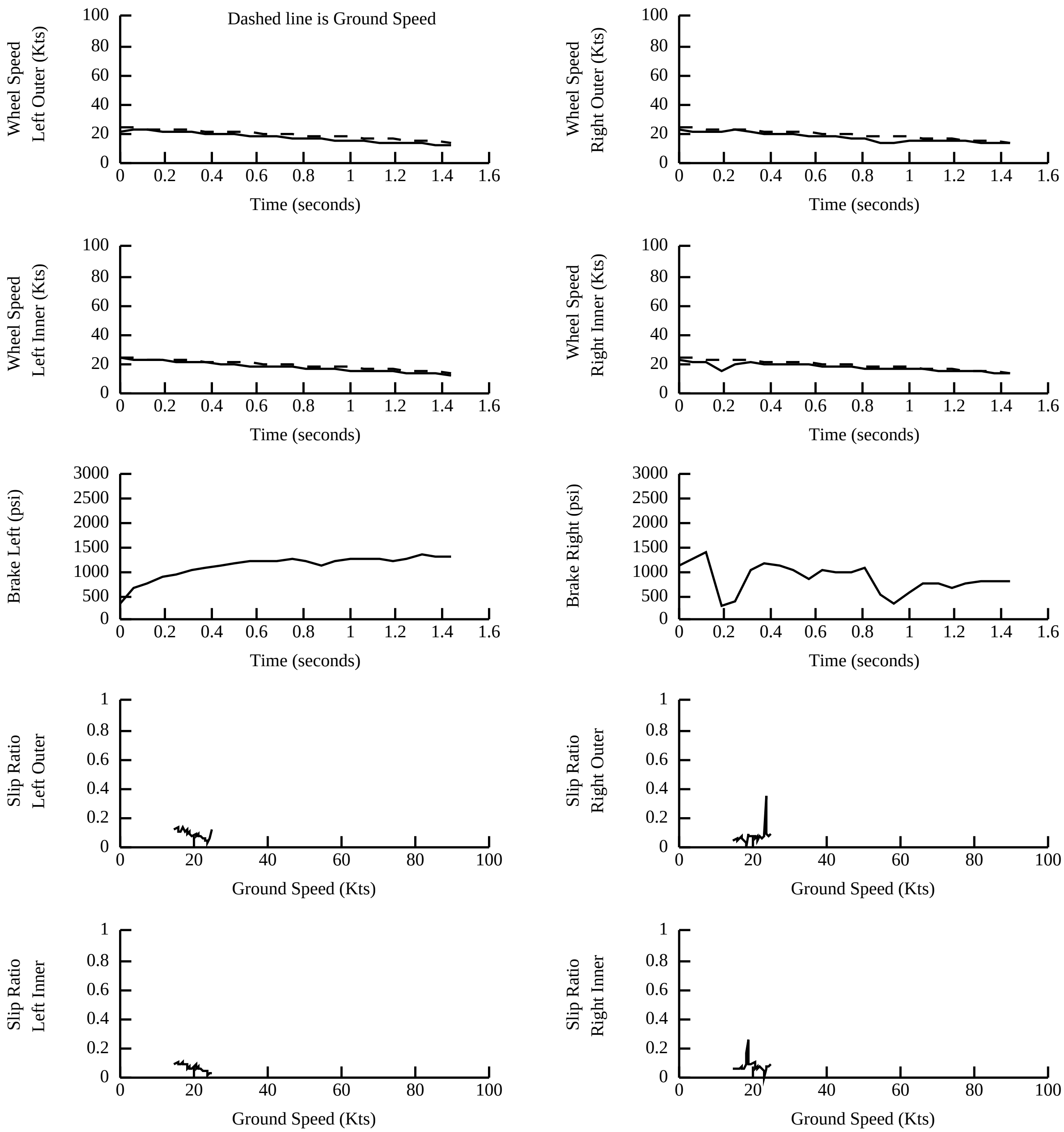


Surface: 100% Smooth Ice and Potassium Acetate

Flight t30919, Run Number 41

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.22, CRFI Average 0.37

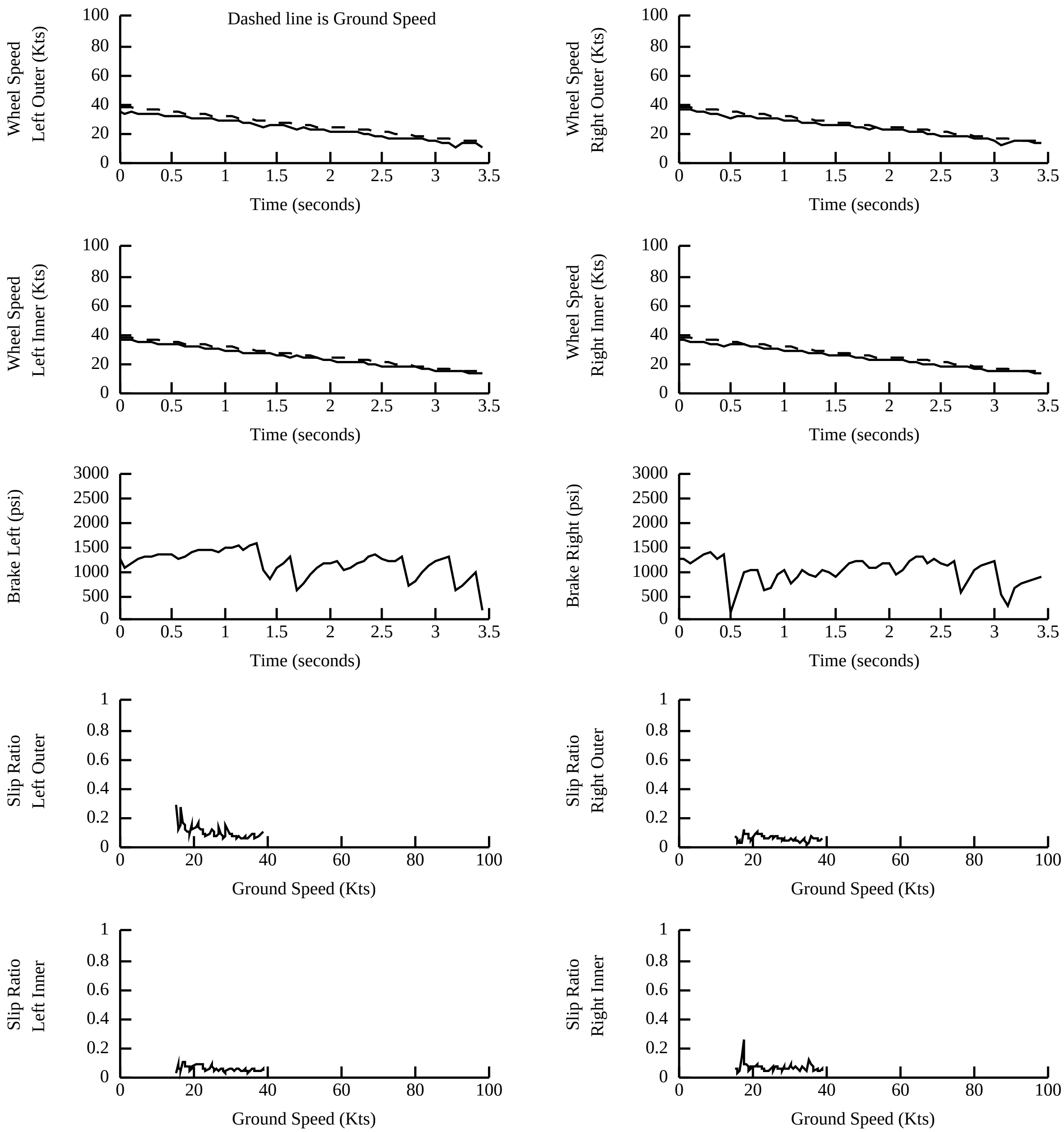


Surface: 100% Smooth Ice and Potassium Acetate

Flight t30919, Run Number 42

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.45, CRFI Average 0.50

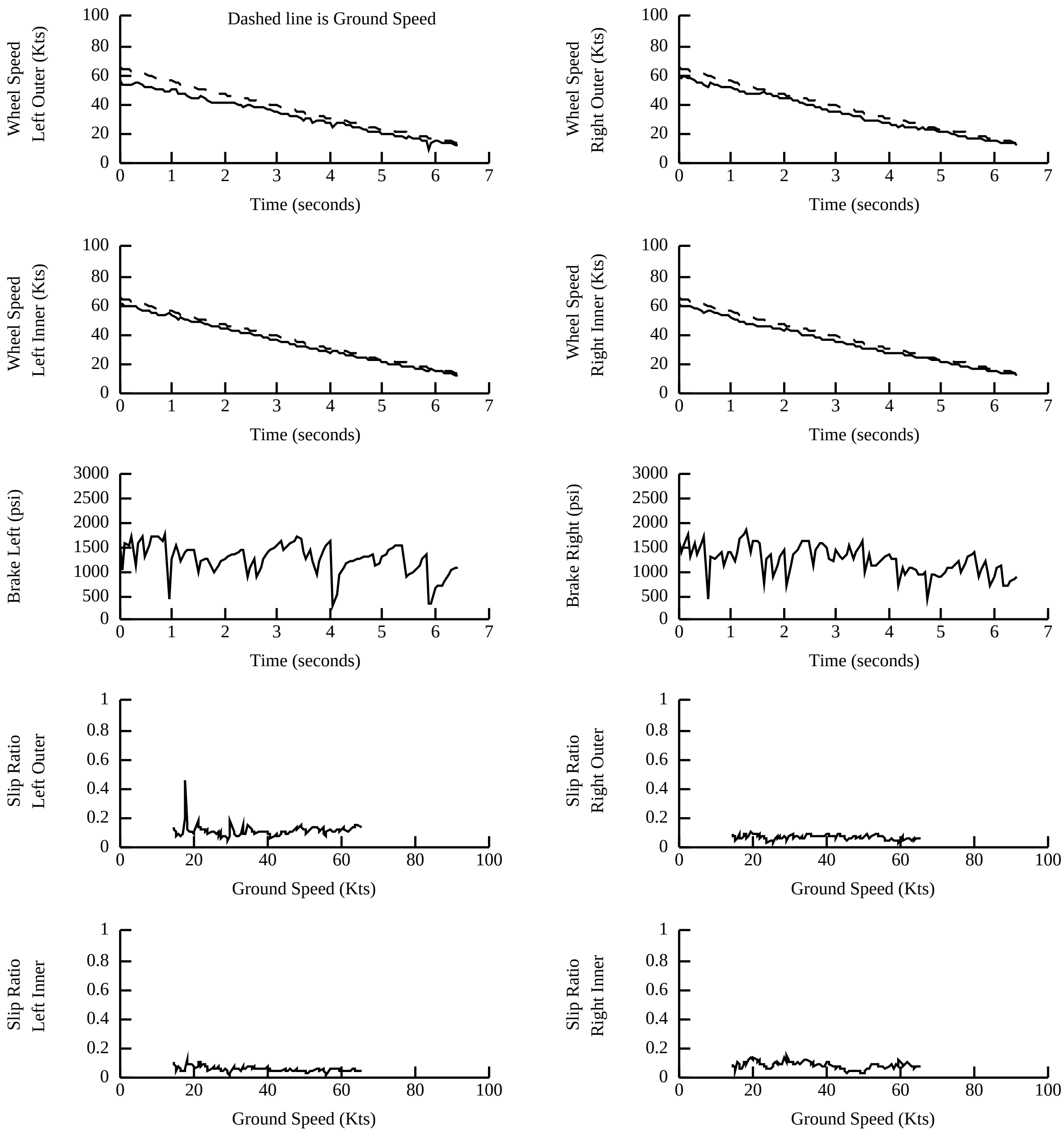


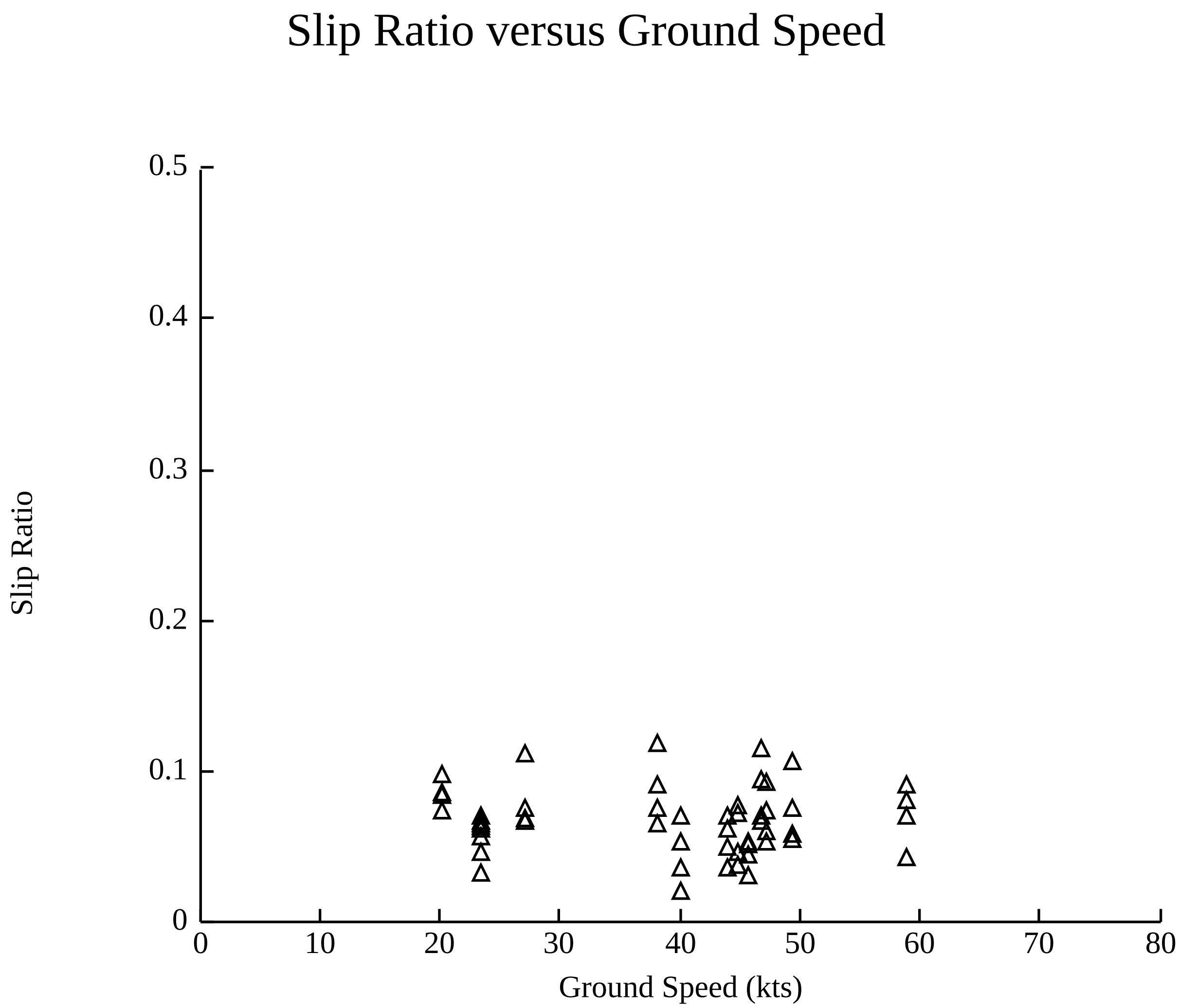
Surface: 100% Smooth Ice and Potassium Acetate

Flight t30919, Run Number 43

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.68, CRFI Average 0.63




Slip Ratio versus Ground Speed
Slip Ratio
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
Ground Speed (kts)

TEST RUNS FOR AIRCRAFT BRAKING COEFFICIENT ON RUNWAY SURFACES WITH NO OR NEGLIGIBLE CONTAMINATION DRAG

The following table shows the test runs used to determine the aircraft braking coefficient ($_B$) on runway surfaces with no or negligible contamination drag. Pages D2 to D6 show the variation of $_B$ with ground speed for each run. Page D7 shows the mean $_B$ plotted against the mean CRFI value for each run, together with the results obtained from previous tests. Page D8 shows the mean $_B$ plotted against the mean IRFI values for each run, together with the results obtained from the previous test.

FLT/ Date	RUN/ Time	RW	TAXI/ RTO/ LAND	FLAP/PWR BRK	Weight (LB)	MEAN CRFI	MEAN IRFI	MEAN SPEED (KTGS)	MEAN $_B$
T30916 28/02/01	41 14:12	26	RTO	32/IDLE/B	26500	0.92	Not Available	44	0.450
	42 14:29	26	RTO	32/IDLE/B	26240	0.92	Not Available	45	0.435
T30916 28/02/01	61 15:09	26			25700	0.72	0.80	45	0.367
	62 15:28	26	RTO	32/IDLE/B	25435	0.72	0.78	47	0.362
T30919 01/03/01	21 08:27	26	RTO	32/IDLE/B	27125	0.09	0.17	23	0.041
	22 08:32	26	RTO	32/IDLE/B	27060	0.10	0.17	44	0.052
	23 08:36	26	RTO	32/DISC/B	27000	0.10	0.17	59	0.053
	24 09:15	26	RTO	32/DISC/B	27033	0.14	0.16	46	0.103
	25 08:58	26	RTO	32/DISC/B	26750	0.16	0.14	40	0.065
See Note	26 08:54	26	RTO	32/IDLE/B	26691				
T30919 01/03/01	41 10:12	26	RTO	32/DISC/B	26837	0.37	0.22	20	0.352
	42 10:15	26	RTO	32/IDLE/B	26817	0.50	0.45	27	0.352
	43 10:26	26	RTO	32/IDLE/B	26640	0.63	0.68	37	0.398

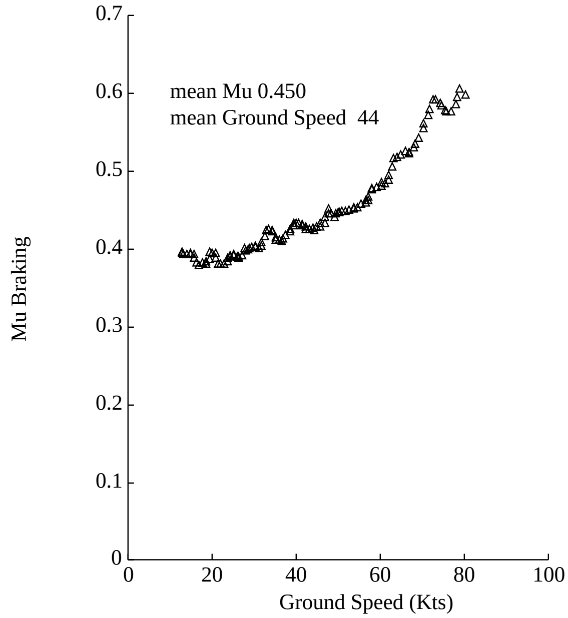
Note: This test run was aborted due to a lateral departure of the test section.

Surface: 100% Bare and Dry

Flight t30916, Run Number 41

Configuration: Flaps 32, Ground Idle, Max Braking

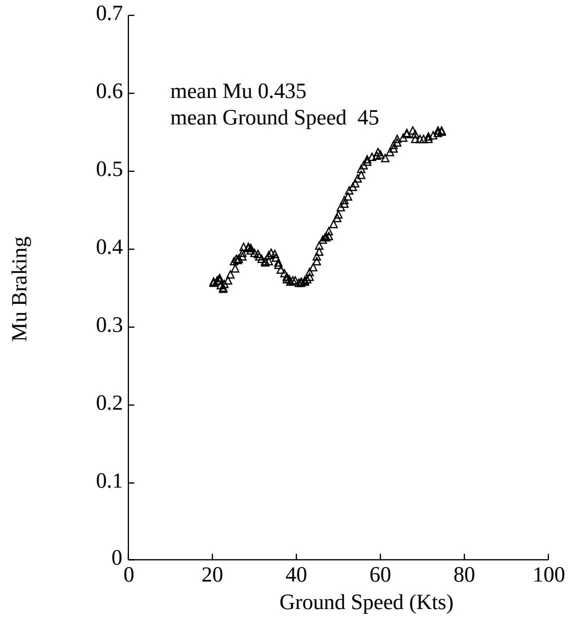
IRFI Average Not Available, CRFI Average 0.92



Flight t30916, Run Number 42

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average Not Available, CRFI Average 0.92

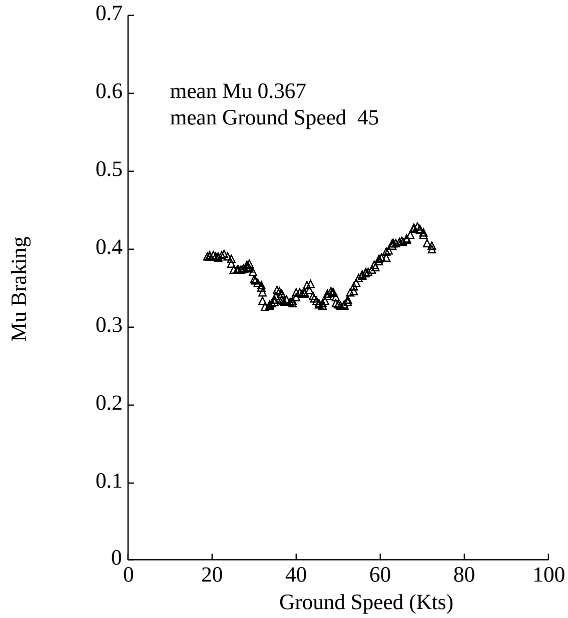


Surface: 100% Bare and Wet

Flight t30916, Run Number 61

Configuration: Flaps 32, Ground Idle, Max Braking

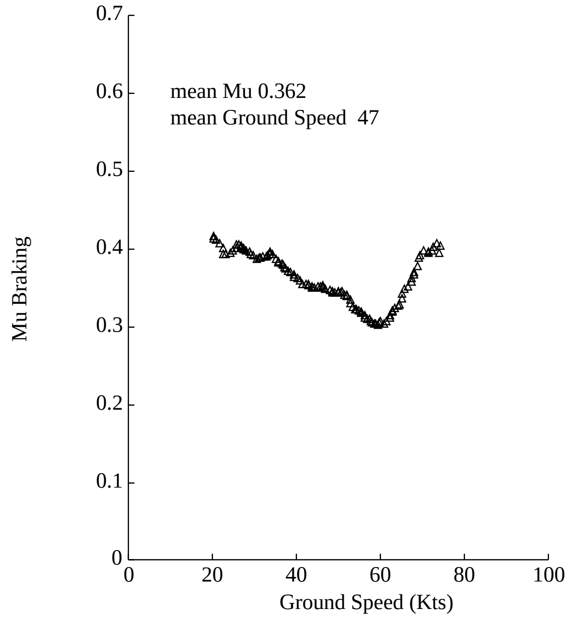
IRFI Average 0.80, CRFI Average 0.72



Flight t30916, Run Number 62

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.78, CRFI Average 0.72

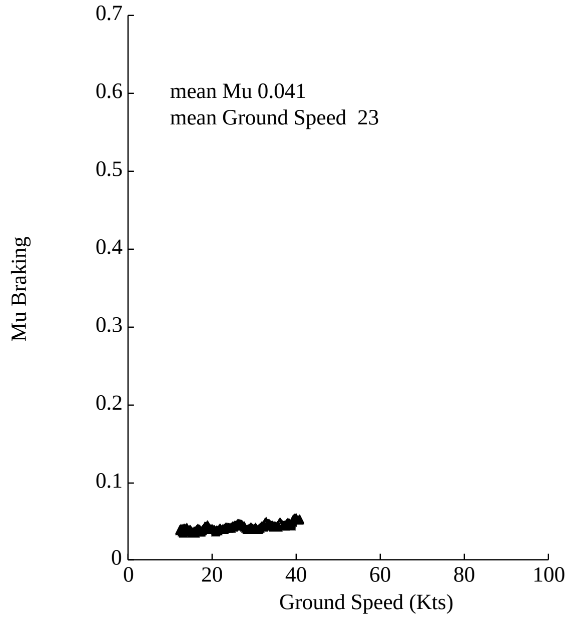


Surface: 100% Smooth Ice

Flight t30919, Run Number 21

Configuration: Flaps 32, Ground Idle, Max Braking

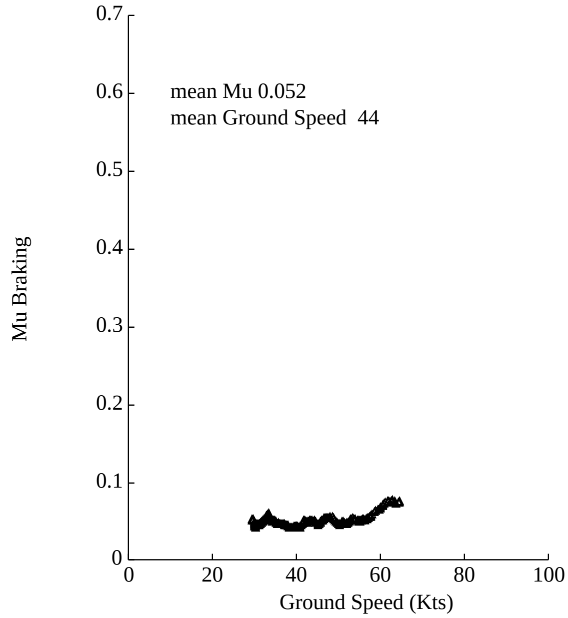
IRFI Average 0.17, CRFI Average 0.09



Flight t30919, Run Number 22

Configuration: Flaps 32, Ground Idle, Max Braking

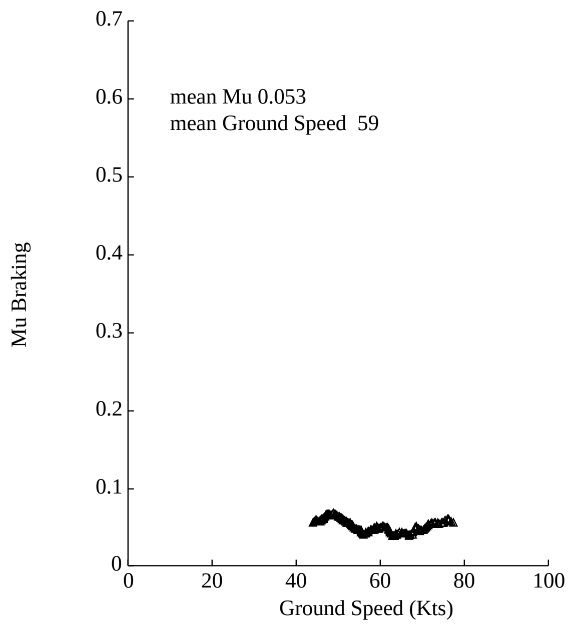
IRFI Average 0.17, CRFI Average 0.10



Flight t30919, Run Number 23

Configuration: Flaps 32, Ground Idle, Max Braking

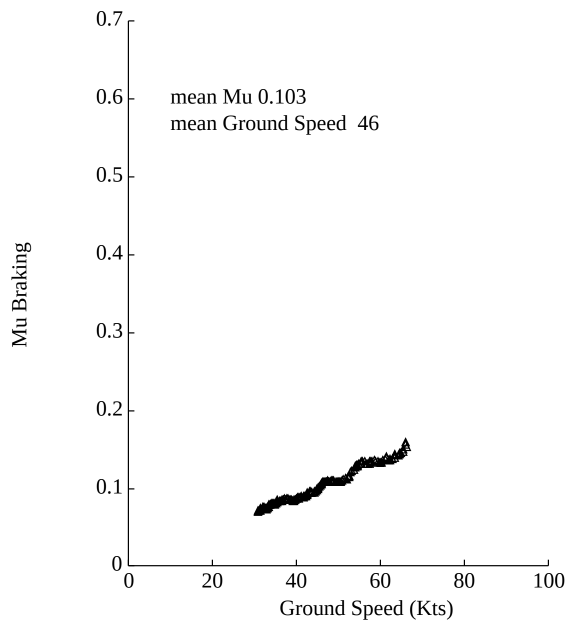
IRFI Average 0.17, CRFI Average 0.10



Flight t30919, Run Number 24

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.16, CRFI Average 0.14

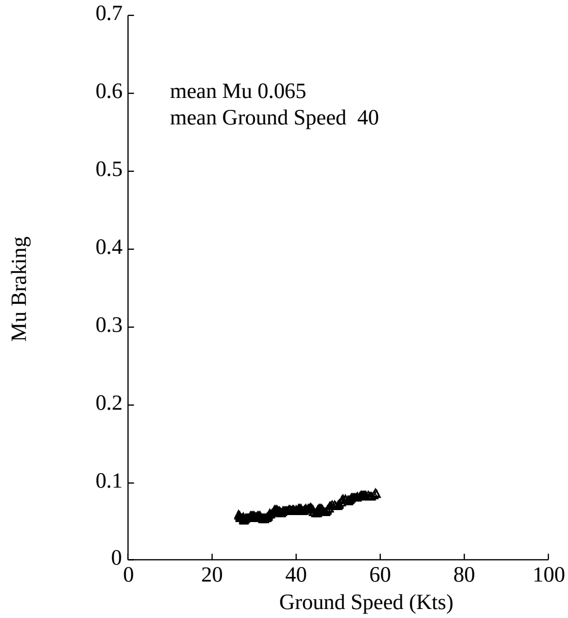


Surface: 100% Smooth Ice

Flight t30919, Run Number 25

Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.14, CRFI Average 0.16

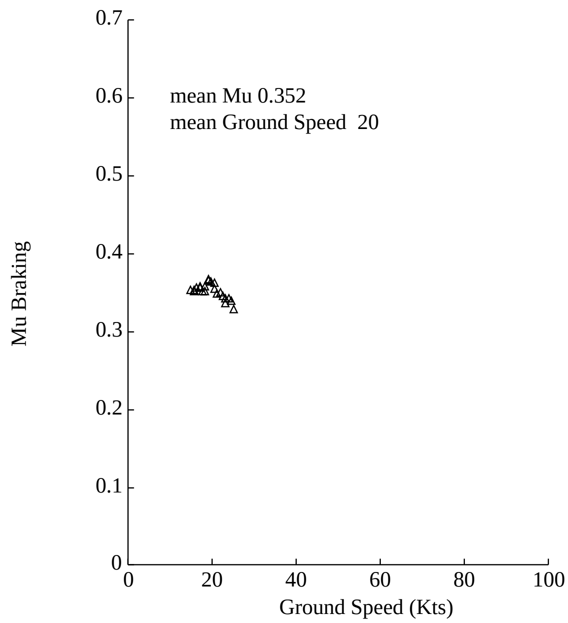


Surface: 100% Smooth Ice and Potassium Acetate

Flight t30919, Run Number 41

Configuration: Flaps 32, Ground Idle, Max Braking

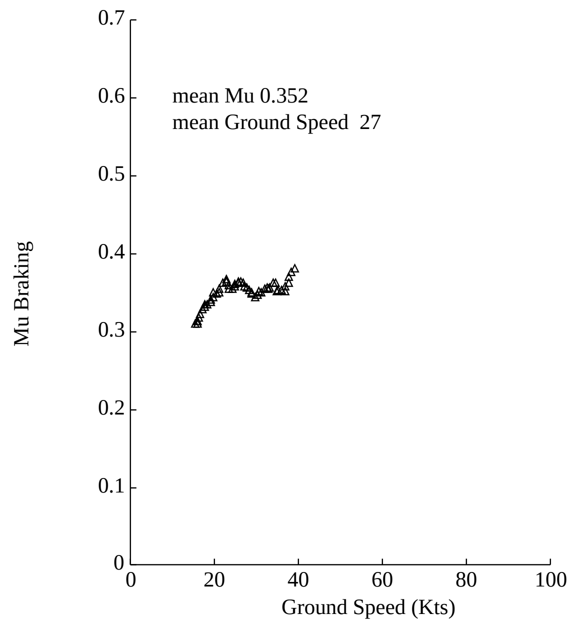
IRFI Average 0.22, CRFI Average 0.37



Flight t30919, Run Number 42

Configuration: Flaps 32, Ground Idle, Max Braking

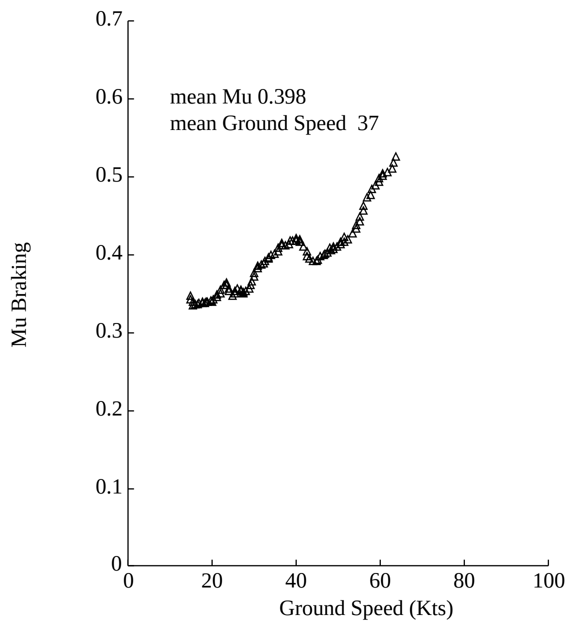
IRFI Average 0.45, CRFI Average 0.50



Flight t30919, Run Number 43

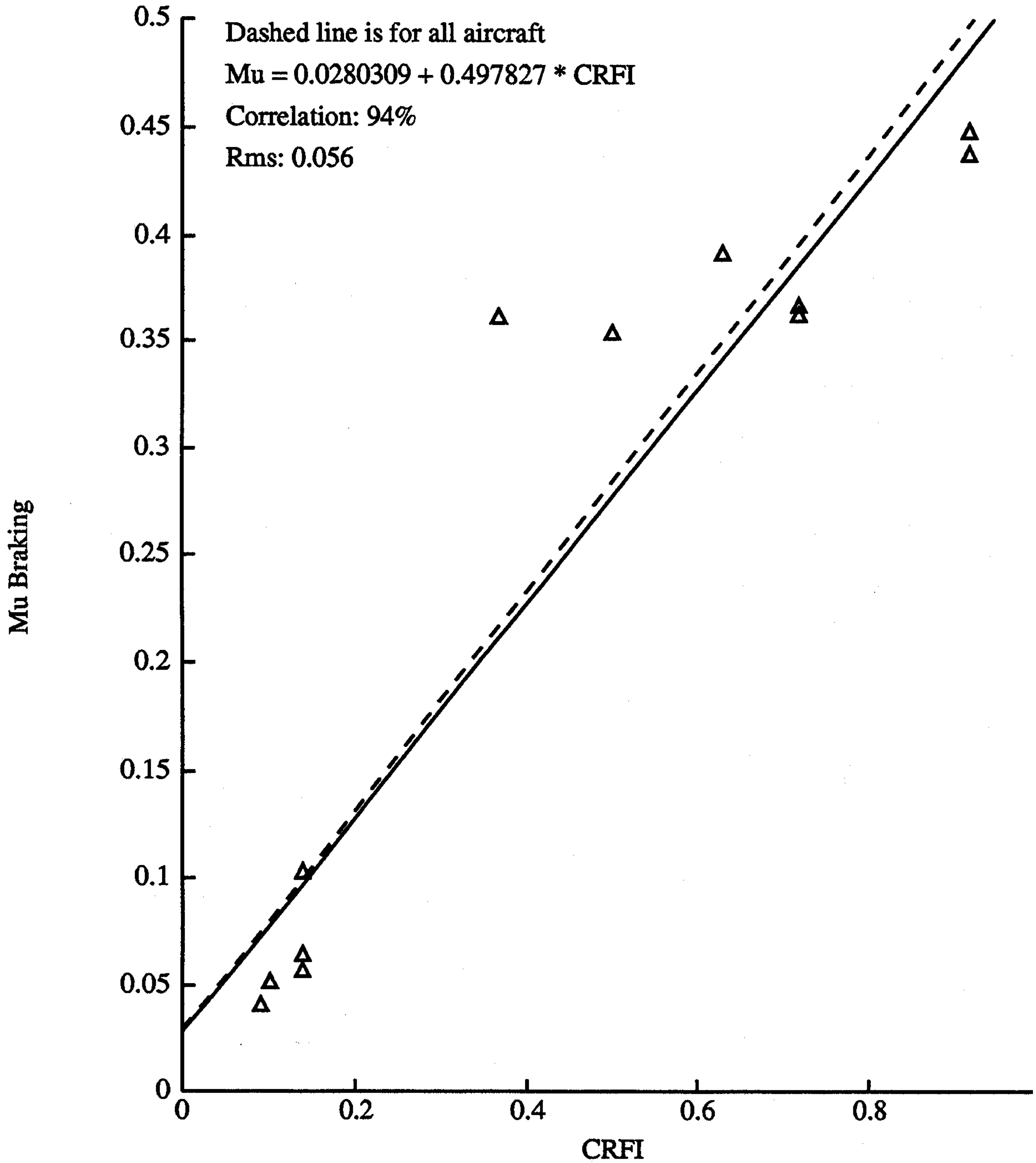
Configuration: Flaps 32, Ground Idle, Max Braking

IRFI Average 0.68, CRFI Average 0.63



Mean Mu Braking versus CRFI

Surfaces with No or Negligible Contamination Drag



Mean Mù Braking versus IRFI

Surfaces with No or Negligible Contamination Drag