NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

May 25, 2006

Aircraft Performance Group Study Addendum #1

I. ACCIDENT

NTSB Number:	DCA06MA009
Description:	Runway Overrun
Location:	Chicago Midway Airport, Chicago, Illinois
Date:	December 8, 2005
Time:	1914 CST
Aircraft:	Boeing 737-7H4, N471WN
Operator:	Southwest Airlines Co.

II. GROUP

Chairman	Kevin J. Renze, Ph.D. National Transportation Safety Board Vehicle Performance Division, RE-60
Member	Brian Gleason Southwest Airlines Co. Director of Flight Operations Technical
Member	Captain John Gadzinski Southwest Airlines Pilot Association Air Safety Committee
Member	Don Stimson Aerospace Engineer Airplane & Flight Crew Interface Branch, ANM-111 FAA Transport Standards Staff
Member	John D. Anderson Accident/Incident Investigation Aerodynamics Engineering The Boeing Company

SUMMARY

On December 8, 2005, 1914 Central Standard Time, Southwest Airlines (SWA) flight 1248, a Boeing B-737-7H4 registered as N471WN, overran runway 31C at Chicago Midway International Airport (MDW) in Chicago, Illinois, during the landing rollout. The airplane departed the end of the runway, rolled through a blast fence, a perimeter fence, and onto a roadway. Instrument meteorological conditions prevailed at the time. The airplane was substantially damaged. The flight was conducted under 14 CFR Part 121 of the Federal Aviation Regulations (FARs) and had departed from the Baltimore/ Washington International Thurgood Marshall Airport, Maryland.

Data in this addendum are specific to the Boeing 737-300/500/700W. However, B737-300 advisory landing performance data and the Southwest Airlines OPC implementation of B737-300 operational landing performance data are the primary focus. General background on the Southwest Airlines Onboard Performance Computer (OPC) is provided in Section 1.0. The history of Southwest Airlines B737-300 OPC operational landing performance calculations is defined in Section 2.0 and available B737-300 advisory landing data are documented in Section 3.0.

1.0 Southwest Airlines Onboard Performance Computer

The aircraft performance group examined the goals, data sources, and assumptions embedded in operational landing performance calculations for SWA B737-300/500/ 700W airplanes. The landing performance module of the Southwest Airlines OPC enables flight crews to estimate actual airplane landing performance at the arrival airport for both normal and non-normal airplane configurations. These performance calculations are based on a combination of Airplane Flight Manual (AFM), advisory, and operator-specific data and depend on specific stabilized approach, airplane configuration, environmental, and runway surface condition assumptions.

The OPC requires the flight crew to specify the airplane tail number, runway, landing weight and flap setting, wind speed and direction, temperature, barometric pressure, and runway condition. It subsequently calculates approximate stop margin[1] based primarily on advisory information for three autobrake settings (2, 3, and maximum). The goal is to use actual conditions to provide the flight crew with guidance on the level of braking effort required (in combination with other deceleration systems) to safely decelerate the airplane and exit the runway.

The airplane tail number dictates which OPC airframe data, engine data, and landing performance submodule will be used. The OPC implementation for the B737-700 incorporates a default setup of two-engine detent[2] reverse thrust and utilizes the Boeing Landing Module (BLM) first principles model to compute landing performance.

[1] The runway distance remaining after the airplane comes to a complete stop, measured from the nose wheel to the end of the landing distance available.

[2] Detent reverse thrust corresponds to approximately 75 percent nominal engine N1 corrected (for temperature and pressure effects). Maximum reverse thrust corresponds to approximately 82 percent nominal engine N1 corrected.

In contrast, the OPC implementation for the B737-300/500 calls a landing submodule that was initially developed from digitized hardcopy data by Teledyne Controls and subsequently maintained and enhanced by Southwest Airlines.

Southwest Airlines released the OPC for service on the B737-200/300/500 in July 1997 with autobrake stopping distance calculations rooted in the respective airplane model AFM autobrake charts. The OPC B737-700 landing performance capability was added in December 1997 in preparation for the airplane's revenue service entry in April 1998. The B737-200 aircraft was retired from the Southwest Airlines fleet in January 2005, and was removed from the OPC at that time.

2.0 Southwest Airlines B737-300 OPC Operational Landing Performance

The history of Southwest Airlines B737-300 OPC operational landing performance calculations was reconstructed and the resulting landing distance data are presented graphically in Attachments 1-4. The data correspond to the B737-300 Flight Planning and Performance Manual (FPPM) [with CFM56-3_20K engines, category A brakes, flaps 40, dated August 15, 2004] for dry runway and good, medium, and poor reported braking action, respectively. With the exception of FPPM poor reported braking action, NTSB calculated and OPC data are compared to Boeing FPPM reference data for each runway or reported braking action condition. Maximum landing weight is not identified on the plots, consistent with Boeing's historic presentation of similar landing performance data. For reference, the maximum certified landing weight for the Southwest B737-300 is 114,000 pounds.

The plots in Attachments 1-4 for each runway or reported braking action condition are generally organized as follows:

Page A#.2: Boeing FPPM data for each braking configuration for sea level, standard day, no wind or slope, V_{REF40} approach speed, air distance adjusted to 1,500 feet (for comparison to OPC data), with and without reverse thrust. These data are presented for reference on each page for a given runway or reported braking action condition.

Page A#.3: Boeing 737-300 AFM data from the "Stopping Distance with Automatic Wheel Brakes" chart, document D6-8730, section 4.13, page 11, dated 11/14/84 (See Attachment 5, pages A5.2-3). Data extracted from this chart correspond to the MAX setting, WET RUNWAY (LESS SLIPPERY), setting 3, WET RUNWAY (MORE SLIPPERY), and setting 2 curves/boundaries. Approach speed was mapped to gross weight based on data available on the OPC. An air distance of 1,500 feet was added to the actual stopping distance from touchdown to determine the landing distance presented.

Page A#.4: Southwest Airline's historic interpretation of curves for autobrake 2, 3, and MAX (label suffix "raw") as a function of the runway surface condition based on the AFM data presented on page A#.3. For example, on a dry runway, present the values corresponding to autobrake 2, 3, and MAX. For SWA WET-GOOD reported braking action, present the values corresponding to autobrake 2, 3, and WET RUNWAY (LESS SLIPPERY). For SWA WET-POOR reported braking action,

present the values corresponding to autobrake 2, WET RUNWAY (MORE SLIPPERY), and WET RUNWAY (MORE SLIPPERY).

Page A#.5: NTSB calculation of SWA curves for autobrake 2, 3, and MAX (label suffix "factored") based on the application of SWA provided wet runway correction factors to the AFM-based autobrake ground distance data. SWA wet runway correction factors are multiplied by the corresponding SWA dry runway autobrake ground distance for autobrake settings 2, 3, and MAX prior to the addition of the air distance.

Table 1: SWA OPC release 0512 wet runway correction factors applied to the SWA dry runway autobrake actual stopping distance based on the B737-300 airplane flight manual "Stopping Distance With Automatic Wheel Brakes" chart (D6-8730, section 4.13, page 11, 11/14/84).

Runway Condition	***Autobrake Setting***		
	Autobrake 2	*Autobrake 3*	*Autobrake MAX*
Wet-Good	1.0	1.0025	1.2
Wet-Fair	1.0	1.05	1.35
Wet-Poor	1.025	1.15	1.65

Page A#.6: SWA OPC release 0512 data (December 2005, installed fleet wide at the time of the accident). Ideally these data should be similar or identical to the data presented on page A#.5, with the exception that an additional logic check is in place on the SWA OPC to present the more conservative of the page A#.5 value or 0.8 times the dispatch value. This logic check is manifest, for example, at high gross weight and autobrake MAX.

Page A#.7: SWA OPC release 0602 data (February 2006, installed fleet wide post-accident) that correspond to Boeing FPPM data for no thrust reverser.

Page A#.8: SWA OPC release 0602A data (February 2006, installed fleet wide post-accident) that correspond to Boeing FPPM data for no thrust reverser with an additional SWA logic check to ensure that the stopping margin for autobrake MAX >= autobrake 3 >= autobrake 2. This logic check is manifest, for example, at low gross weight and autobrake MAX.

A comparison of the B737-300 OPC release 0512 operational landing performance results to the respective Boeing FPPM normal configuration advisory landing data showed that for sea level, standard day conditions on a dry runway, the OPC landing distance was more conservative than the FPPM value, independent of the use of reverse thrust. However, for runway conditions worse than “dry,” the B737-300 OPC release 0512 maximum autobrake stop margin could not be achieved without the use of two-engine detent reverse thrust, which contradicted the SWA Flight Operations Manual (FOM) statement that “(**-300/-500**: stop margins do not include the effects of reverse thrust)” (see Rev. 3-05, page 10.1.7, dated Nov. 9-05).

The OPC implementation of reverse thrust credit for the B737-300/500 was traced to improper reference to the respective AFM autobrake charts. Boeing indicated during a teleconference call in April 2006 that these charts contain dry runway data, but no quantifiable wet or contaminated runway data. In addition, because the charts only contain dry runway data, they may be used with or without reverse thrust. Finally, Boeing stated that the gray shaded area on the chart that depicts a range of stopping distance for varying wet runway slipperiness is notional only and should not be used to calculate stopping distances.

Southwest Airlines used the gray region of the AFM autobrake chart in an attempt to quantify stopping distance expected for varying wet runway slipperiness, contrary to the April 2006 Boeing position on the proper use of these data. However, Boeing did acknowledge that the wet runway guidance notes on the 1984 AFM chart and the accompanying Boeing written guidance were not completely clear that the gray band was intended to be notional only.

In short, the B737-300/500 autobrake performance adjustments required to support the desired SWA set of OPC runway conditions and normal configuration operational landing calculations were not available in 1997 when the OPC was released. As documented in Section 3.0, the necessary performance adjustments did not become available until December 2001.

In January 2006 Southwest Airlines reported that they were unaware that more current, comprehensive, and suitable B737-300/500 advisory landing data had been available from Boeing since December 2001. However, Boeing documents indicate that the Quick Reference Handbook (QRH) data were available to Southwest Airlines in December 2001, February 2002, and June 2004.[3]

Southwest Airlines updated the B737-300/500 landing performance submodule of the OPC[4] in February 2006 with current QRH Normal Configuration Landing Distance data and excluded reverse thrust effects from the B737-300/500 operational landing performance calculations, consistent with the SWA FOM. As of May 2006, no significant changes were made to the B737-700 operational landing performance calculations following the flight 1248 accident.

[3] The December 2001 and February 2002 SWA QRH data contained the erroneous note, “Autobrake data does not include the use of reverse thrust. Corrections for inoperative reversers do not apply.” Boeing corrected the erroneous note with the release of the June 2002 QRH data.

[4] The non-normal configuration OPC operational landing performance data for the B737-300/500/700W are all based on the use of maximum reverse thrust, with no corrections available to support a two-engine thrust reverser inoperable calculation.

3.0 Available B737-300 Advisory Landing Data

A summary of available B737-300 normal configuration advisory landing data as a function of publication document and date is provided in Table 2. The identified publication documents include the AFM, Performance Engineers Manual (PEM), FPPM, and QRH, ordered left to right.

Table 2: Boeing 737-300 Advisory Landing Data

Year	AFM	PEM	FPPM	QRH
1984	Autobrake	None	No Manual	None
1985		Slippery (.20, .15, .10)	No Manual	None
1994		Slippery (.20, .15, .10, .05)	No Manual	None
1998			Autobrake	Autobrake & Slippery
2001			Autobrake & Slippery/Autobrake	Autobrake & Slippery/Autobrake
2003			Normal Configuration Landing Distance	Normal Configuration Landing Distance

Graphical and tabular flaps 40 data excerpted from these documents are included in Attachment 5. In this presentation, the QRH equivalent data are identified as either Operations Manual or Flight Crew Operations Manual (FCOM) data.

The number and detail level of performance adjustments available in Boeing normal configuration advisory landing data has evolved over time for current production and some out-of-production models. Advisory stopping distance data for the B737-300 were originally presented in the AFM in 1984 as a function of approach speed and autobrake setting.[5] This AFM autobrake chart also contained wet runway guidance and wet runway "more slippery" and "less slippery" notes. Accompanying written guidance stated, among other things, that 1) "The stopping distances shown are based on demonstrated deceleration values using automatic speed brakes and are valid for all landing flap settings, with or without reverse thrust," 2) "Stopping distances that can be achieved on wet runways depend on the friction characteristics, or slipperiness, of the particular runway. A range of stopping distance for varying slipperiness is shown; the range shown is based on the variation of wet runway friction characteristics expected in service," and 3) "The use of reverse thrust will decrease wet runway stopping distance when the deceleration is limited by runway friction characteristics. Extremely wet and slippery conditions can result in longer distances than indicated." These data remain in the AFM today.

In 1985, slippery landing distance data were published in the PEM as a function of gross weight and airplane braking coefficient (for values of 0.20, 0.15, and 0.10), but data were only available for maximum manual braking and two-engine reverse thrust.

[5] The autobrake chart also provided stopping distance adjustments for tailwind, temperature, and pressure altitude.

In 1994, the PEM data issued in 1985 were updated to add landing distance data for an airplane braking coefficient value of 0.05.

In 1998, the previously plotted AFM autobrake data were presented in tabular format in the QRH[6,7] together with a subset of the PEM slippery data. The QRH slippery data mapped airplane braking coefficient values of 0.20, 0.10, and 0.05 to Boeing "good," "medium," and "poor" reported braking action, respectively. Actual (unfactored) slippery landing distance data remained available only for maximum manual braking and assumed the use of two-engine maximum reverse thrust, an air distance of 1000 feet, and an approach speed of V_{REF} for the selected flap. Performance adjustments were included for variations in weight, airport pressure altitude, and approach speed.

By December 2001, reference data for a reported "dry" runway condition and autobrake settings of 2, 3, and maximum were added to the QRH, in addition to lumped adjustments (independent of braking configuration) for wind, runway slope, and use of reverse thrust. The reference landing distances were based on an air distance of 1000 feet, an approach speed of V_{REF} for the selected flap, and the use of two-engine detent reverse thrust. As of 2003, the QRH contained an additional temperature adjustment and the previously lumped distance adjustments were defined as a function of reported braking action and braking configuration.

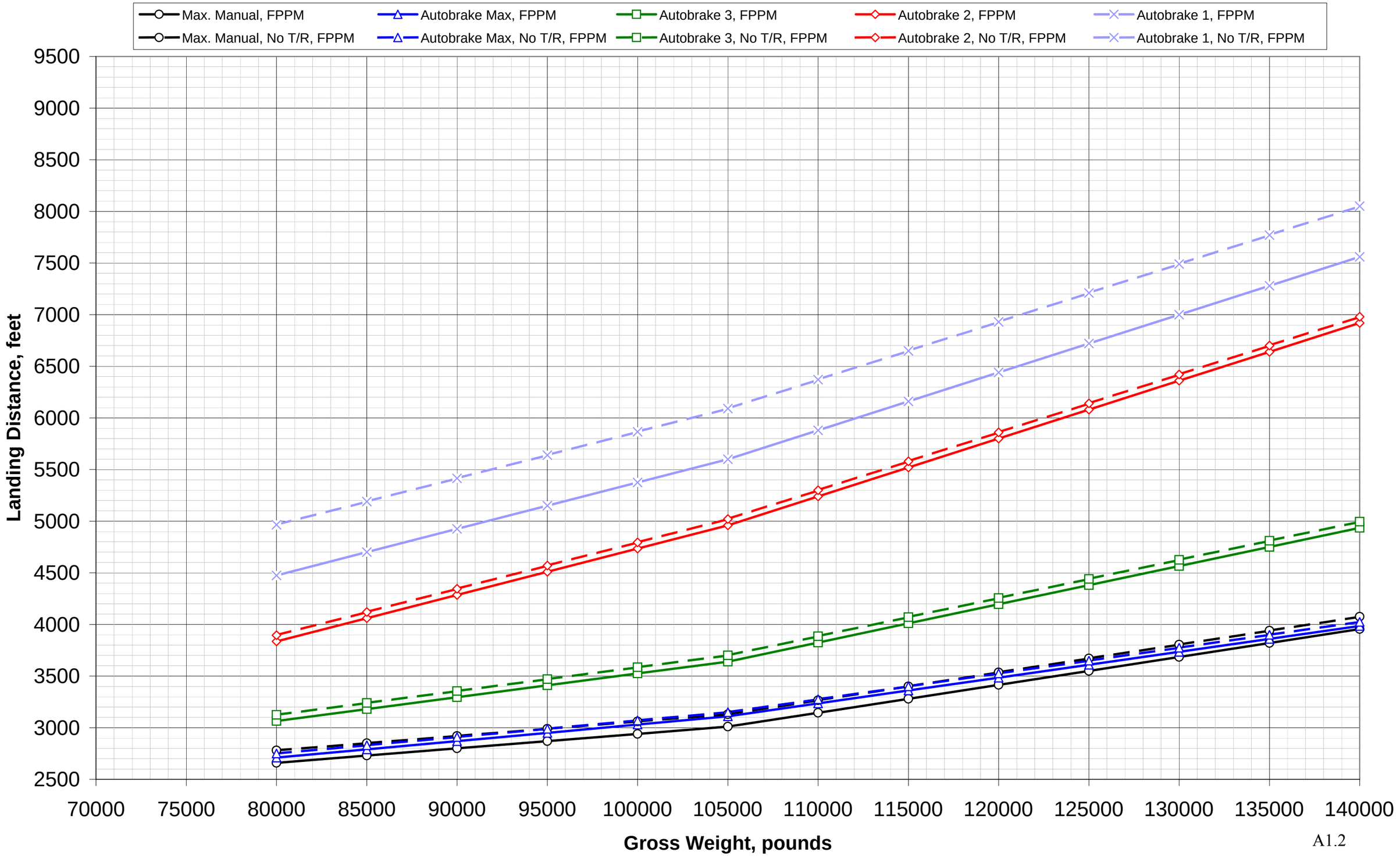
[6] The tabulated QRH autobrake advisory stopping distance data do not include any wet runway guidance notes, unlike the original 1984 AFM chart.

[7] In 1998, the B737-300 FPPM contained the same basic autobrake advisory stopping distance data as that available in the 1984 AFM chart, but the wet runway guidance and the more/less slippery notes were removed. Beginning in 2001, the FPPM and QRH advisory landing data content and format were essentially synchronized.

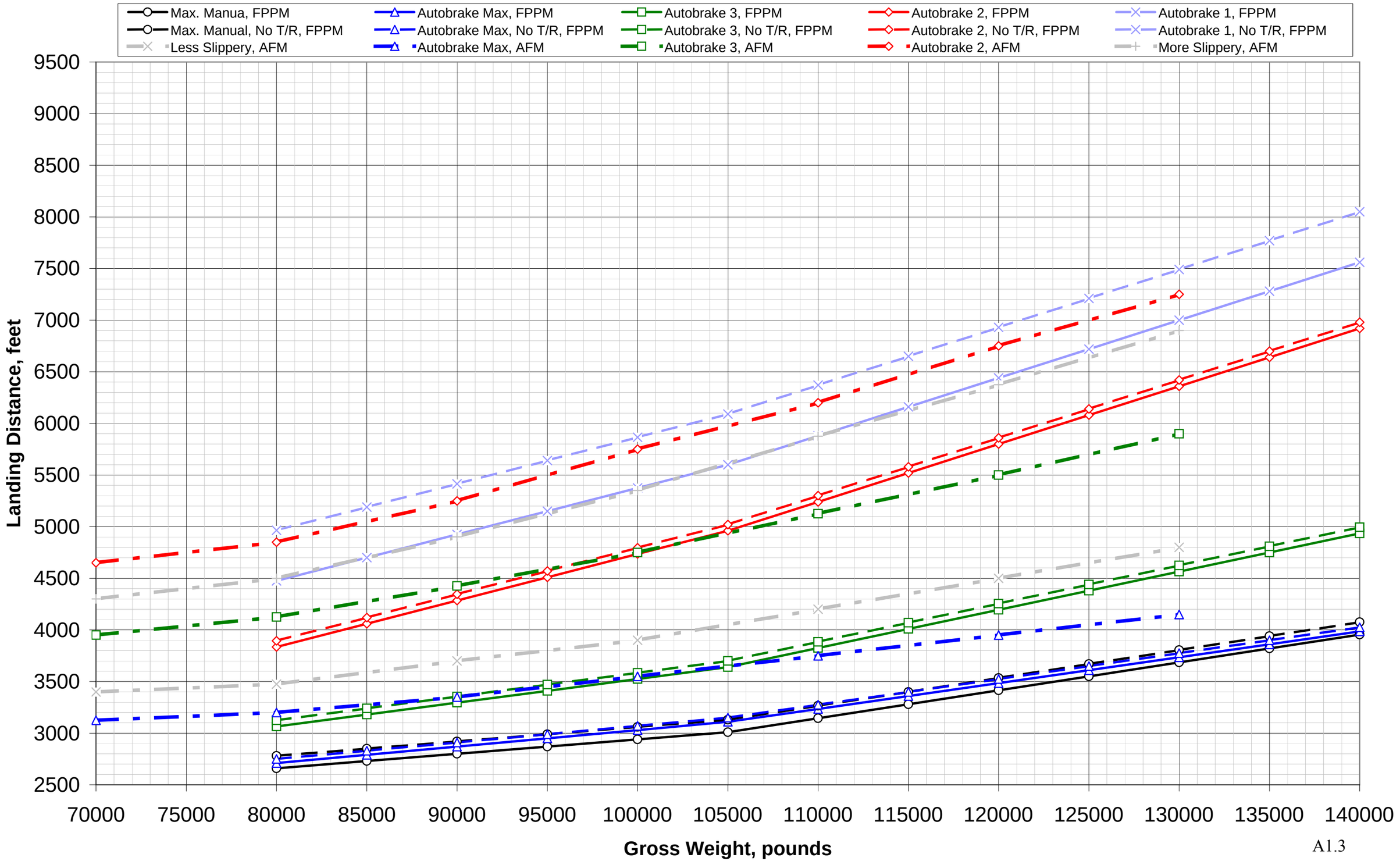
Attachment 1: Southwest Airlines B737-300 OPC History

Dry Runway (airplane braking coefficient = 0.40)

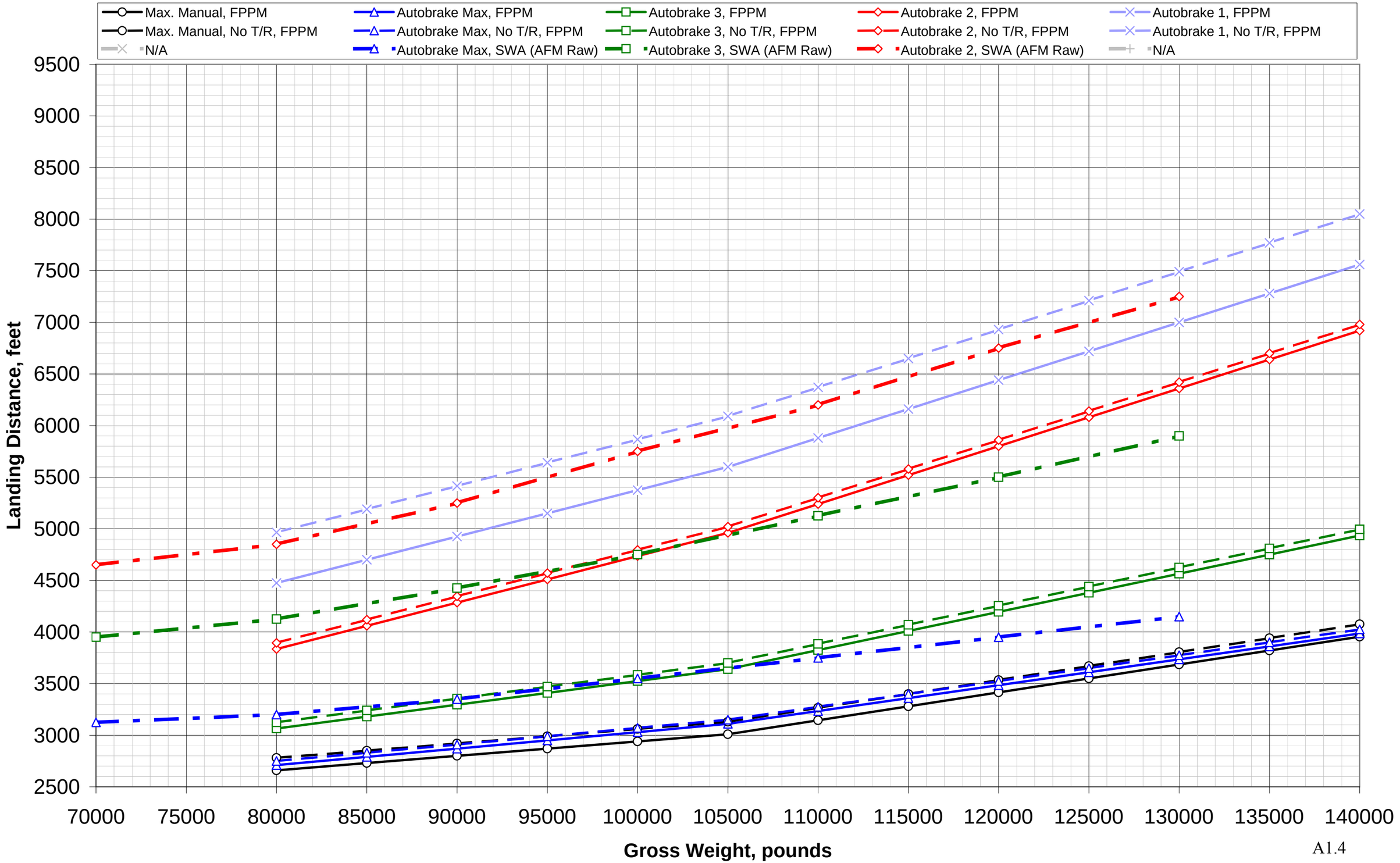
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



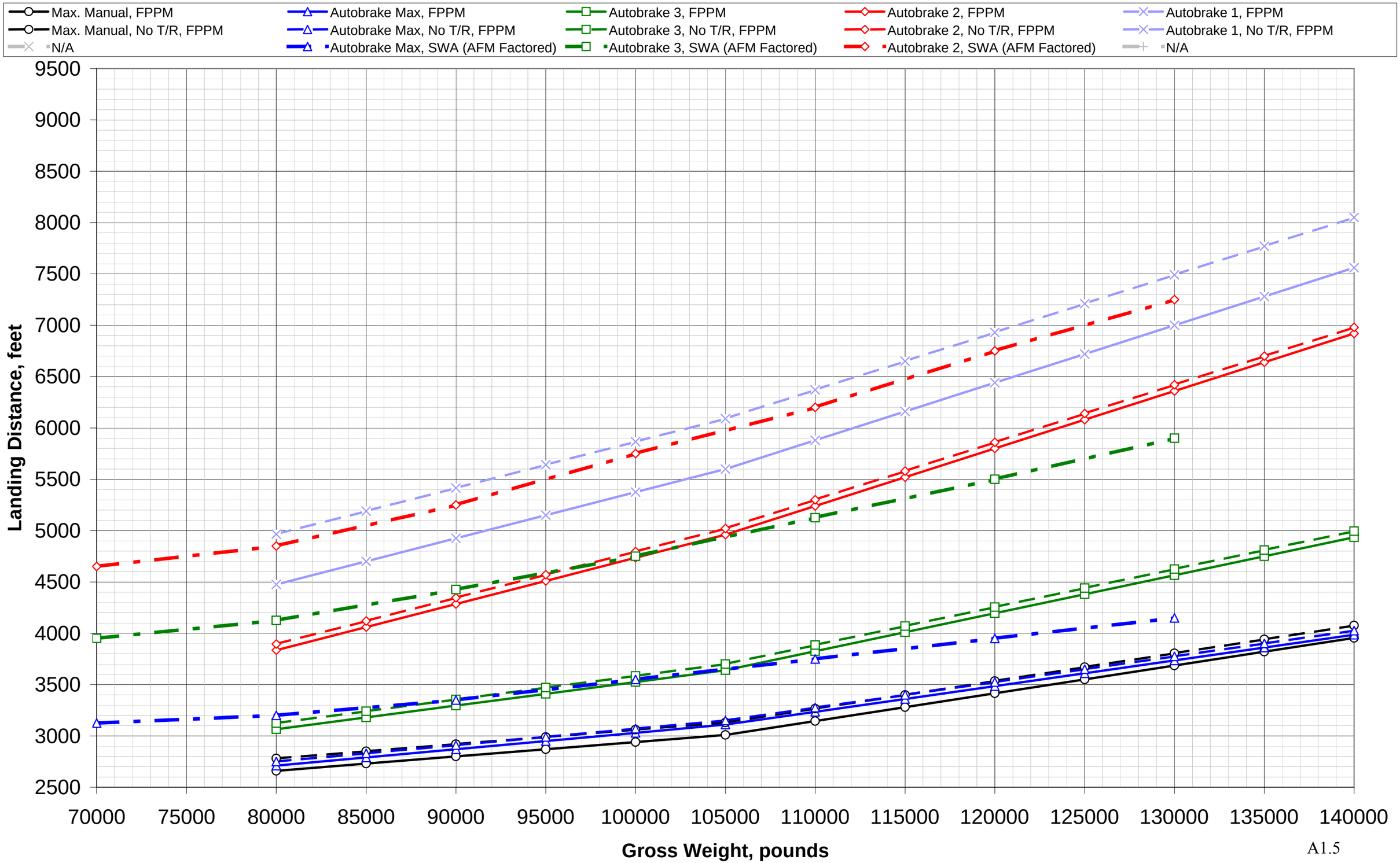
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



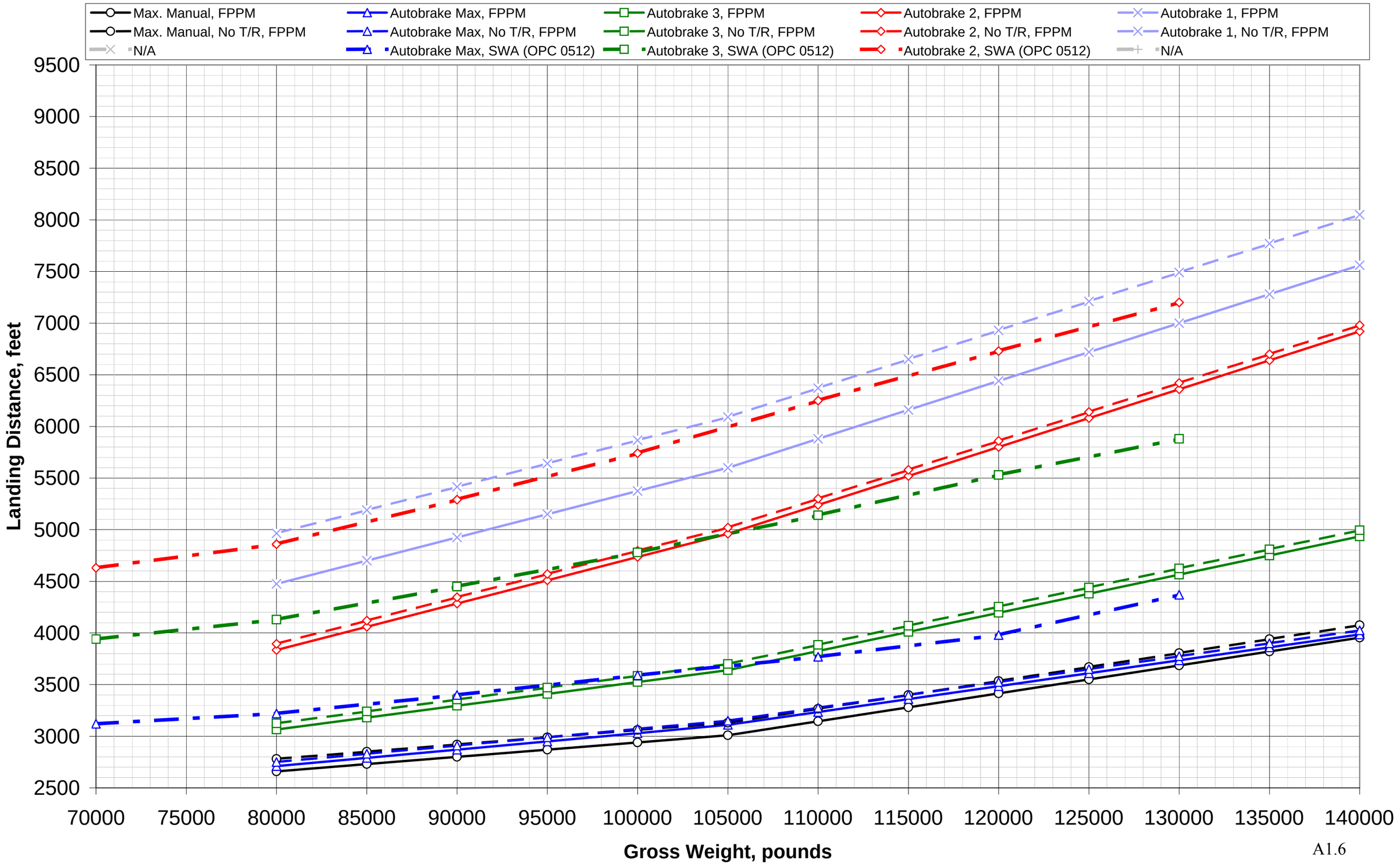
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



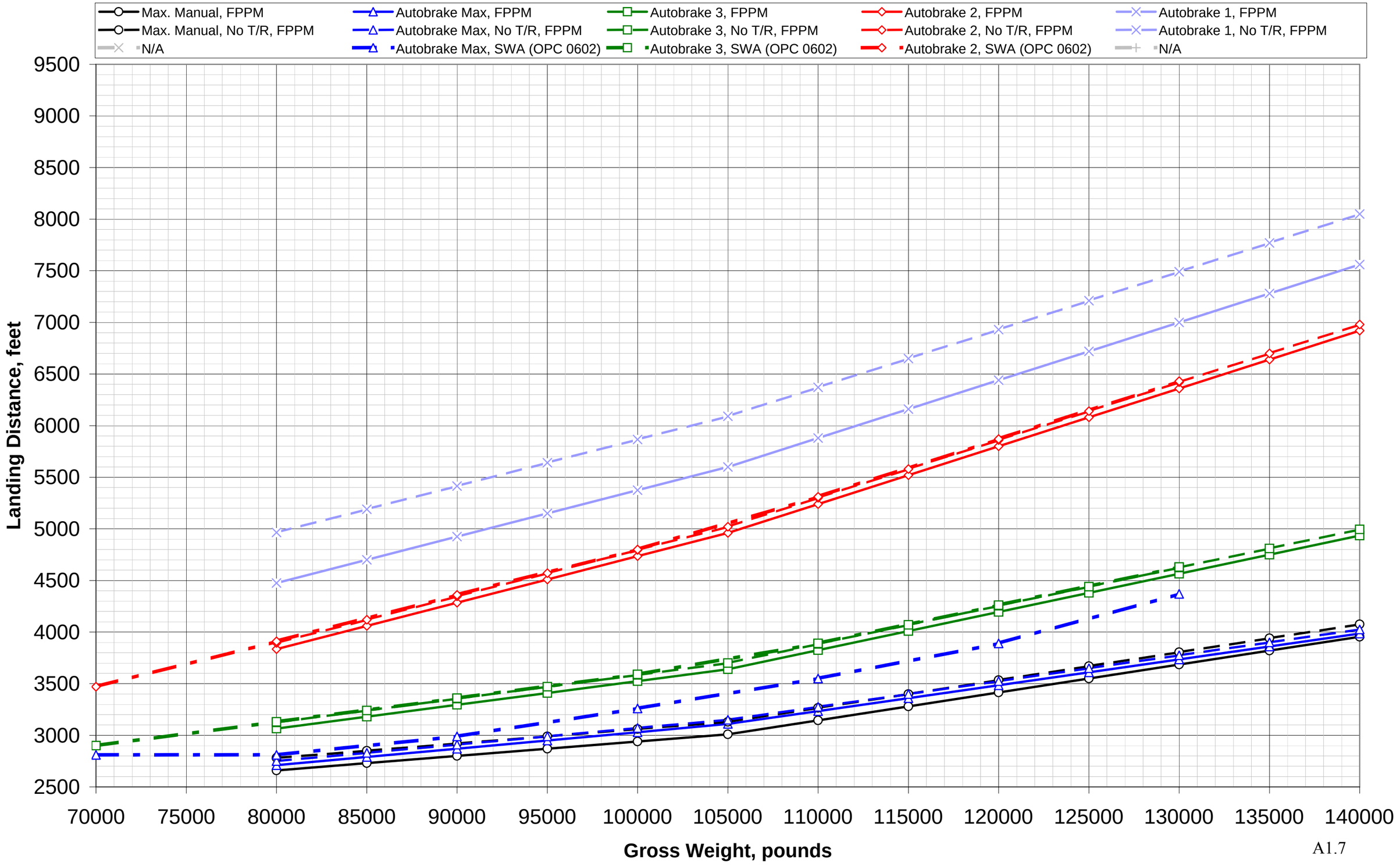
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



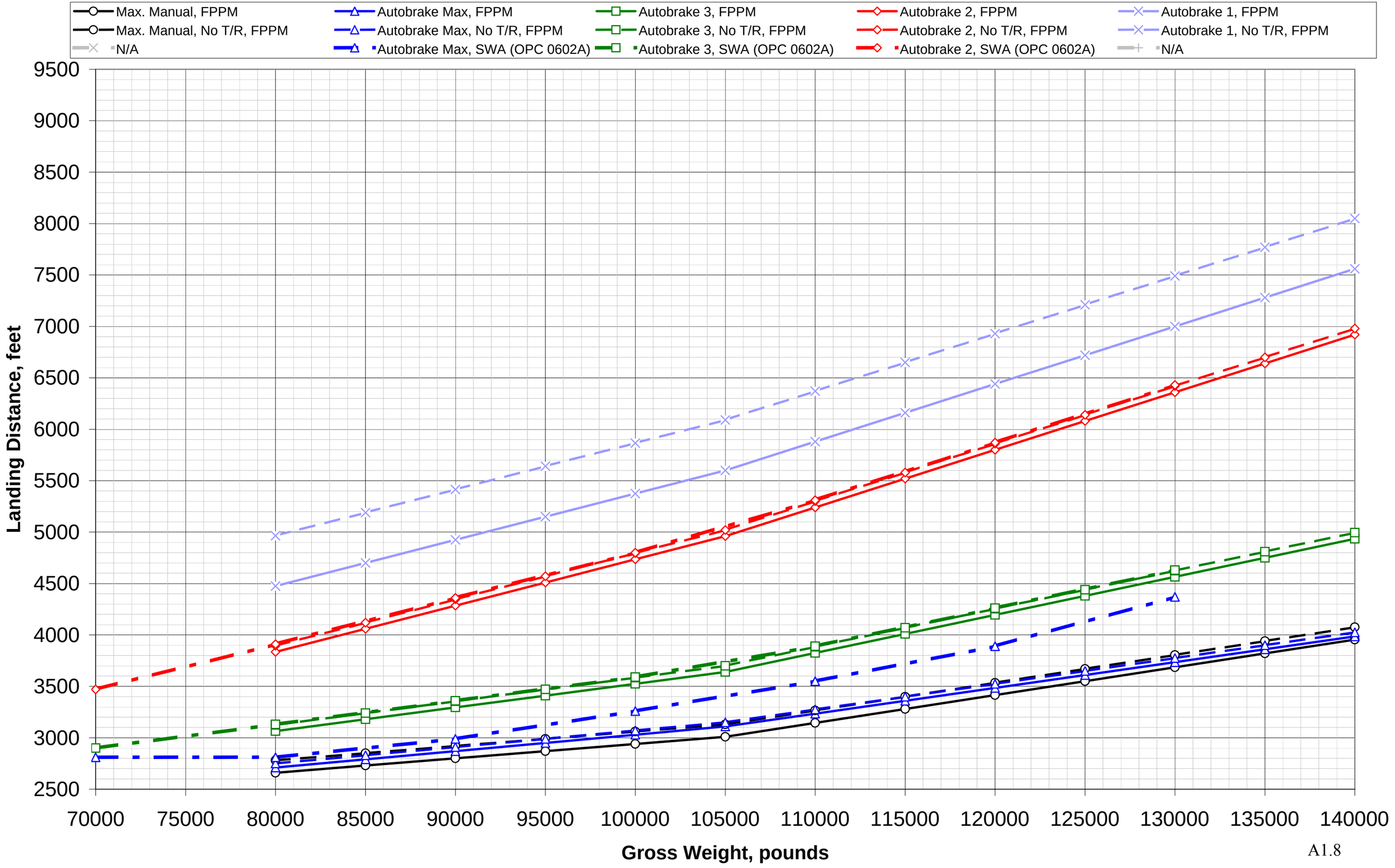
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



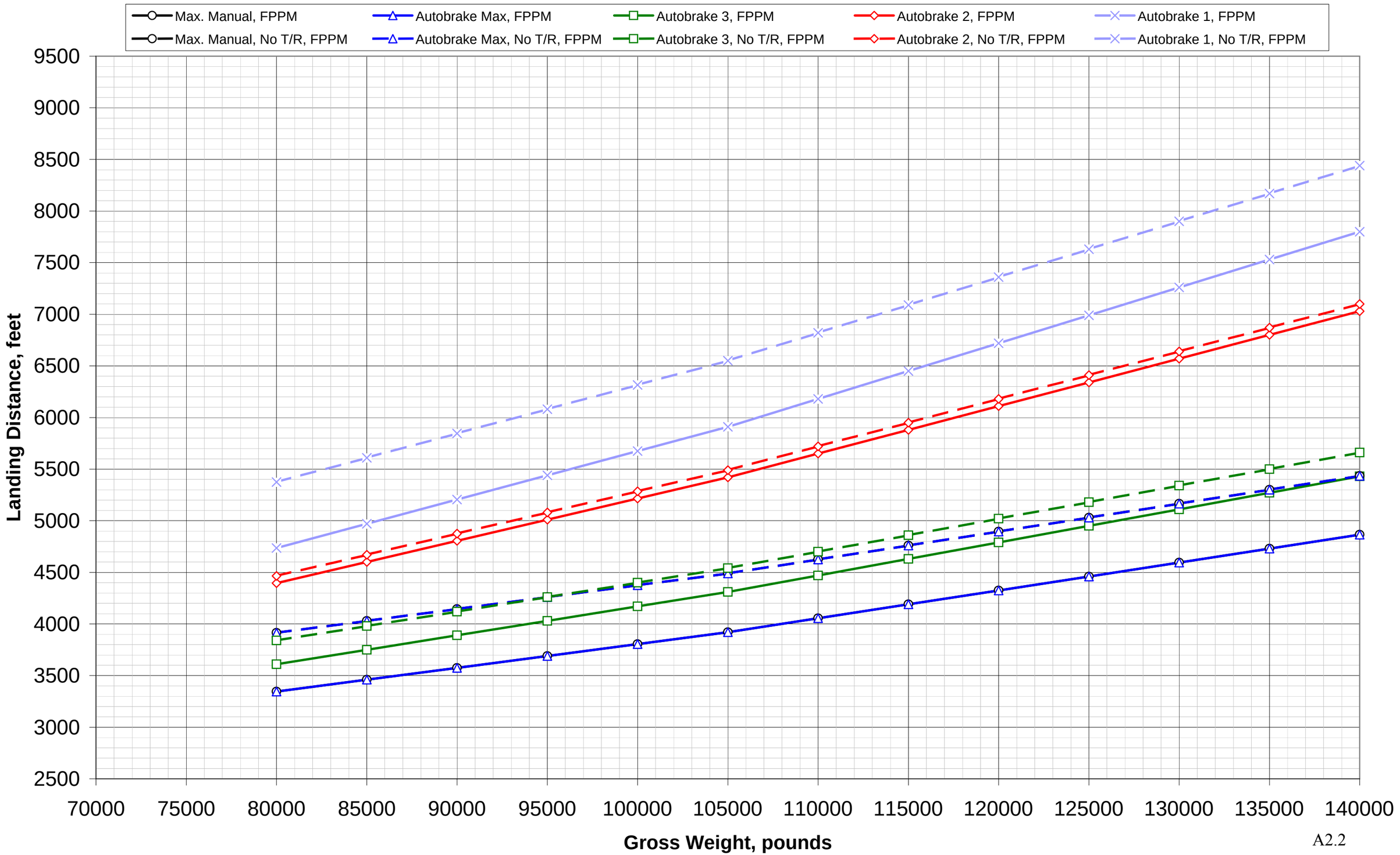
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [DRY Runway]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



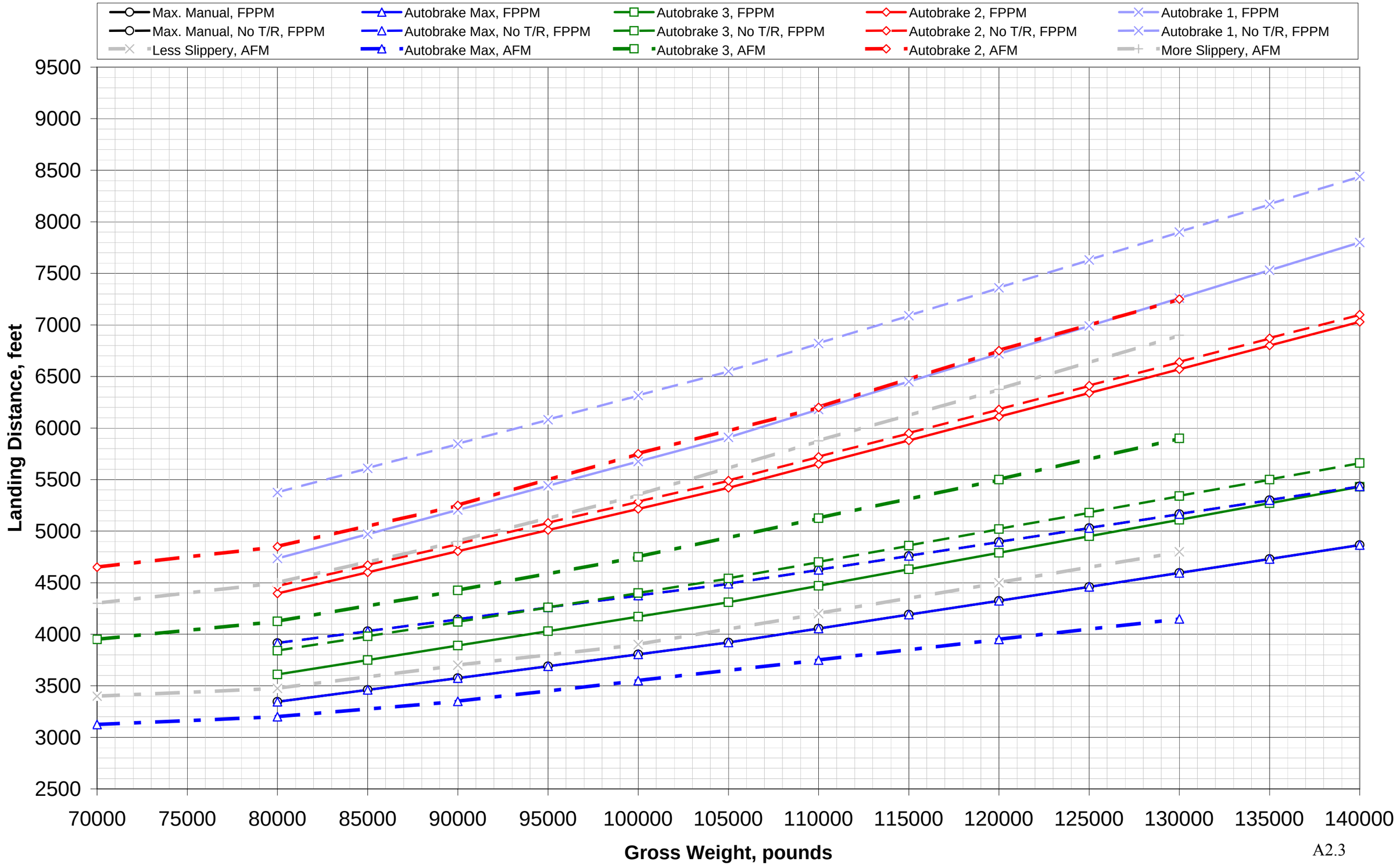
Attachment 2: Southwest Airlines B737-300 OPC History

Boeing Good Reported Braking Action (airplane braking coefficient = 0.20)

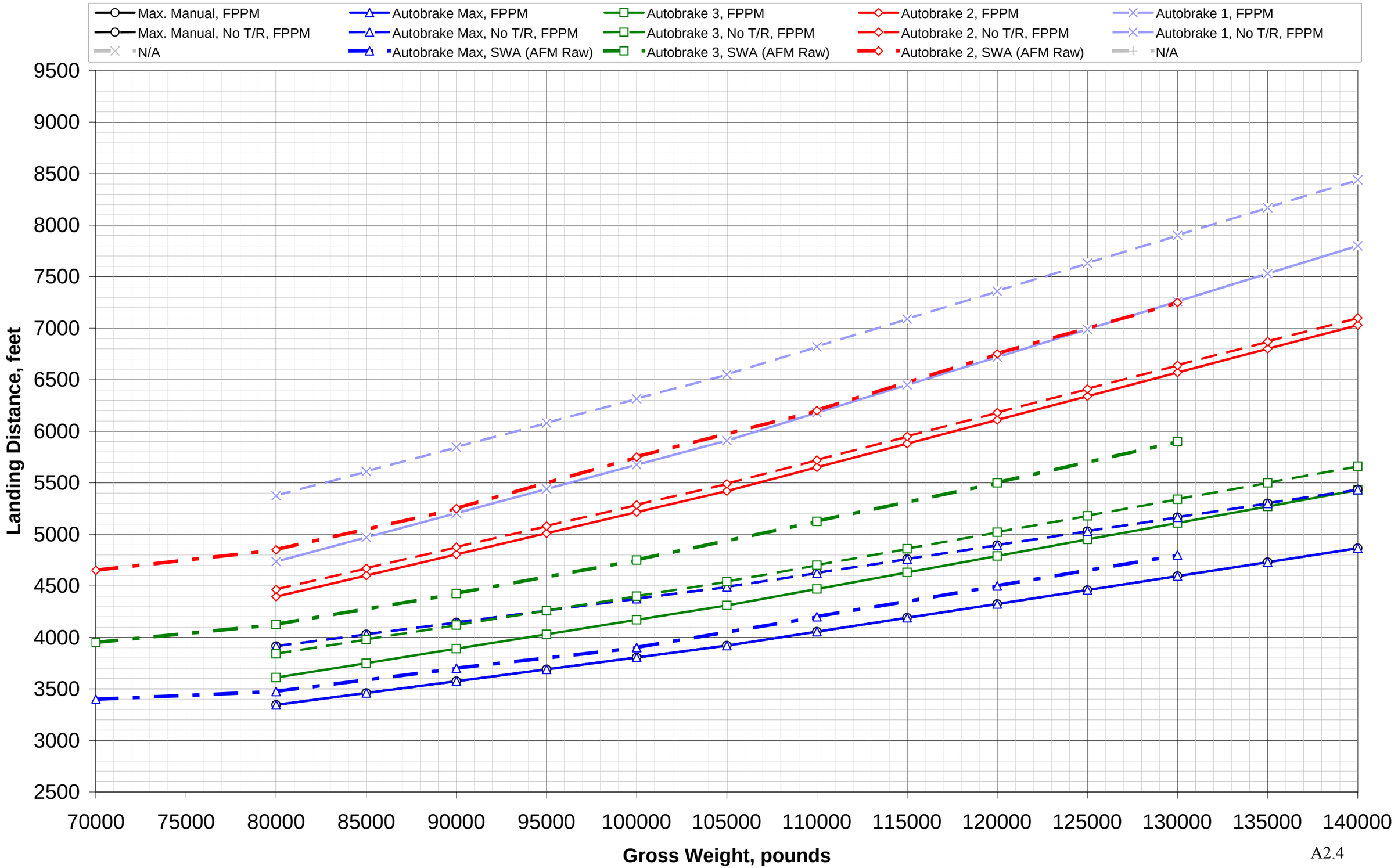
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



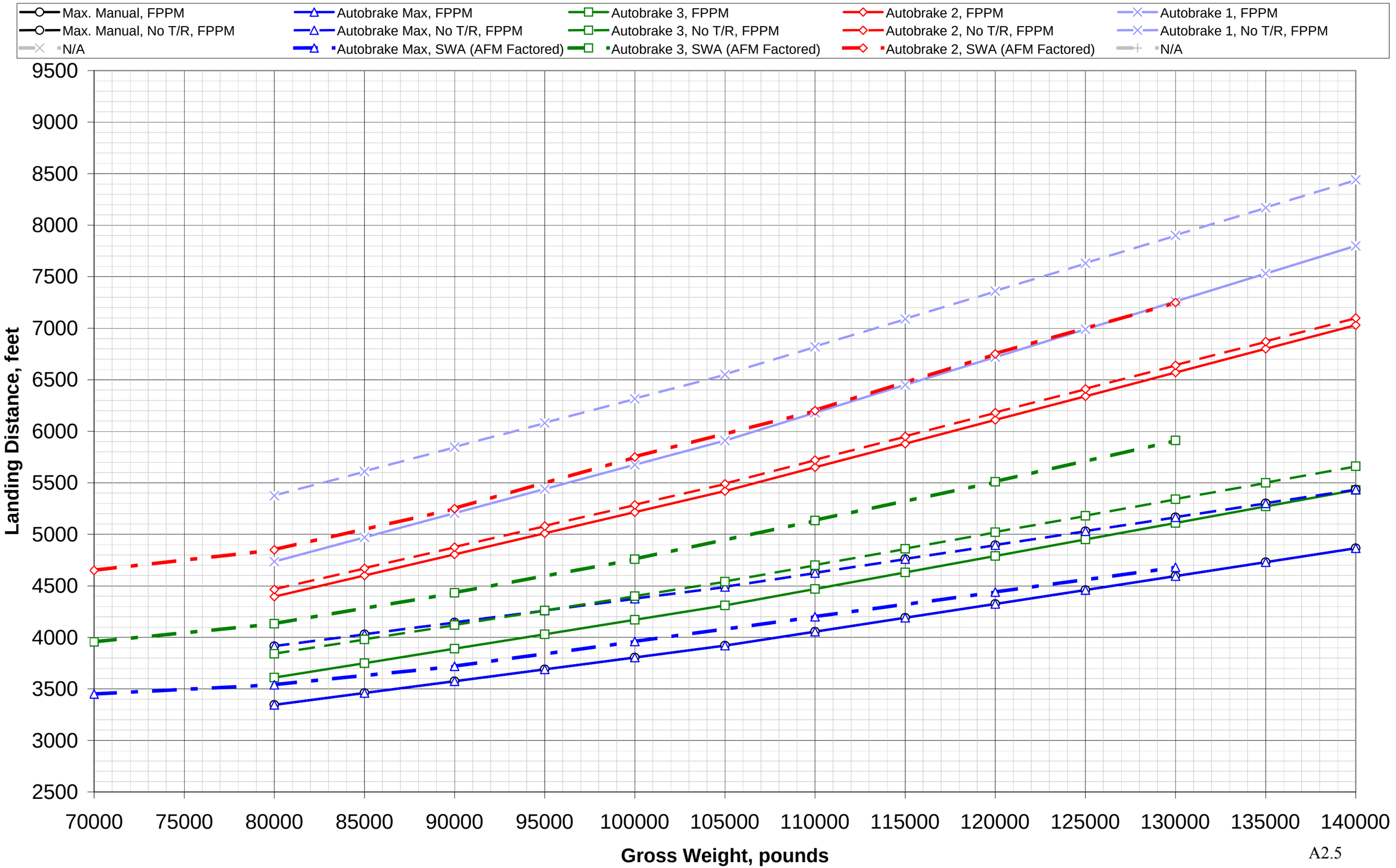
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



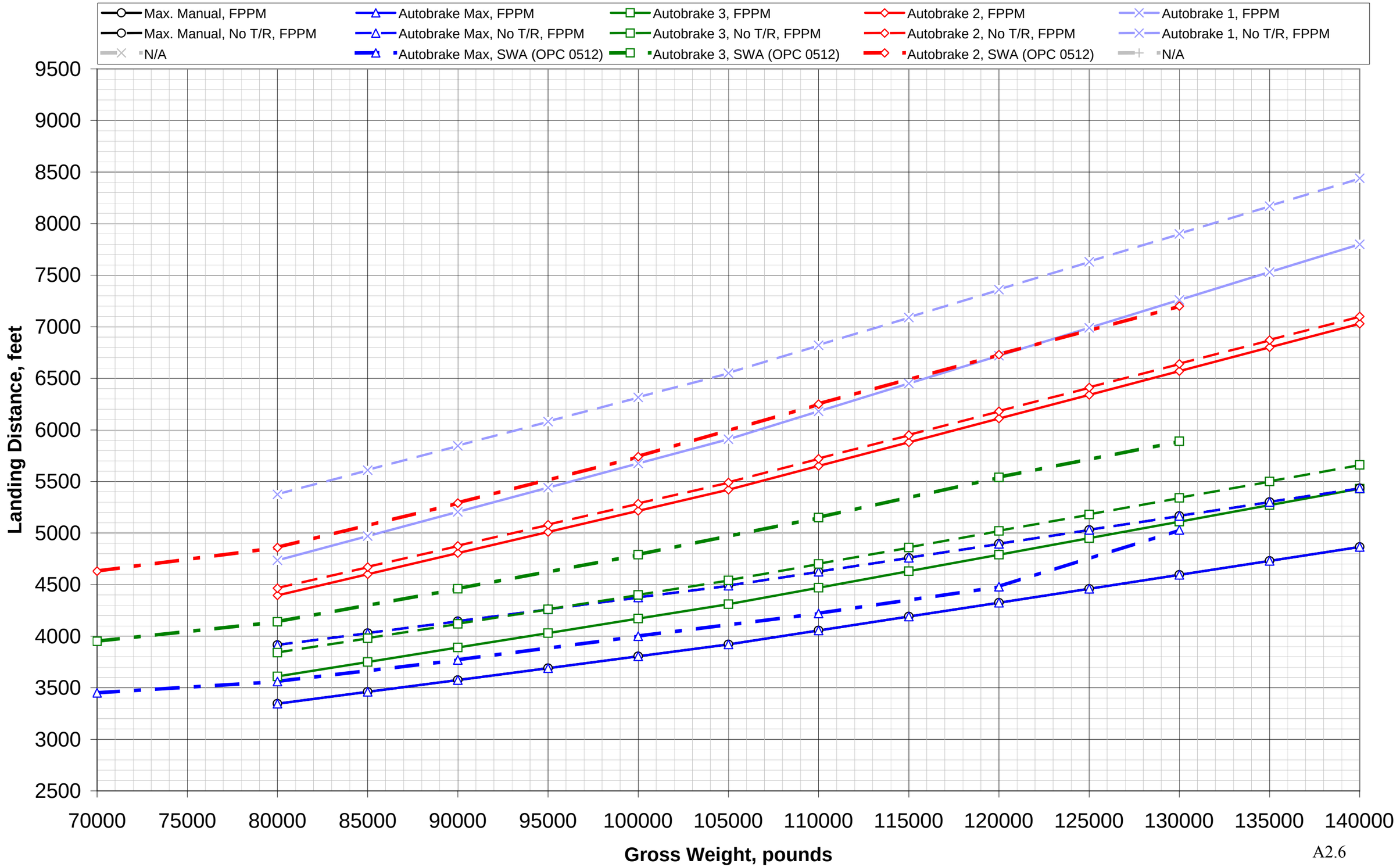
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



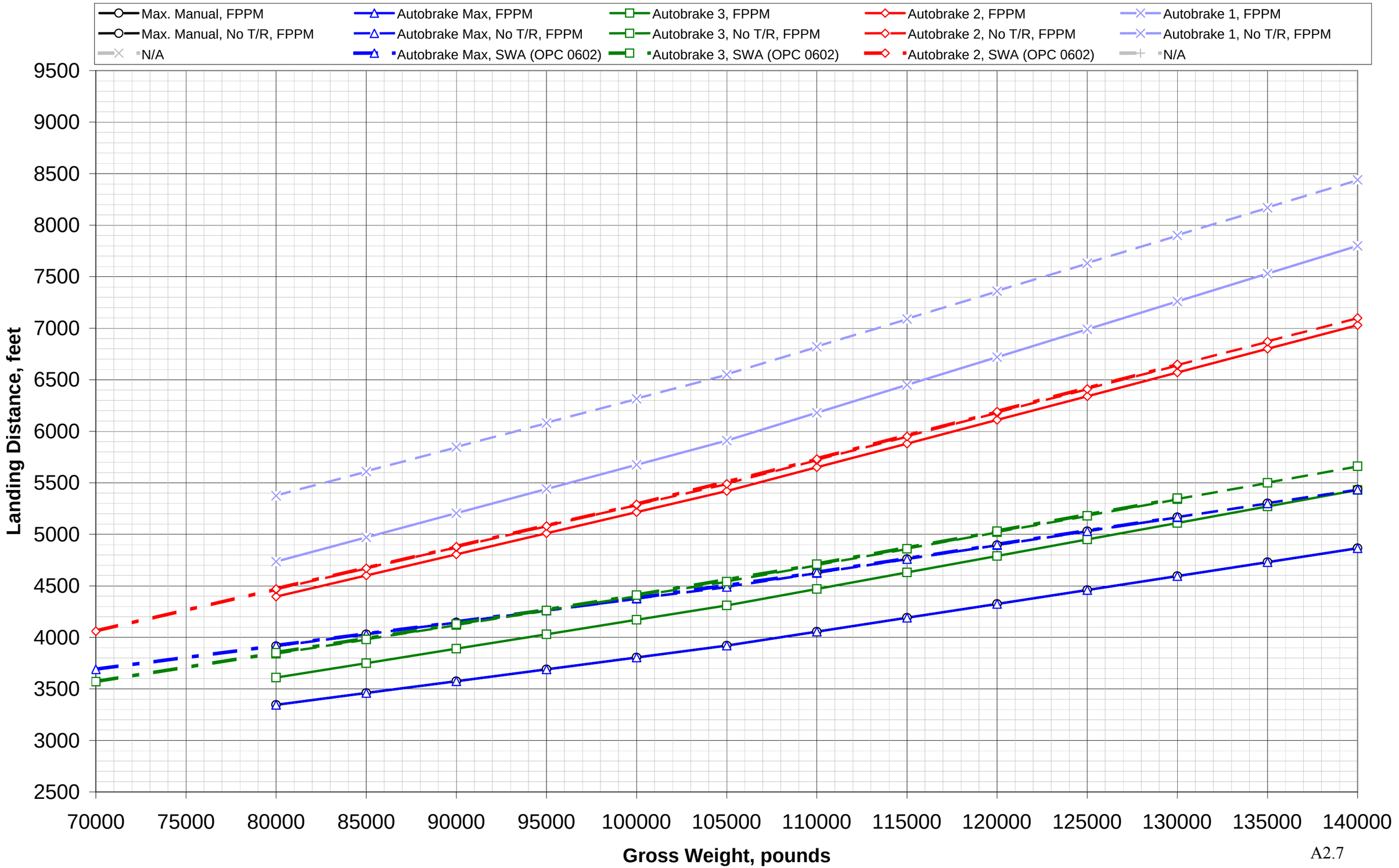
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



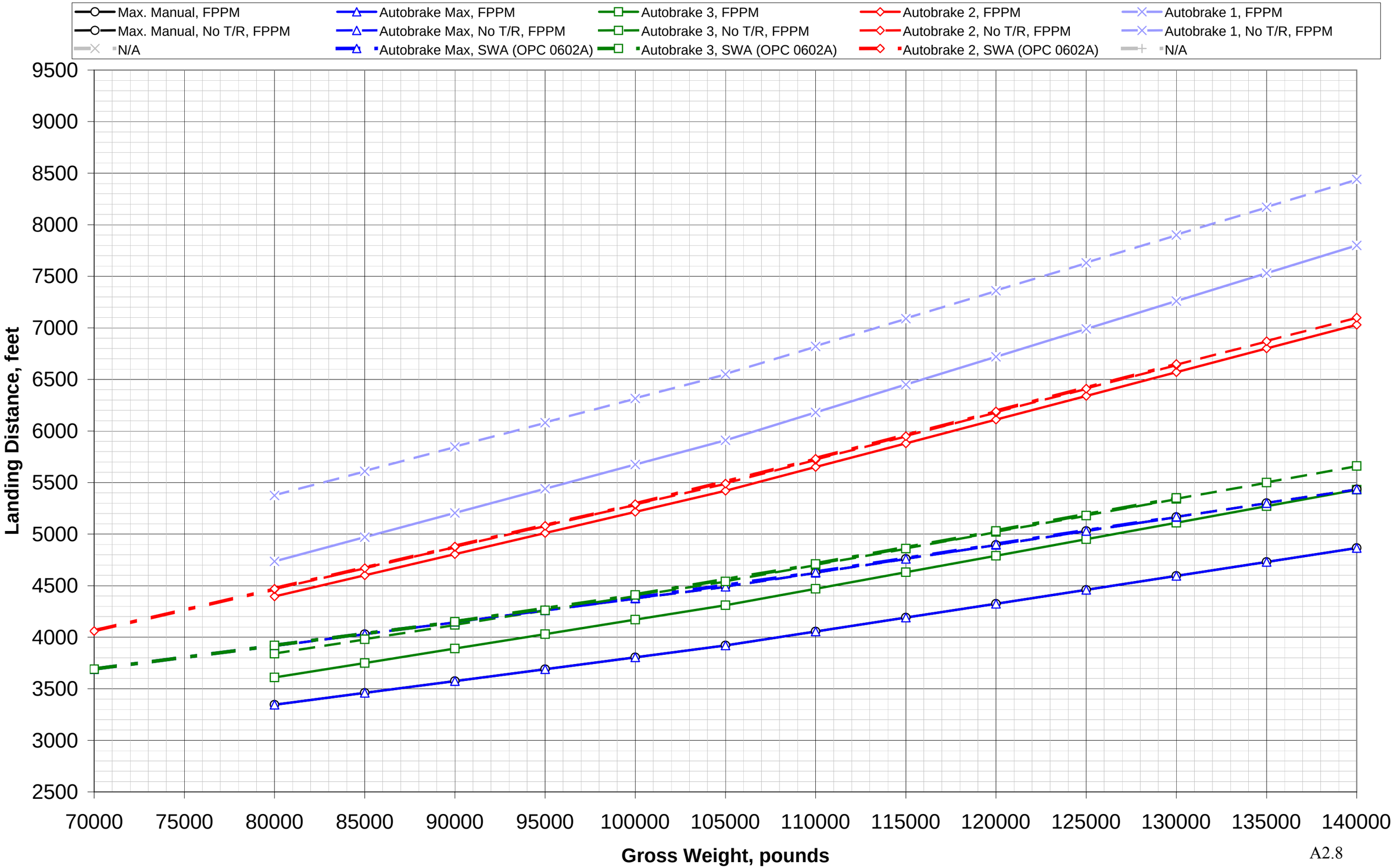
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



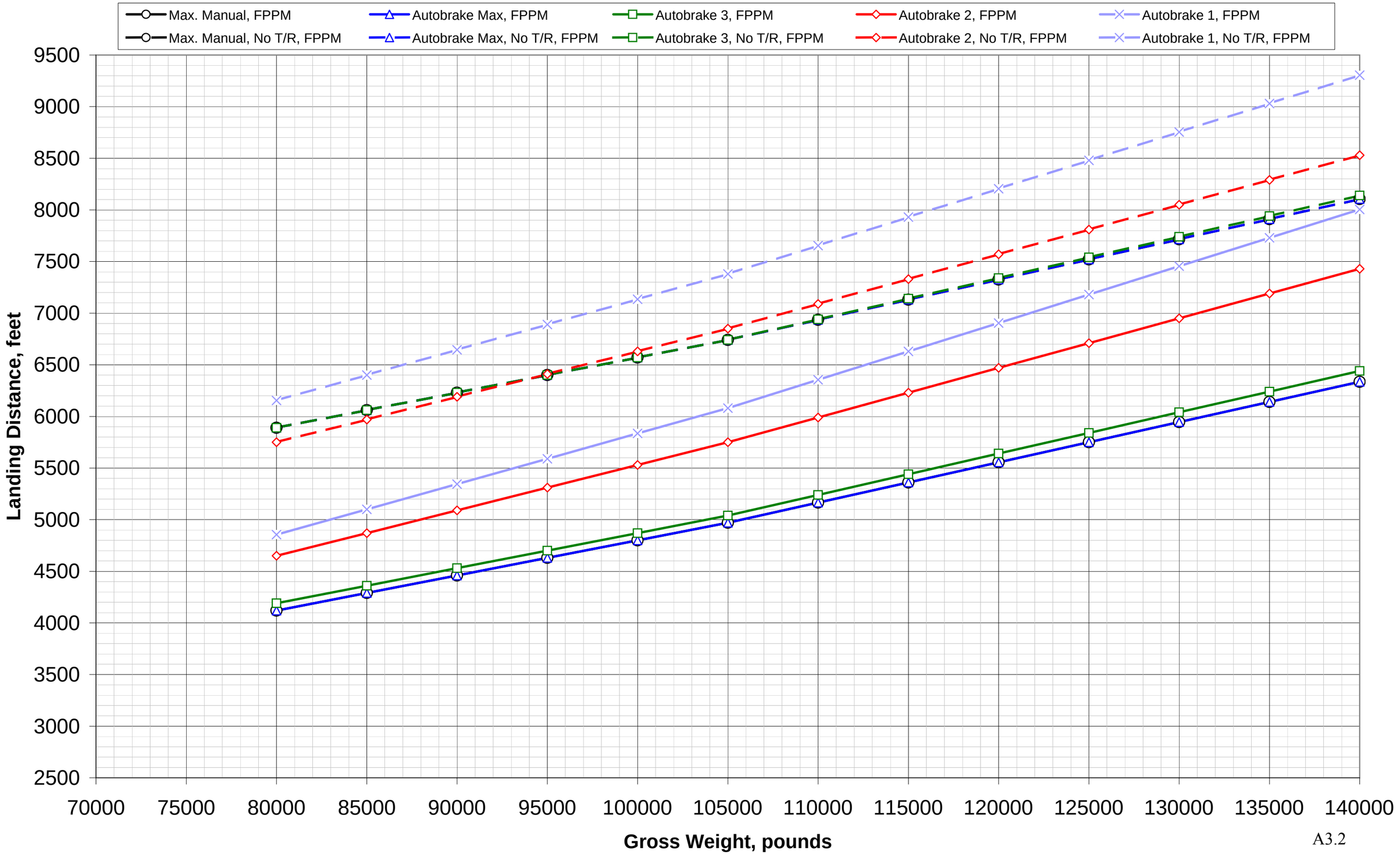
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [GOOD Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



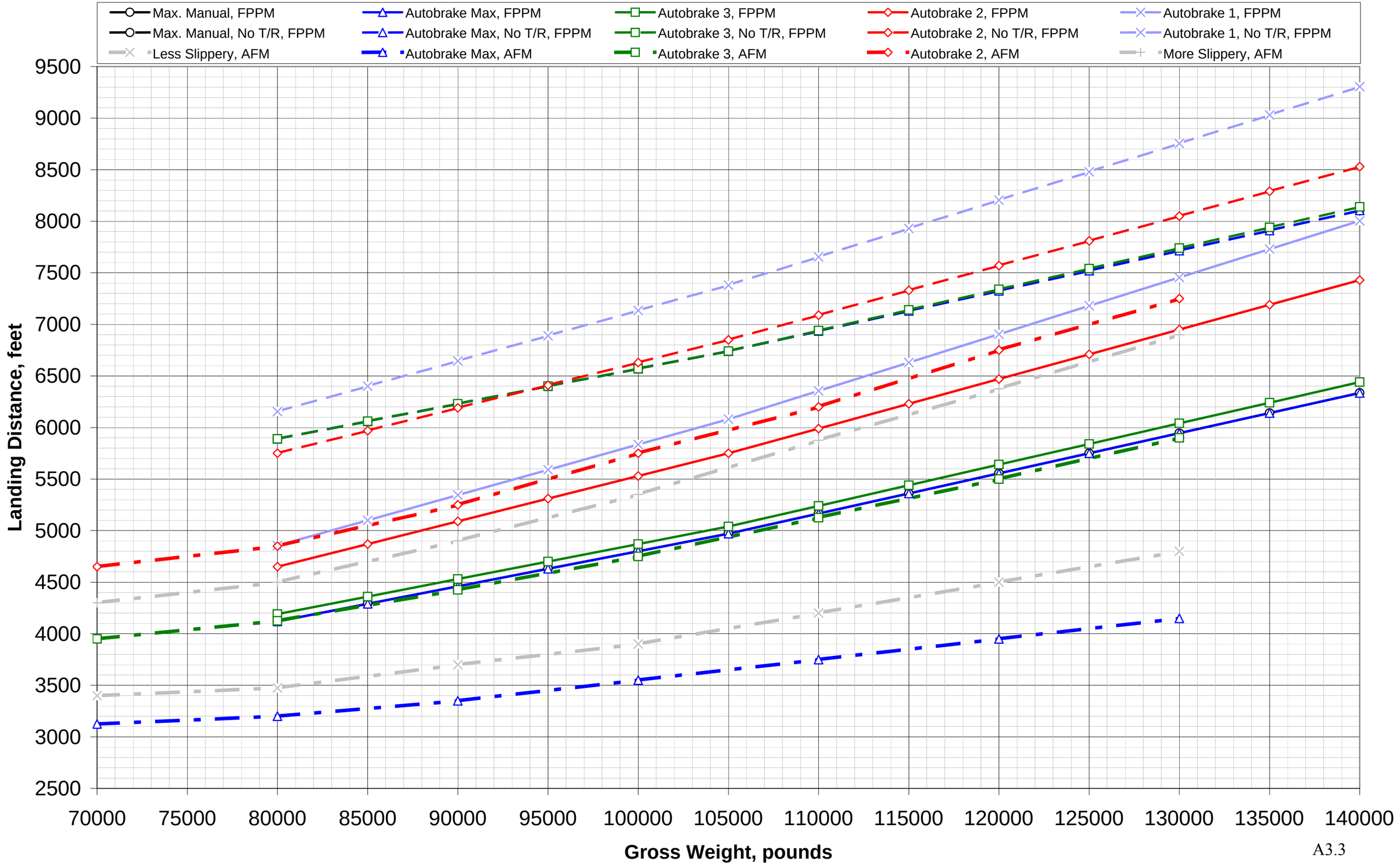
Attachment 3: Southwest Airlines B737-300 OPC History

Boeing Medium Reported Braking Action (airplane braking coefficient = 0.10)

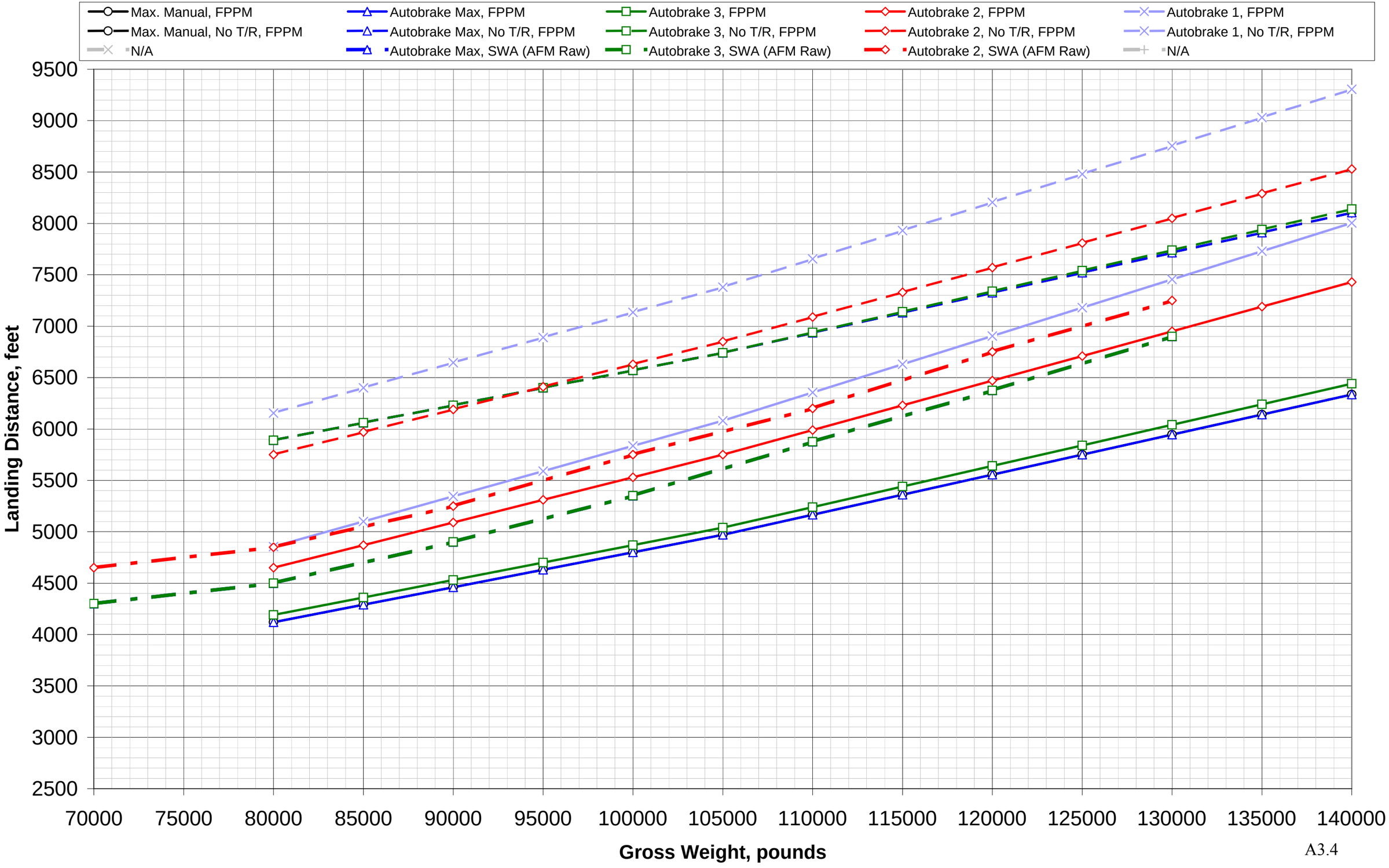
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



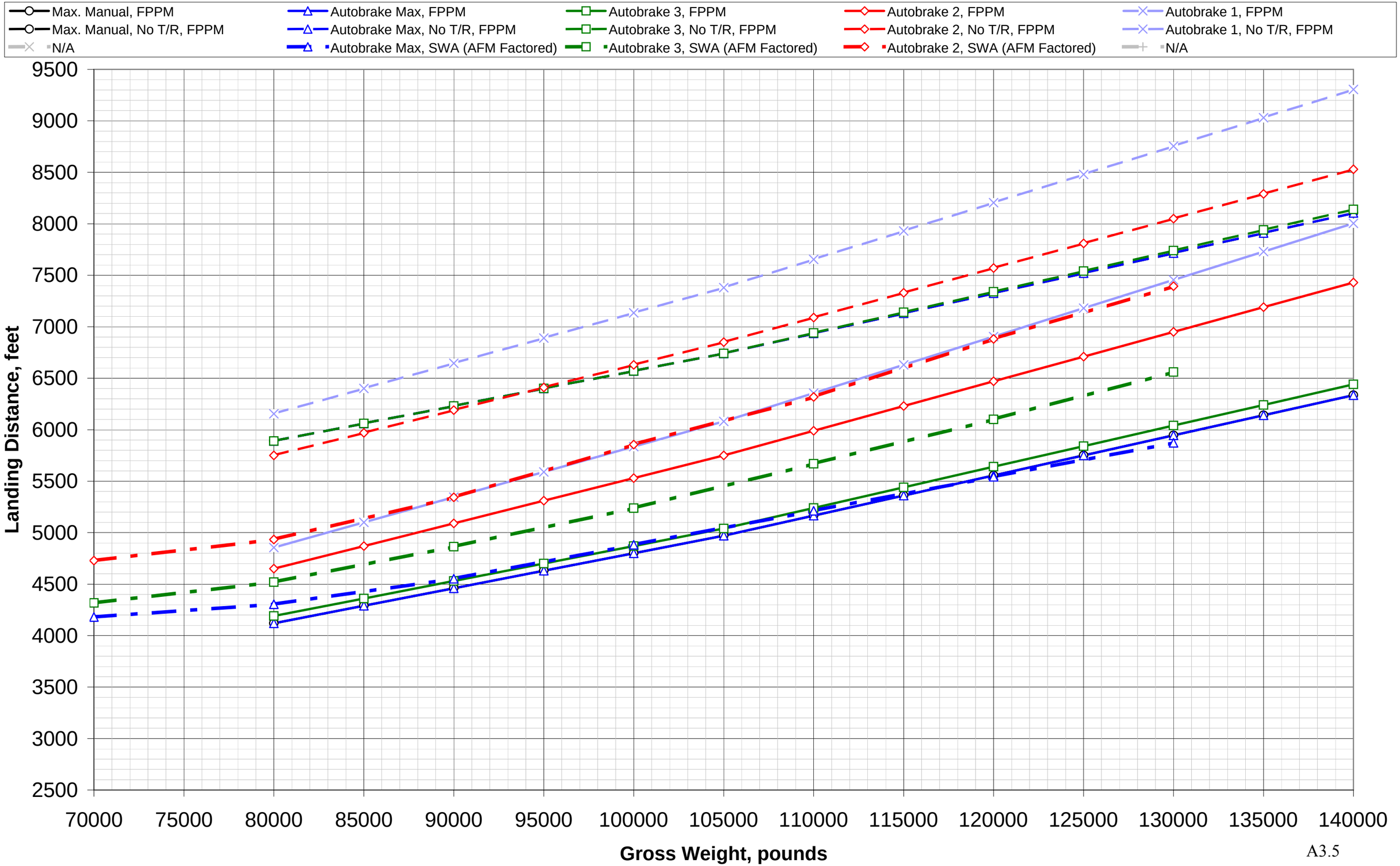
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



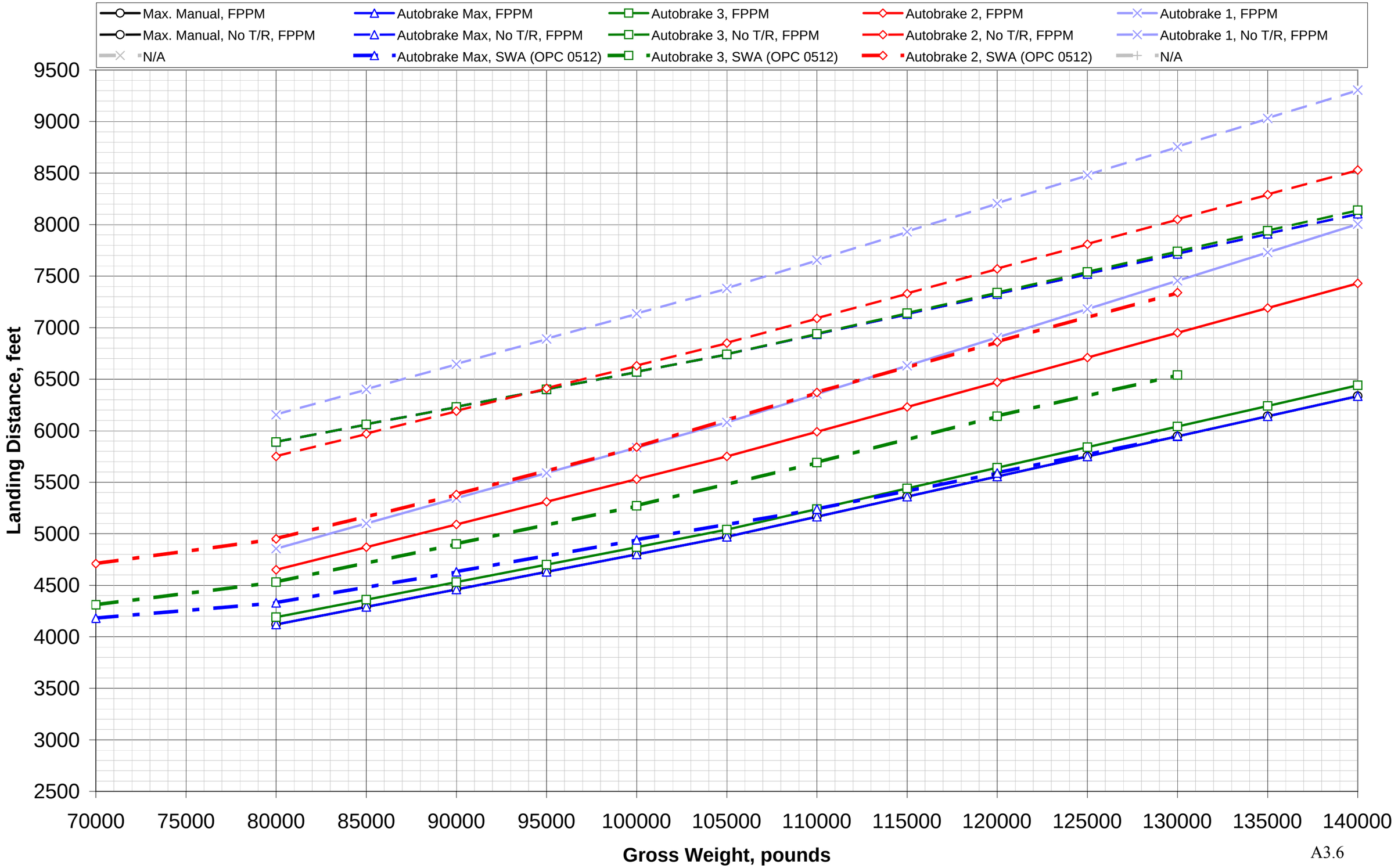
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



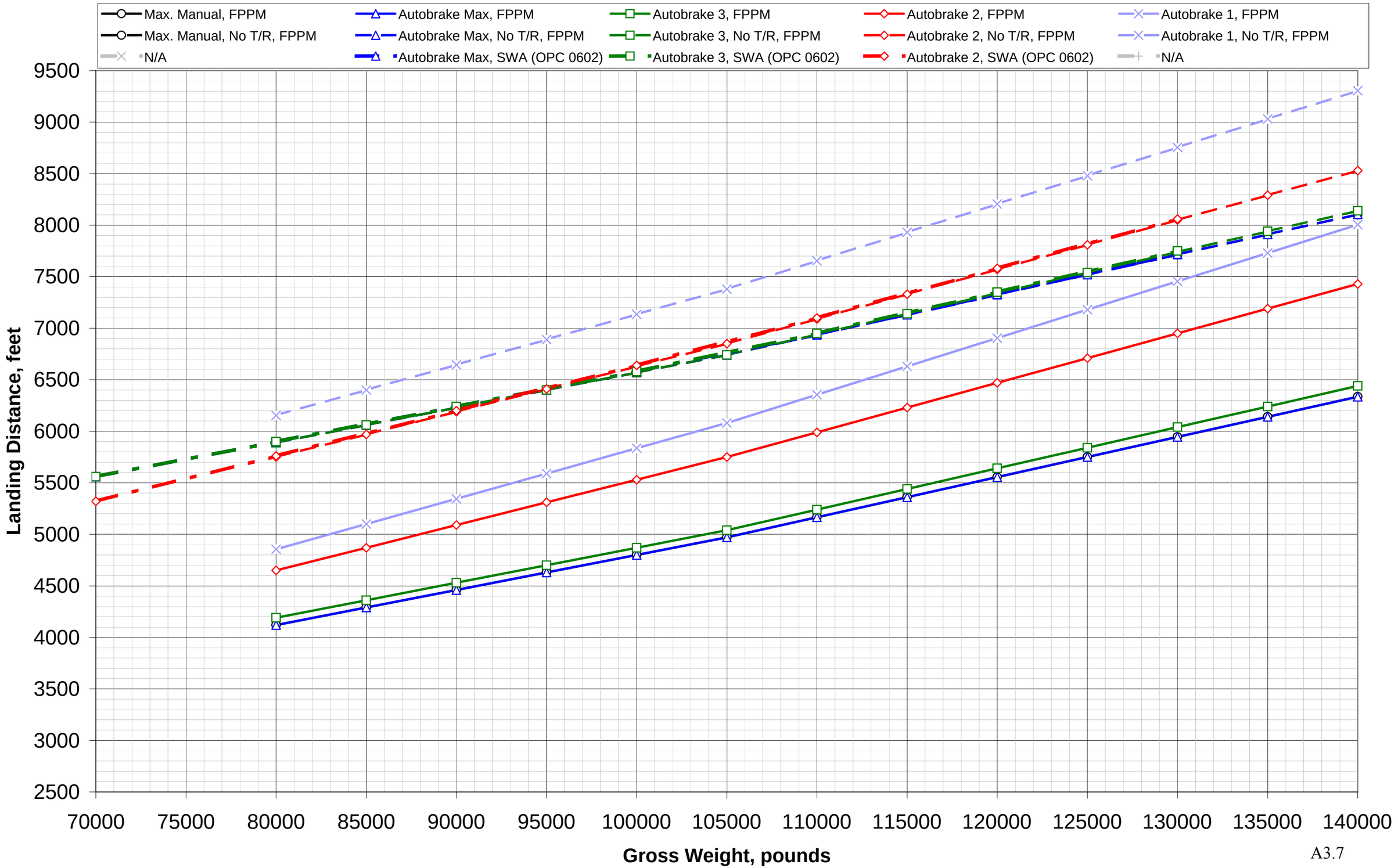
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



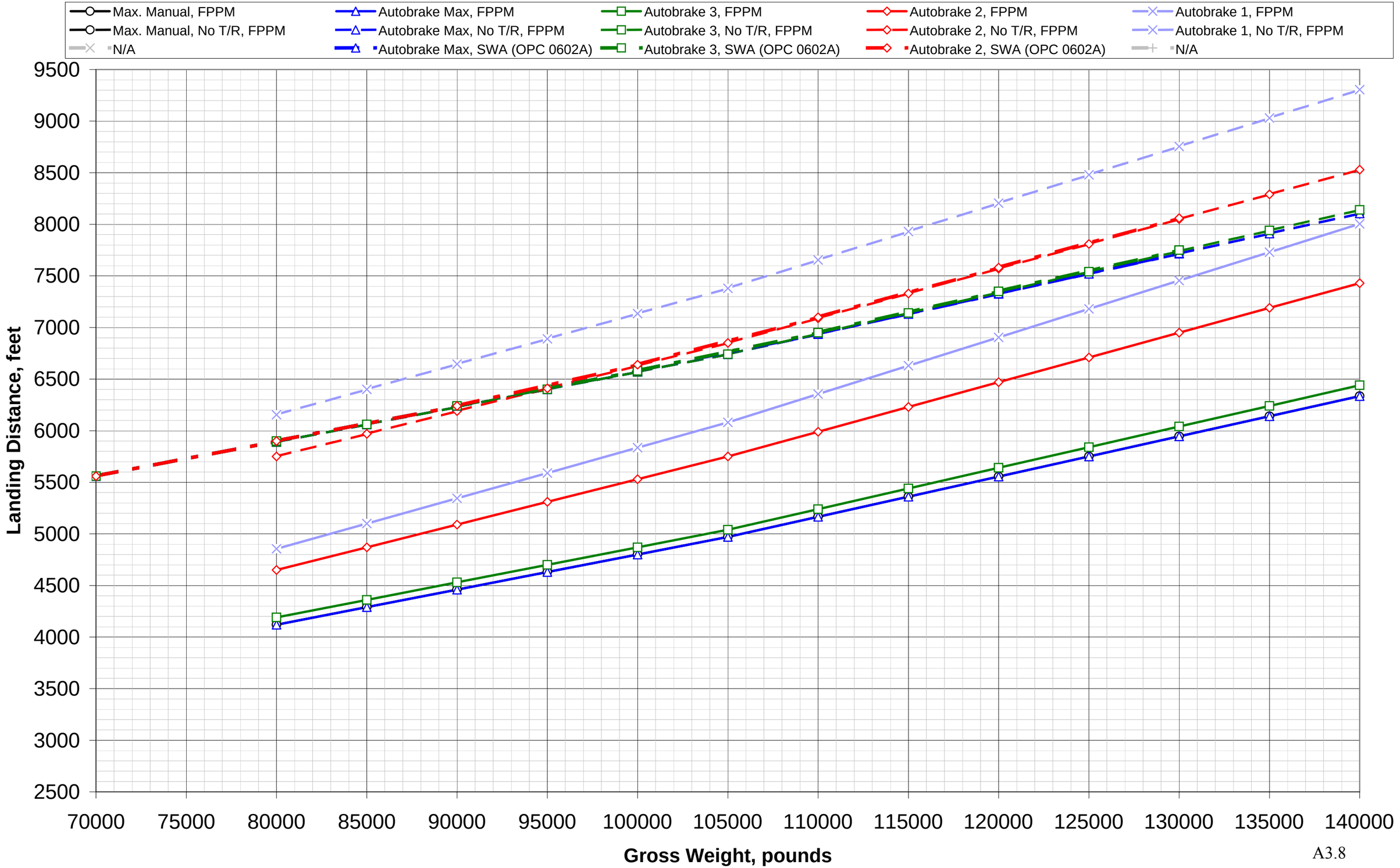
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



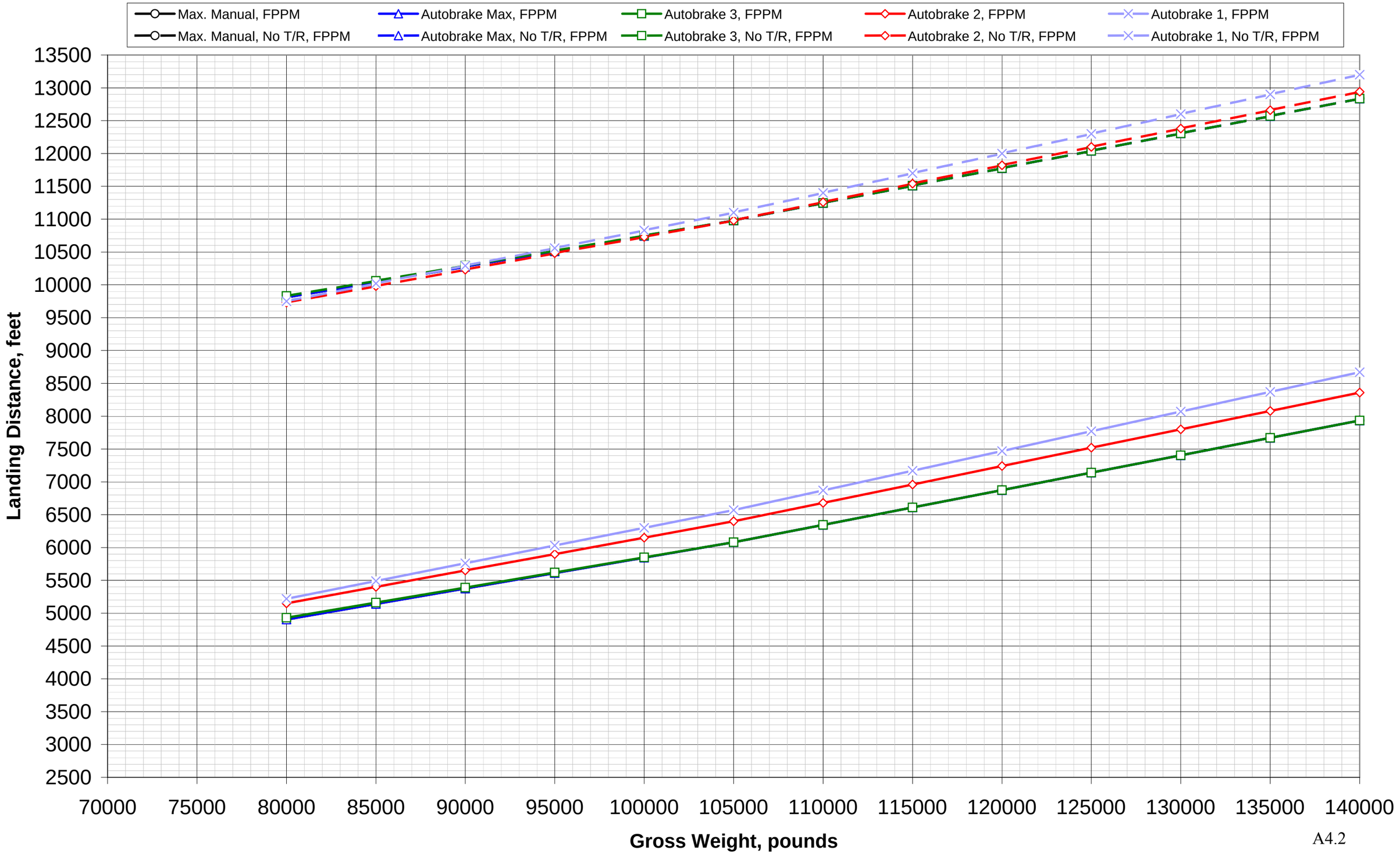
737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [MEDIUM Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



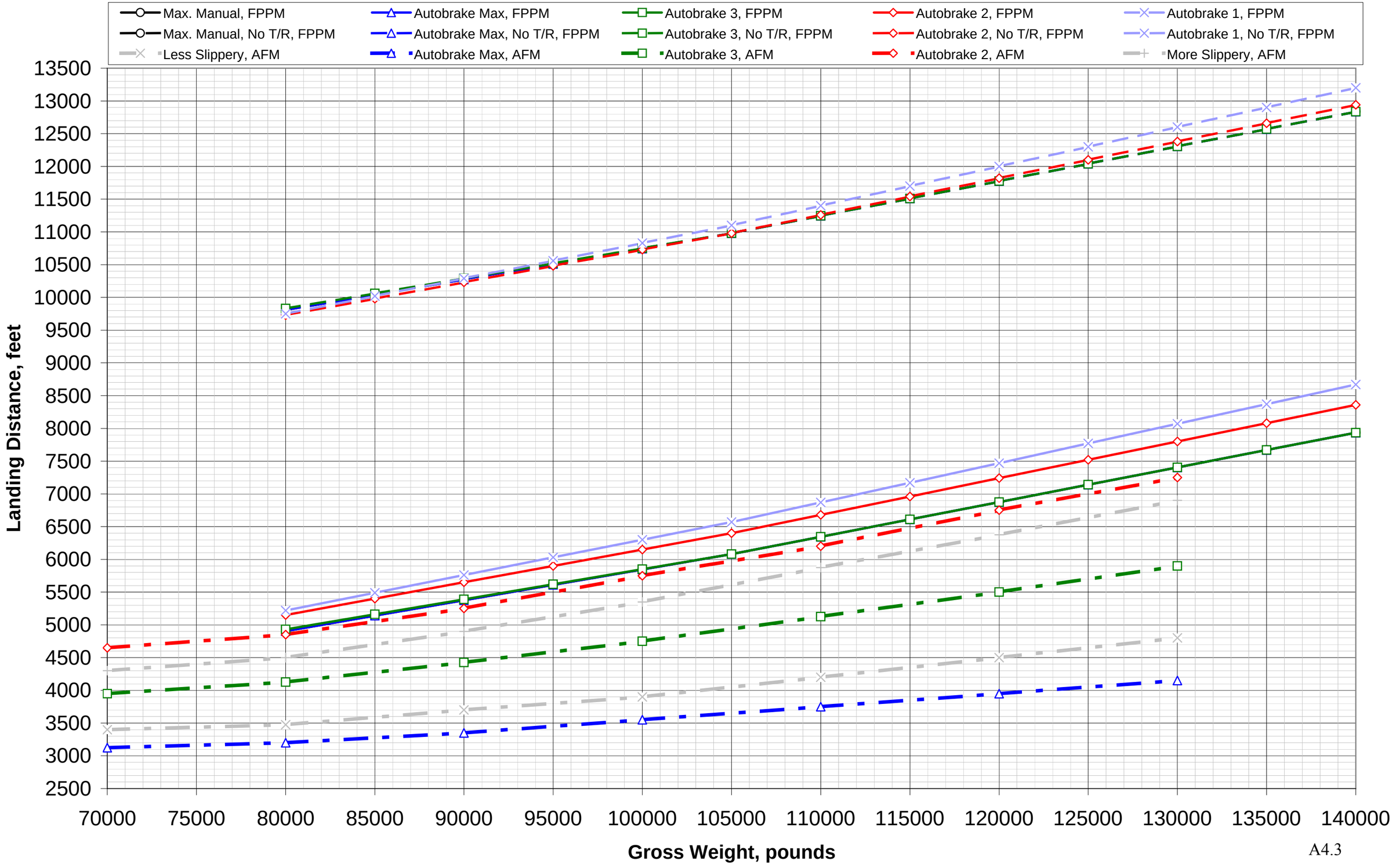
Attachment 4: Southwest Airlines B737-300 OPC History

Boeing Poor Reported Braking Action (airplane braking coefficient = 0.05)

737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [POOR Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



737-300/CFM56-3-B1 Flaps 40 Operational Landing Performance [POOR Reported Braking Action]
(sea level, standard day, no wind or slope, V_{REF40} approach speed, 1500 feet air distance)



Attachment 5: B737-300 Advisory Landing Data

Document	Page
Airplane Flight Manual (AFM)	A5.2
Performance Engineers Manual (PEM)	A5.4
Flight Planning and Performance Manual (FPPM)	A5.6
Quick Reference Handbook (QRH)	A5.8

LANDING FIELD LENGTH AND SPEED

AUTOMATIC WHEEL BRAKES (Continued)

The Stopping Distance With Automatic Wheel Brakes chart shows actual (unfactored) distances for settings 1 through MAX from touchdown to full stop that can be expected when using this system. The stopping distances shown are based on demonstrated deceleration values using automatic speed brakes and are valid for all landing flap settings, with or without reverse thrust. Distance corrections for tail wind and non-standard temperatures are provided.

Recommended use of the stopping distance chart is as follows:

1) Determine the available or desired distance from touchdown to stop.
2) Estimate approach speed considering approach conditions, flap setting, and operating procedures.
3) Enter the Stopping Distance with Automatic Wheel Brakes chart with approach speed from step 2, correcting for airport altitude to determine stopping distance and autobrake setting.

Stopping distances that can be achieved on wet runways depend on the friction characteristics, or slipperiness, of the particular runway. A range of stopping distance for varying slipperiness is shown; the range shown is based on the variation of wet runway friction characteristics expected in service. The wet runway stopping distance that is achieved for a given setting will be the longer of (1) the distance produced by the fixed deceleration of the setting or (2) the distance produced by the runway friction available, as indicated by the shaded region on the chart. A higher setting (MAX rather than 3, or 3 rather than 2) will produce shorter stopping distances on wet runways if friction characteristics are such to permit the higher deceleration. The use of reverse thrust will decrease wet runway stopping distance when the deceleration is limited by runway friction characteristics. Extremely wet and slippery conditions can result in longer distances than indicated.

NOTE: When using automatic wheel brakes with autoland operations, touchdown should be assumed to occur at 2,500 feet from the runway threshold. Enter chart with the remaining stopping distance available and approach speed, to find the Minimum autobrake setting.

R07070

PERFORMANCE

STOPPING DISTANCE WITH AUTOMATIC WHEEL BRAKES

GUIDANCE INFORMATION ONLY - SEE TEXT

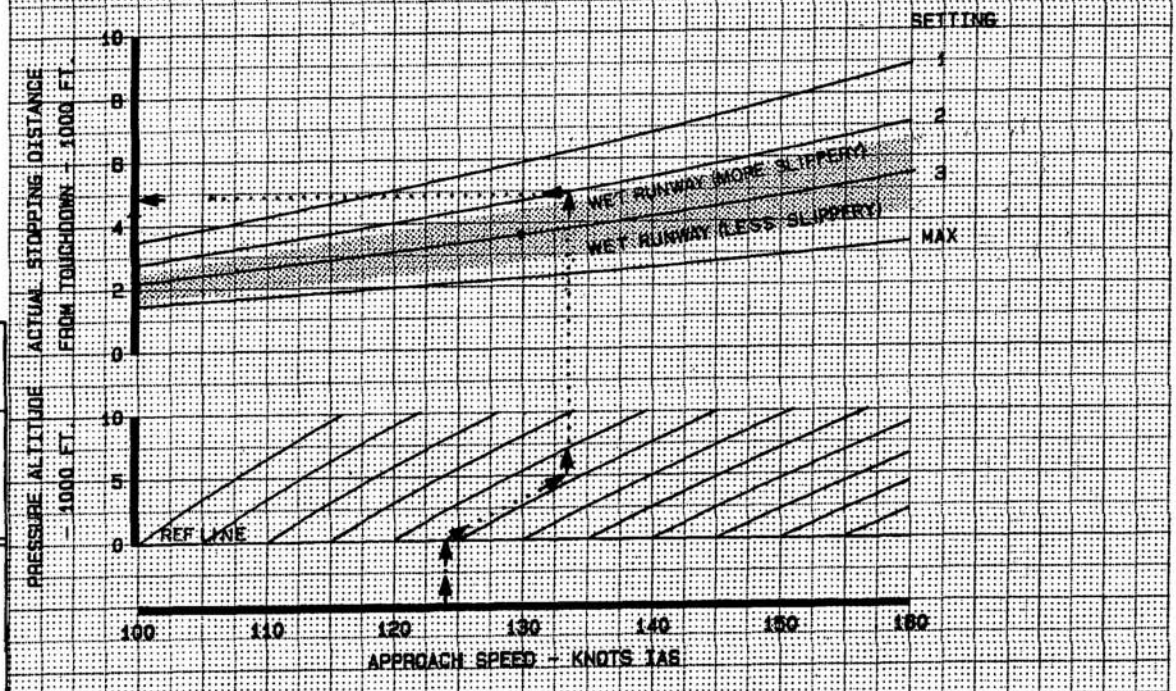
NOTE: VALID FOR FLAPS 15, 30, OR 40

● CHART ASSUMES ZERO WIND:
FOR TAILWIND ADD:

SETTING	FEET PER KNOT OF REPORTED TAILWIND
MAX	40
3	85
2	90
1	110

● CHART ASSUMES STANDARD DAY TEMPERATURE:
FOR HOTTER DAYS ADD:

SETTING	FEET PER 2°F (1°C) ABOVE STANDARD DAY
MAX	10
3	20
2	25
1	30



WET RUNWAY GUIDANCE

● STOPPING DISTANCE WILL DEPEND ON SELECTED SETTING AND WET RUNWAY FRICTION CHARACTERISTICS (SEE TEXT).
● EXTREMELY WET AND SLIPPERY CONDITIONS CAN RESULT IN LONGER DISTANCES THAN INDICATED.
● A HIGHER SETTING (MAX RATHER THAN SETTING 3, OR SETTING 3 RATHER THAN SETTING 2) WILL PRODUCE BETTER STOPPING PERFORMANCE ON WET RUNWAYS ONLY IF RUNWAY FRICTION CHARACTERISTICS PERMIT BETTER DECELERATION.
● THE USE OF REVERSE THRUST WILL IMPROVE WET RUNWAY STOPPING PERFORMANCE PARTICULARLY WHEN THE PERFORMANCE IS LIMITED BY RUNWAY FRICTION CHARACTERISTICS.

P.C. 9S000042
D6-37409 PAGE 4.13-11

	DATE
APPROVED	10/3/84

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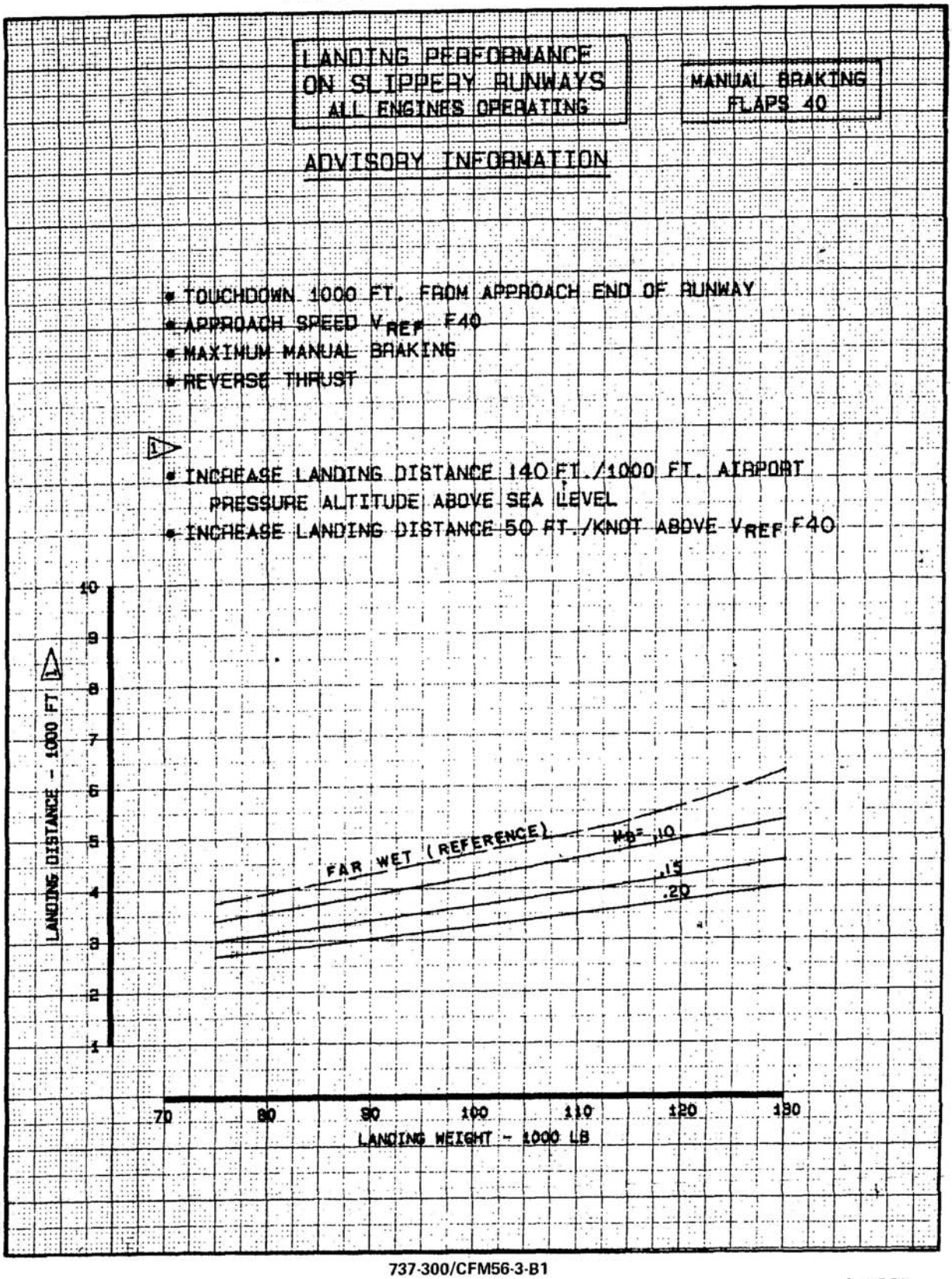


737-300/CFM56-3-B1

3-L57A
Apr 01/85

LANDING PERFORMANCE
ON SLIPPERY RUNWAYS
ALL ENGINES OPERATING

BOEING 737-300

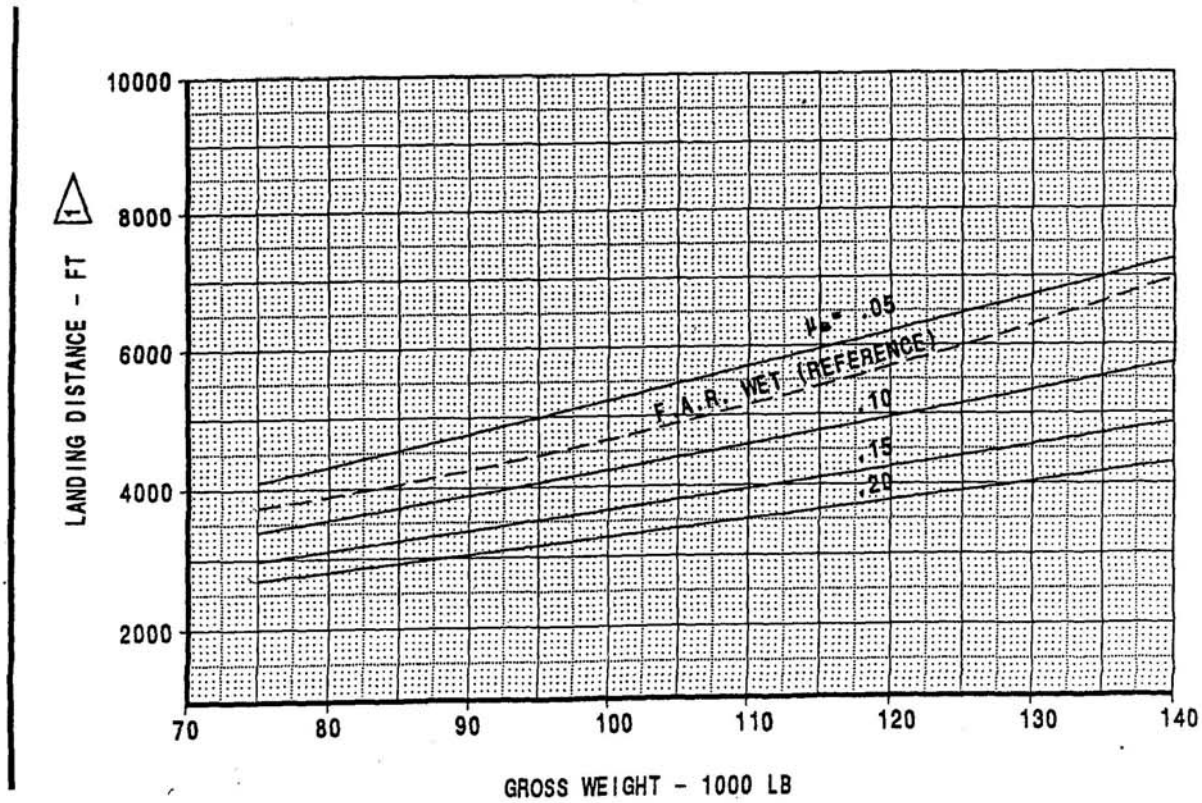
PERFORMANCE ENGINEERS MANUAL

MANUAL BRAKING
FLAPS 40

ADVISORY INFORMATION

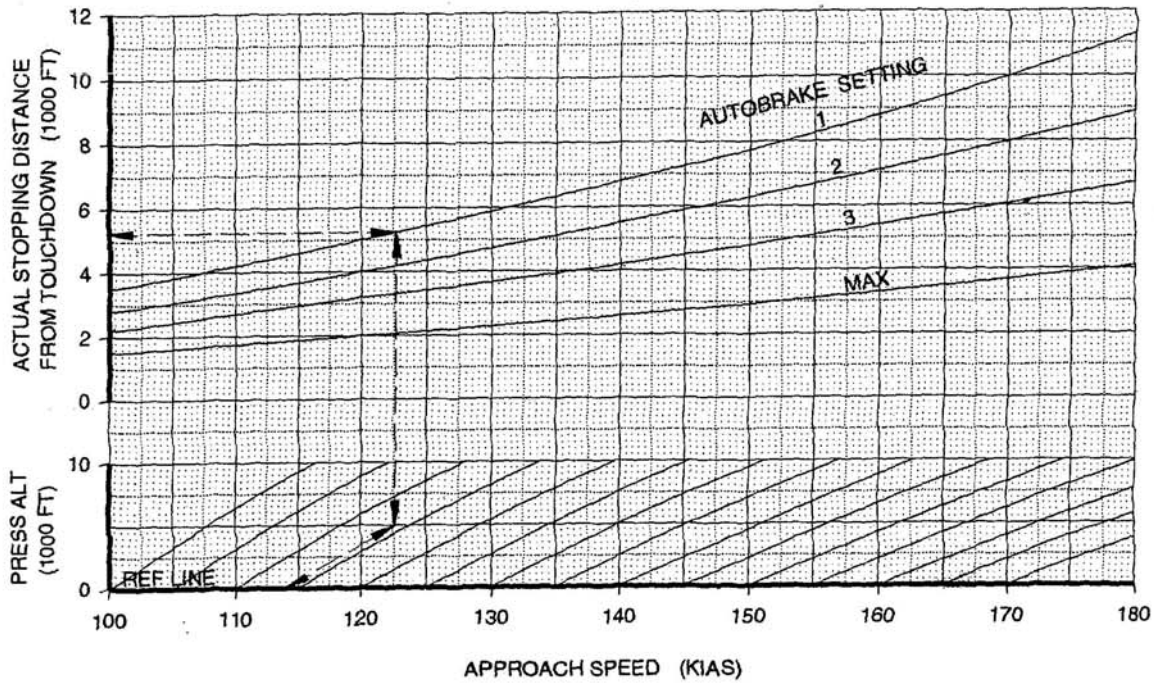
- TOUCHDOWN 1000 FT. FROM APPROACH END OF RUNWAY
- APPROACH SPEED $V_{REF\ 40}$
- REVERSE THRUST
- MAXIMUM MANUAL BRAKING

(1) • INCREASE LANDING DISTANCE 140 FT. PER 1000 FT AIRPORT PRESSURE ALTITUDE ABOVE SEA LEVEL (190 FT. PER 1000 FT. FOR μ_B = .05)
• INCREASE LANDING DISTANCE 50 FT. PER KNOT ABOVE $V_{REF\ 40}$



ADVISORY INFORMATION

Stopping Distance with Autobrakes



Wind and Temperature Stopping Distance Adjustment

AUTOBRAKE SETTING	FT PER KNOT TAILWIND (FT/KT)	FT PER 1°C ABOVE ISA (FT/°C)
1	110	30
2	90	25
3	65	20
MAX	40	10

ADVISORY INFORMATION

Normal Configuration Landing Distance

Flaps 40

Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/ BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABOVE ISA	BELOW ISA	PER 10 KTS ABOVE VREF40	ONE REV	NO REV
MAX MANUAL	2510	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-90	460	390	490
Good Reported Braking Action												
MAX MANUAL	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
MAX AUTO	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
AUTOBRAKES 3	3810	320/-280	100	-170	630	50	-30	60	-50	400	40	230
AUTOBRAKES 2	4920	460/-410	140	-240	870	70	-70	80	-80	470	70	70
AUTOBRAKES 1	5410	540/-470	170	-290	1030	160	-150	90	-90	440	490	640
Medium Reported Braking Action												
MAX MANUAL	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
MAX AUTO	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
AUTOBRAKES 3	4540	400/-340	130	-240	910	160	-110	70	-70	420	340	1700
AUTOBRAKES 2	5250	480/-440	150	-270	1010	140	-140	80	-80	440	200	1100
AUTOBRAKES 1	5580	550/-490	180	-300	1080	210	-170	90	-90	430	540	1300
Poor Reported Braking Action												
MAX MANUAL	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
MAX AUTO	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
AUTOBRAKES 3	5580	530/-460	170	-350	1370	410	-260	80	-80	400	810	4900
AUTOBRAKES 2	5900	560/-500	180	-360	1420	370	-260	90	-90	430	620	4580
AUTOBRAKES 1	6070	600/-540	190	-370	1450	410	-290	90	-90	430	800	4530

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed and 2 engine reverse thrust
Actual (unfactored) distances are shown
Based on Flaps 40
Includes distance from 50 ft above threshold (1000 feet of air distance)

ADVISORY INFORMATION

Autobrake Landing Distance

Reference Landing Distance (FT)

AUTOBRAKE SETTING	APPROACH SPEED (KIAS)						
	100	110	120	130	140	150	160
1	4500	5300	6100	6930	7850	8850	9950
2	3800	4440	5080	5730	6450	7240	8100
3	3200	3680	4150	4650	5220	5840	6500
MAX	2500	2760	3010	3280	3600	4000	4500

Actual (unfactored) distances are shown.

Landing distance required includes 1000 ft of air distance.

The distances are valid with or without reverse thrust and for any flap.

If entering with ground speed, ignore adjustments.

Landing Distance Adjustments (FT)

AUTOBRAKE SETTING	ALTITUDE ADJUSTMENT *PER 1000 FT ABOVE SEA LEVEL*	TAILWIND ADJUSTMENT *PER 10 KTS*	TEMP ADJUSTMENT *PER 10°C ABOVE ISA*
1	250	1100	300
2	200	900	250
3	140	650	200
MAX	80	400	100

Slippery Runway Landing Distance

Reference Landing Distance (FT)

BRAKING CONFIGURATION	REPORTED BRAKING ACTION		
	GOOD	MEDIUM	POOR
MAX MANUAL BRAKING	3500	4600	5700

Landing Distance Adjustments (FT)

CONDITIONS		ADJUSTMENTS		
WEIGHT	PER 5000 LB BELOW 110000 LB	-110	-170	-220
	PER 5000 LB ABOVE 110000 LB	140	190	260
AIRPORT PRESSURE ALTITUDE	PER 1000 FT ABOVE SEA LEVEL	140	140	190
APPROACH SPEED	PER 10 KTS ABOVE VREF	500	500	500

Actual (unfactored) distances are shown.

Landing distance required includes 1000 ft of air distance.

Max manual braking includes 2 engine maximum reverse thrust.

Based on flaps 40, VREF40 approach speed.

ADVISORY INFORMATION

Autobrake Landing Distance

Reference Landing Distance (FT)

AUTOBRAKE SETTING	APPROACH SPEED (KIAS)						
	100	110	120	130	140	150	160
1	4500	5300	6100	6930	7850	8850	9950
2	3800	4440	5080	5730	6450	7240	8100
3	3200	3680	4150	4650	5220	5840	6500
MAX	2500	2760	3010	3280	3600	4000	4500

Actual (unfactored) distances are shown.
Landing distance required includes 1000 ft of air distance.
The distances are valid with or without reverse thrust and for any flap.
If entering with ground speed, ignore adjustments.

Landing Distance Adjustments (FT)

AUTOBRAKE SETTING	ALTITUDE ADJUSTMENT PER 1000 FT ABOVE SEA LEVEL	TAILWIND ADJUSTMENT PER 10 KTS	TEMP ADJUSTMENT PER 10°C ABOVE ISA
1	250	1100	300
2	200	900	250
3	140	650	200
MAX	80	400	100

Slippery Runway Landing Distance

Reference Landing Distance (FT)

BRAKING CONFIGURATION	REPORTED BRAKING ACTION			
	DRY	GOOD	MEDIUM	POOR
MAX MANUAL BRAKING	2510	3420	4470	5580
AUTOBRAKE SETTING 2	4460	4910	5250	5890
AUTOBRAKE SETTING 3	3140	3810	4540	5580
MAX AUTOBRAKE SETTING	2610	3420	4470	5580

Landing Distance Adjustments (FT)

CONDITIONS		ADJUSTMENTS			
WEIGHT	PER 10000 LB BELOW 105,000 LB	-140	-230	-340	-460
	PER 10000 LB ABOVE 105,000 LB	480	450	475	545
AIRPORT PRESSURE ALTITUDE	PER 1000 FT ABOVE SEA LEVEL	130	140	145	170
WIND	PER 10 KTS HEADWIND	-90	-155	-240	-350
	PER 10 KTS TAILWIND	835	885	1040	1470
APPROACH SPEED	PER 10 KTS ABOVE VREF	515	470	440	425
SLOPE	PER 1% DOWNHILL SLOPE	30	80	190	450
	PER 1% UPHILL SLOPE	-25	-40	-110	-265
REVERSE THRUST	1 REVERSER INOPERATIVE	35	155	410	805
	2 REVERSERS INOPERATIVE	120	565	1765	4895
	MAXIMUM REVERSE THRUST	0	0	-40	-100

Actual (unfactored) distances are shown.
Landing Distance Required Includes 1000 ft of Air Distance.
Based on flaps 40, VREF40 approach speed.
Max manual braking includes 2 engine detent reverse thrust.
Autobrake data does not include the use of reverse thrust. Corrections for inoperative reversers do not apply.

ADVISORY INFORMATION

Autobrake Landing Distance

Reference Landing Distance (FT)

AUTOBRAKE SETTING	APPROACH SPEED (KIAS)						
	100	110	120	130	140	150	160
1	4500	5300	6100	6930	7850	8850	9950
2	3800	4440	5080	5730	6450	7240	8100
3	3200	3680	4150	4650	5220	5840	6500
MAX	2500	2760	3010	3280	3600	4000	4500

Actual (unfactored) distances are shown.
Landing distance required includes 1000 ft of air distance.
The distances are valid with or without reverse thrust and for any flap.
If entering with ground speed, ignore adjustments.

Landing Distance Adjustments (FT)

AUTOBRAKE SETTING	ALTITUDE ADJUSTMENT PER 1000 FT ABOVE SEA LEVEL	TAILWIND ADJUSTMENT PER 10 KTS	TEMP ADJUSTMENT PER 10°C ABOVE ISA
1	250	1100	300
2	200	900	250
3	140	650	200
MAX	80	400	100

Slippery Runway Landing Distance

Reference Landing Distance (FT)

BRAKING CONFIGURATION	REPORTED BRAKING ACTION			
	DRY	GOOD	MEDIUM	POOR
MAX MANUAL BRAKING	2510	3420	4470	5580
AUTOBRAKE SETTING 2	4460	4910	5250	5890
AUTOBRAKE SETTING 3	3140	3810	4540	5580
MAX AUTOBRAKE SETTING	2610	3420	4470	5580

Landing Distance Adjustments (FT)

CONDITIONS		ADJUSTMENTS			
WEIGHT	PER 10000 LB BELOW 105,000 LB	-140	-230	-340	-460
	PER 10000 LB ABOVE 105,000 LB	480	450	475	545
AIRPORT PRESSURE ALTITUDE	PER 1000 FT ABOVE SEA LEVEL	130	140	145	170
WIND	PER 10 KTS HEADWIND	-90	-155	-240	-350
	PER 10 KTS TAILWIND	835	885	1040	1470
APPROACH SPEED	PER 10 KTS ABOVE VREF	515	470	440	425
SLOPE	PER 1% DOWNHILL SLOPE	30	80	190	450
	PER 1% UPHILL SLOPE	-25	-40	-110	-265
REVERSE THRUST	1 REVERSER INOPERATIVE	35	155	410	805
	2 REVERSERS INOPERATIVE	120	565	1765	4895
	MAXIMUM REVERSE THRUST	0	0	-40	-100

Actual (unfactored) distances are shown.
Landing Distance Required Includes 1000 ft of Air Distance.
Based on flaps 40, VREF40 approach speed.
Max manual braking includes 2 engine detent reverse thrust.
Autobrake data does not include the use of reverse thrust. Corrections for inoperative reversers do not apply.

ADVISORY INFORMATION

Autobrake Landing Distance

Reference Landing Distance (FT)

AUTOBRAKE SETTING	APPROACH SPEED (KIAS)						
	100	110	120	130	140	150	160
1	4500	5300	6100	6930	7850	8850	9950
2	3800	4440	5080	5730	6450	7240	8100
3	3200	3680	4150	4650	5220	5840	6500
MAX	2500	2760	3010	3280	3600	4000	4500

Actual (unfactored) distances are shown.
Landing distance required includes 1000 ft of air distance.
The distances are valid with or without reverse thrust and for any flap.
If entering with ground speed, ignore adjustments.

Landing Distance Adjustments (FT)

AUTOBRAKE SETTING	ALTITUDE ADJUSTMENT PER 1000 FT ABOVE SEA LEVEL	TAILWIND ADJUSTMENT PER 10 KTS	TEMP ADJUSTMENT PER 10°C ABOVE ISA
1	250	1100	300
2	200	900	250
3	140	650	200
MAX	80	400	100

Slippery Runway Landing Distance

Reference Landing Distance (FT)

BRAKING CONFIGURATION	REPORTED BRAKING ACTION			
	DRY	GOOD	MEDIUM	POOR
MAX MANUAL BRAKING	2510	3420	4470	5580
AUTOBRAKE SETTING 2	4460	4910	5250	5890
AUTOBRAKE SETTING 3	3140	3810	4540	5580
MAX AUTOBRAKE SETTING	2610	3420	4470	5580

Landing Distance Adjustments (FT)

CONDITIONS		ADJUSTMENTS			
WEIGHT	PER 10000 LB BELOW 105,000 LB	-140	-230	-340	-460
	PER 10000 LB ABOVE 105,000 LB	480	450	475	545
AIRPORT PRESSURE ALTITUDE	PER 1000 FT ABOVE SEA LEVEL	130	140	145	170
WIND	PER 10 KTS HEADWIND	-90	-155	-240	-350
	PER 10 KTS TAILWIND	835	885	1040	1470
APPROACH SPEED	PER 10 KTS ABOVE VREF	515	470	440	425
SLOPE	PER 1% DOWNHILL SLOPE	30	80	190	450
	PER 1% UPHILL SLOPE	-25	-40	-110	-265
REVERSE THRUST	1 REVERSER INOPERATIVE	35	155	410	805
	2 REVERSERS INOPERATIVE	120	565	1765	4895
	MAXIMUM REVERSE THRUST	0	0	-40	-100

Actual (unfactored) distances are shown.
Landing Distance Required Includes 1000 ft of Air Distance.
Based on flaps 40, VREF40 approach speed.
Includes 2 engine detent reverse thrust.

ADVISORY INFORMATION

Normal Configuration Landing Distance

Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF40	1 REV	NO REV
MAX MANUAL	2570	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-80	460	390	490

Good Reported Braking Action

MAX MANUAL	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
MAX AUTO	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
AUTOBRAKES 3	3810	320/-280	100	-170	630	50	-30	60	-50	400	40	230
AUTOBRAKES 2	4920	460/-410	140	-240	870	70	-70	80	-80	470	70	70
AUTOBRAKES 1	5410	540/-470	170	-290	1030	160	-150	90	-90	440	490	640

Medium Reported Braking Action

MAX MANUAL	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
MAX AUTO	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
AUTOBRAKES 3	4540	400/-340	130	-240	910	160	-110	70	-70	420	340	1700
AUTOBRAKES 2	5250	480/-440	150	-270	1010	140	-140	80	-80	440	200	1100
AUTOBRAKES 1	5580	550/-490	180	-300	1080	210	-170	90	-90	430	540	1300

Poor Reported Braking Action

MAX MANUAL	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
MAX AUTO	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
AUTOBRAKES 3	5580	530/-460	170	-350	1370	410	-260	80	-80	400	810	4900
AUTOBRAKES 2	5900	560/-500	180	-360	1420	370	-260	90	-90	430	620	4580
AUTOBRAKES 1	6070	600/-540	190	-370	1450	410	-290	90	-90	430	800	4530

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed and 2 engine detent reverse thrust.

Based on Flaps 40.

Actual (unfactored) distances are shown.

Includes distance from 50 ft above threshold (1000 ft of air distance).

ADVISORY INFORMATION

Normal Configuration Landing Distance

Flaps 40

Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/ BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF40	1 REV	NO REV
MAX MANUAL	2570	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-80	460	390	490
Good Reported Braking Action												
MAX MANUAL	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
MAX AUTO	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
AUTOBRAKES 3	3810	320/-280	100	-170	630	50	-30	60	-50	400	40	230
AUTOBRAKES 2	4920	460/-410	140	-240	870	70	-70	80	-80	470	70	70
AUTOBRAKES 1	5410	540/-470	170	-290	1030	160	-150	90	-90	440	490	640
Medium Reported Braking Action												
MAX MANUAL	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
MAX AUTO	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
AUTOBRAKES 3	4540	400/-340	130	-240	910	160	-110	70	-70	420	340	1700
AUTOBRAKES 2	5250	480/-440	150	-270	1010	140	-140	80	-80	440	200	1100
AUTOBRAKES 1	5580	550/-490	180	-300	1080	210	-170	90	-90	430	540	1300
Poor Reported Braking Action												
MAX MANUAL	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
MAX AUTO	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
AUTOBRAKES 3	5580	530/-460	170	-350	1370	410	-260	80	-80	400	810	4900
AUTOBRAKES 2	5900	560/-500	180	-360	1420	370	-260	90	-90	430	620	4580
AUTOBRAKES 1	6070	600/-540	190	-370	1450	410	-290	90	-90	430	800	4530

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed and 2 engine detent reverse thrust.
Based on Flaps 40.
Actual (unfactored) distances are shown.
Includes distance from 50 ft above threshold (1000 ft of air distance).

ADVISORY INFORMATION

Normal Configuration Landing Distance

Flaps 40

Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/ BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF40	1 REV	NO REV
MAX MANUAL	2510	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-80	460	390	490
Good Reported Braking Action												
MAX MANUAL	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
MAX AUTO	3420	270/-230	80	-150	560	80	-60	50	-40	280	160	570
AUTOBRAKES 3	3810	320/-280	100	-170	630	50	-30	60	-50	400	40	230
AUTOBRAKES 2	4920	460/-410	140	-240	870	70	-70	80	-80	470	70	70
AUTOBRAKES 1	5410	540/-470	170	-290	1030	160	-150	90	-90	440	490	640
Medium Reported Braking Action												
MAX MANUAL	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
MAX AUTO	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
AUTOBRAKES 3	4540	400/-340	130	-240	910	160	-110	70	-70	420	340	1700
AUTOBRAKES 2	5250	480/-440	150	-270	1010	140	-140	80	-80	440	200	1100
AUTOBRAKES 1	5580	550/-490	180	-300	1080	210	-170	90	-90	430	540	1300
Poor Reported Braking Action												
MAX MANUAL	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
MAX AUTO	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
AUTOBRAKES 3	5580	530/-460	170	-350	1370	410	-260	80	-80	400	810	4900
AUTOBRAKES 2	5900	560/-500	180	-360	1420	370	-260	90	-90	430	620	4580
AUTOBRAKES 1	6070	600/-540	190	-370	1450	410	-290	90	-90	430	800	4530

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed and 2 engine detent reverse thrust.

Actual (unfactored) distances are shown.

Includes distance from 50 ft above threshold (1000 ft of air distance).