AEM

*Area Equivalent Method
Version 6.0c*

User's Guide

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Office of Environment and Energy
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1. Introduction

The Area Equivalent Method (AEM) is a screening procedure used to simplify the assessment step in determining the need for further analysis with the Integrated Noise Model (INM) as part of Environmental Assessments and Impact Statements (EA/EIS) and Federal Aviation Regulations (FAR) Part 150 studies. AEM is a mathematical procedure that provides an estimated change in noise contour area for an airport given the types of aircraft and the number of operations for each aircraft. The noise contour area is a measure of the size of the landmass enclosed within a level of noise as produced by a given set of aircraft operations.

The noise contour metric is the Day-Night Average Sound Level (DNL), which provides a single quantitative rating of a noise level over a 24-hour period. This rating involves a 10-dBA penalty to aircraft operations during the nighttime (between 10 PM and 7 AM) to account for the increased annoyance in the community.

The AEM produces noise contour areas (in square miles) for the DNL 65 dBA noise level and the purpose of AEM is to screen for significant impact within the DNL 65 dBA contour area. The user may specify other contour levels to obtain supplemental information. The AEM is used to develop insight into the potential increase or decrease of noise resulting from a change in aircraft operations.

This version of the model has been developed in a spreadsheet format using Microsoft Excel 2000 and is based upon Version 6.0c of the INM and its database of 132 aircraft.

The following text will provide a more detailed explanation of the AEM as well as instructions for its use.

1.1. Installation

AEM 6.0c is designed for use on Microsoft Windows 95/98/2000 PC operating systems under Microsoft Excel 97 & 2000. There is no formal installation. Only a requirement that the user have a copy of Microsoft Excel 97 or later on their machine.

2. Description

2.1. Background

According to FAA Order 1050.lD, "Policies and Procedures for Considering Environmental Impacts," an assessment must be made to determine the noise impact of a proposed airport action. This assessment compares the present noise impact on the environment with that of the proposed change. If the noise impact is significant, DNL 1.5 dBA increase at noise sensitive areas, then the FAA requires an Environmental Impact Statement (EIS). If the increase of noise impact on the community is not significant then the FAA prepares a Finding of No Significant Impact (FONSI), which briefly outlines the specifications of the change in airport operations for that particular airport.

The aircraft noise analysis for an EIS is a detailed process that requires use of an airport noise computer model such as the INM (Reference 1). The INM can produce a DNL noise contour area based on flight track locations, operations (e.g., a specific mix of aircraft) and takeoff procedures and plots the contour relative to runway configuration. The INM is a useful model for airport planners, airport operators, and local governments in assessing the noise impact to the community around an airport. The INM offers the capability to analyze several operational controls beyond simply changing aircraft mix and number of operations. The INM is the most appropriate tool for EIS's and other federally funded airport environmental studies.

The old Civil Aeronautics Board (CAB) developed the Noise Screening Methodology to decide whether the noise impact due to a change is significant. CAB promulgated this noise screening procedure in 14 CFR 312, Appendix I. It was commonly called the "CAB Procedure." CAB established a decision criterion of 17% increase in cumulative noise contour area. A 17% increase in cumulative noise contour area translates into a one-decibel increase in the airport noise. If the percentage difference due to the change is less than 17%, no further study is necessary. The AEM is an outgrowth of the CAB Procedure. The FAA applies the same decision criterion to AEM as the CAB did with the Noise Screening Methodology.

The AEM is a screening procedure used to simplify the assessment step in determining the need for an EIS or further analysis with the INM. The purpose of the AEM is to show change in airport DNL noise contour area relative to a change in aircraft mix and number of operations. AEM determines the DNL noise contour area in square miles for a mix and number of aircraft types by using linear regressions that relate DNL noise contour area as a function of the number of annual daily average operations. These AEM parameters are derived from INM and generated for each aircraft. A process developed from a Civil Aeronautics Board procedure allows AEM to combine the areas of individual aircraft in order to obtain a single contour for the airport under examination. These are general relationships that relate contour area to number of operations. It is to be used when the analysis can assume similar runway and flight track utilization between the baseline case and the alternative case.

In their report dated August 1992, the Federal Interagency Committee on Noise (FICON) (Reference 2) along with 1050.1D, recommended the use of AEM as a screening tool to determine the need for additional environmental noise analysis. FICON, which was composed of representatives from several Federal Government agencies, as chartered to review specific elements of federal agency procedures for the assessment of airport noise impacts and to make appropriate recommendations. In Volume 2, paragraph 3.3.1.1, of their report, they recommend the use of screening to determine the extent of noise analysis required. As with 1050.1D, FICON also established an increase of 17 percent or more in contour area as the threshold of significance for AEM within a DNL 65 dBA contour. A 17 percent increase indicates that the proposed action could result in a DNL 1.5 dBA or greater increase at a noise sensitive area and that further analysis is required. Conversely, if the screening process shows less than a 17 percent increase, it may be concluded that there are no significant

impacts on a noise sensitive area.

The Office of Environment and Energy (AEE) has had four previous releases of the AEM which are listed in the Appendix (Reference 3, 4, 5, 6)

2.2. How AEM Works

AEM is a method to predict contour area or noise level changes that correlate highly with INM predictions. The activity at airports can be expressed in terms of equivalent aircraft operations and reasonable estimates of impact area can be obtained without the use of more sophisticated and expensive computer modeling. Many studies, particularly those dealing with national impacts, have used variations of the "equivalency" approach. The basic hypothesis of AEM is that while equivalencies can be developed the nature of the relationship changes with the distance between the aircraft and the observation point. This assumption can be illustrated by considering noise versus distance curves--a basic input to models like INM--for two hypothetical aircraft as shown in Figure 2.1.
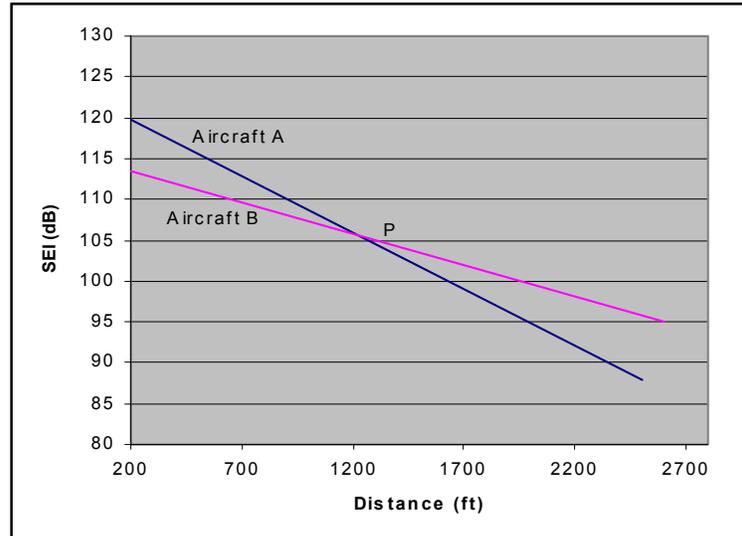

Figure 2.1 Noise versus Distance

The curves for both aircraft A and B are at constant thrust level and noise for both decreases with distance. Note that at a distance from the aircraft of less than P, aircraft A is noisier while beyond P, aircraft B is noisier. At P, both aircraft emit the same noise levels and the equivalence between them is 1.0.

Theoretically, a mathematical proof for AEM could be developed, but this would require the set of equations used within INM to develop contour area estimates. Instead, J. Watson Noah, Inc. developed an iterative process for using AEM and aircraft mix to estimate area and compared AEM estimates to available INM estimates for 30 NEF (DNL 65 dBA). AEM estimates were based on single direction traffic on a single runway.

2.3. Using AEM Effectively

AEM is a screening tool for the INM and a quick way to assess the impact of changes in aircraft mix or number of operations as part of an EA, FONSI, or other environmental noise study. *If there is a 17% increase in DNL 65 dB contour area then further analysis is necessary using the INM.*

AEM calculations are developed on the basis of a single runway, one-way traffic flow configuration-arrivals in and departures out in the same direction. AEM does not produce contours, only an estimate (in square miles) of the area impacted. This does not mean, however, that AEM usage and analysis are limited only to airports that have single runway, single flight track configurations. Airports with multiple runways and multiple flight tracks can also be assessed using AEM that models all operations on a single runway, single flight track configuration.

Whether an AEM-proposed screening analysis is appropriate depends upon the changes under study in the airport vicinity. *AEM use is limited to changes in fleet mix and number of operations.* It cannot be used to evaluate new procedures, alternative track load, or any other changes to airspace structure or utilization that would alter the location of aircraft flights, corresponding noise, and the general shape of the contour.

AEM is most often used prior to INM analysis to determine if the INM is required for the specified type of changes, but it can also be used after initial INM evaluation in certain circumstances to refine analysis. Whether AEM results are acceptable depends both on the threshold of 17 percent area increase (an increase of approximately DNL 1.5 dBA distributed proportionately with no change in contour shape) and the level of public controversy surrounding the study project. Particular attention should be paid to the possibility of additional noise impact to sensitive locations, in which case it may be better to use or rerun the INM to develop contours.

3. Development

3.1. Description

The AEM determines the DNL noise contour area (in square miles) for a specific case of aircraft operations, given the mix of aircraft types and the number of *landing-takeoff cycles* (LTO's) per aircraft. In order to create the AEM, aircraft specific parameters relating DNL noise contour areas to LTO's were derived from INM output for DNL 65 dBA. These parameters, represented by the variables *a* and *b*, are constants that produce the DNL 65 dBA contour area due to a specific number of operations of an aircraft from the following equation:

$$A = a * N * b$$

The constant *a* is the noise contour area in square miles of a single LTO for an aircraft. The constant *b* is a scaling parameter that determines the change in contour area, relative to a change in number of effective LTO's for an aircraft. The noise contour area *A* is the result of applying the parameters *a* and *b* to *N*, the number of effective LTO's. The

number of effective LTO's is the sum of the daytime LTO's and the nighttime LTO's of an aircraft. The nighttime LTO's are weighted by a multiple of 10 to account for the increase in annoyance to the community during the nighttime hours between 10 p.m. and 7 a.m.

Contour values other than DNL 65 dBA are estimated by logarithmically scaling the LTO cycle input file to estimate mathematically equivalent contour values (for example, a ten-fold increase in LTO cycles converts the DNL 65 dBA contour into the DNL 75 dBA contour).

3.2. Calculation of Parameters and Coefficients

The INM Version 6.0c was used to produce aircraft noise contour areas for specific numbers of LTO's. INM was run for each of the 114 aircraft, which contain representative takeoff and approach procedures. The parameters *a* and *b* were determined from the linear regression equation:

*log A = log a + b * log N*

By taking the antilog of both sides of this equation it converts to, the form *A =(antilog a)N^b*. By convention the expression (*antilog a*) is designated simply as *a*, providing the more useful equation *A = aNb*, where *a* is actually the antilog of the value of *log a* in the deriving regression equation.

The parameters *a* and *b* were calculated based on running the INM only once for each aircraft type, using 100 LTO cycles, and requesting contour areas for eight contour intervals. The eight contour intervals equate to DNL 65 dBA for 100 LTO's at different values of LTO's cycles. The result of this exercise was the area of the DNL 65 dBA contour as a function of LTO cycles at eight intervals over a range covering a 100-fold increase in LTO cycles. Areas that are less than 1.4 square miles are excluded from the regression sample to obtain the best possible predictive value for areas that are off airport property. The exception to this threshold is that an aircraft have at least 3 data points.

 An example of producing the *a* and *b* AEM parameters for the 707120 is shown below.

Step 1.   Create an INM input file with one runway, traffic in one direction, 100 LTO's (100 takeoffs and 100 arrivals) per aircraft, and requesting contour areas for eight contour intervals.
Step 2. Run the INM Version 6.0c to find corresponding contour areas for each aircraft type.
Step 3. Using the equation derived above and regression analysis, determine the parameters *a* and *b*. For example, the AEM parameters for the 707120 were obtained in the following manner:

First, the INM run produced the following contour areas:

DNL (dBA)	Equivalent LTO's for DNL 65 dBA (N)	DNL 65 dBA Contour Area (A)
55	1000.0	37.232
58	501.187	24.804
62	199.526	14.470
65	100.0	9.283
68	50.119	6.094
72	19.953	3.165
75	10.0	1.827
85	1.0	0.325

Table 3.1 Example INM Results

Because the contour area for DNL 85 dBA is less than 1.4 square miles, it was discarded.

Next, the logarithm base 10 of *N* and *A* resulted in:

| Log N	Log A
3.0	1.570920
2.7	1.394516
2.3	1.160470
2.0	0.967681
1.7	0.784899
1.3	0.500438
1.0	0.261771

Table 3.2 Example Log Results

Finally, using regression analysis, the parameters *a* and *b* were produced for the 707120:

a = 0.449443 and *b* = 0.647998.

4. Example AEM Analysis

4.1. Download and save the Excel spreadsheet to your PC.

4.2. Go to the folder where you saved the file and double-click on AEM_6.0c.xls icon.

4.3. When Microsoft Excel opens a pop-up window will appear asking you to enable macros. Click on the [Enable Macros] button. The spreadsheet will then open.
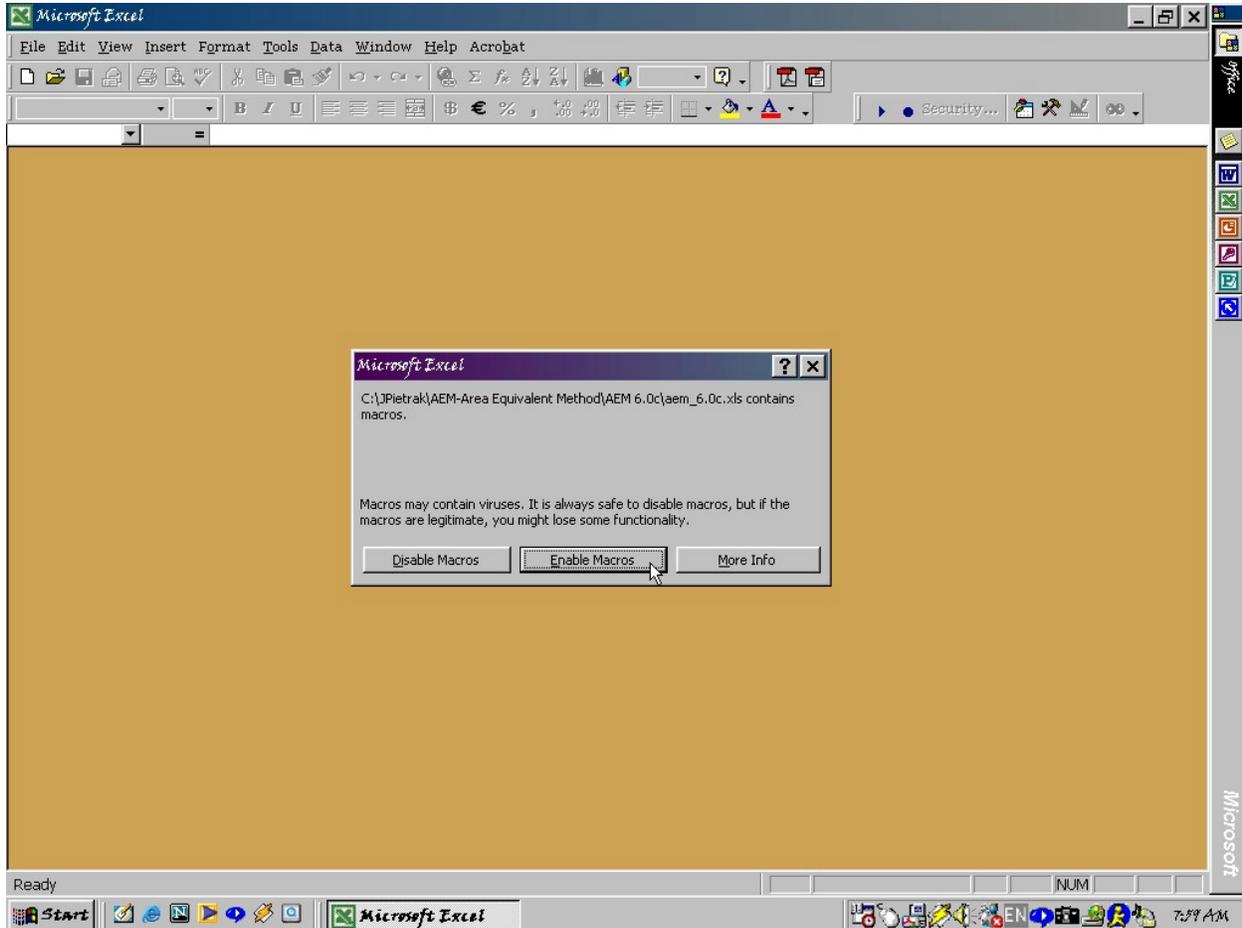
4.4. You can now enter the appropriate information/data manually into the fields highlighted in GREEN. (Note: Data entry is restricted to the GREEN fields.) Results will be displayed in the fields highlighted in BLUE, which cannot be altered even though the cells can be selected. Navigating through the spreadsheet is accomplished by simply using the tab key, arrow keys, vertical scroll bar, pageup/pagedown keys or mouse. The message window, shown to the right of the spreadsheet in the example screenshot above, will prompt the user to enter values within the appropriate ranges. Typically the message window appears initially near the cell where the data is being entered, but can easily be dragged with the mouse to wherever the user wishes.
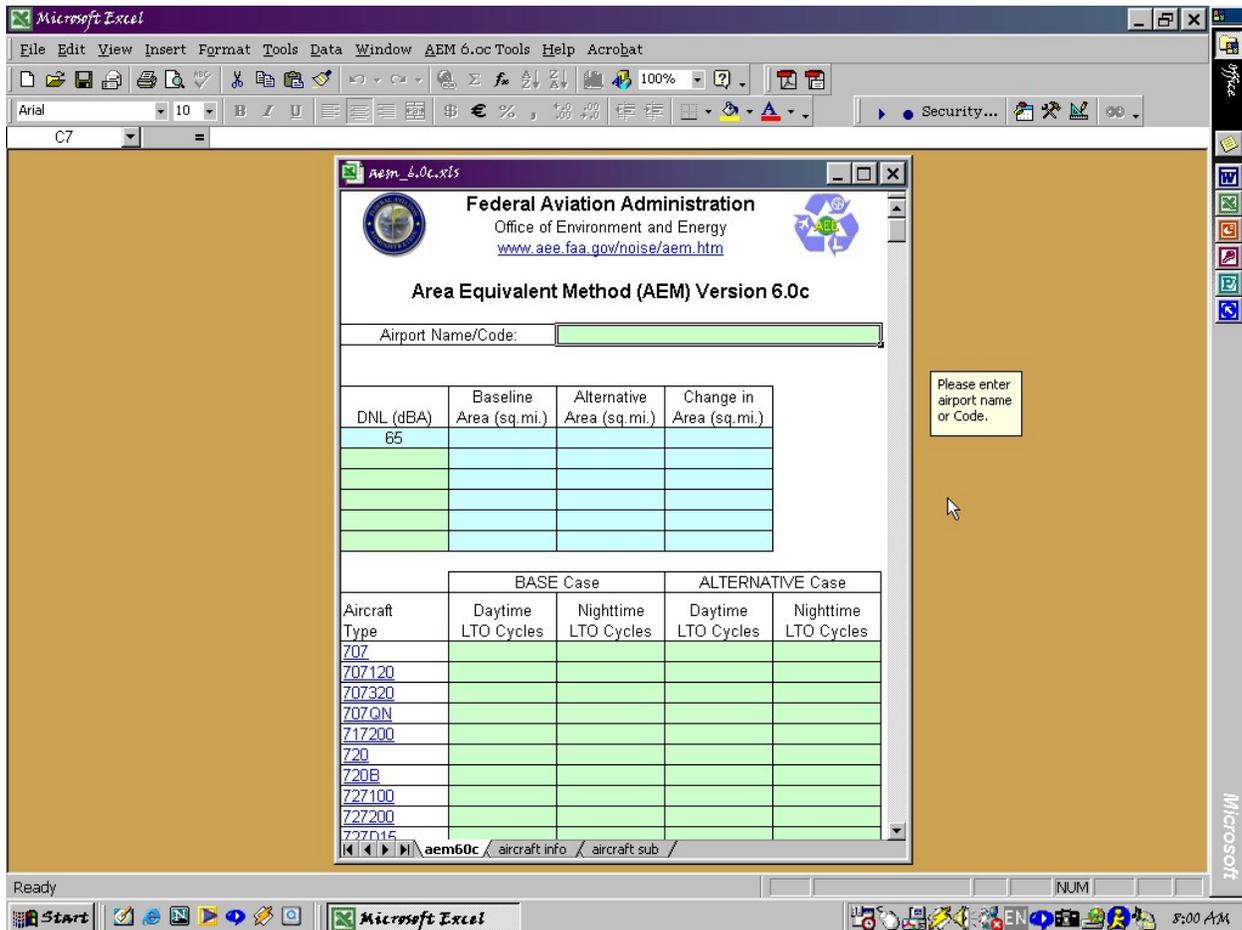
4.5. For those who are "cutting and pasting" information into the spreadsheet from another workbook you must use **[PASTE SPECIAL]** and specify **[VALUE]** otherwise the entire field is overwritten. When this occurs simply click "undo" and the field will be restored. Although the spreadsheet is formatted to validate data, data validation is only accurate with manual entry. If you AutoFill, copy drag, or drag an invalid value to a cell with data validation restrictions, the data validation restrictions are removed from the cell. Microsoft has confirmed this to be a problem in Microsoft Excel 97 and 2000. **Therefore the user must use extra CAUTION to ensure that all data entered are within the specified ranges**.

4.6. There are three new features with AEM 6.0c. A new utility called "AEM 6.0c Tools" has been added to the menu toolbar, which allows the user to hide (and unhide) those aircraft not used in the study. Also, two additional worksheets has been added to the workbook called "aircraft info" and "aircraft sub", which provides the user with a ready reference to Appendix B (AEM 6.0c aircraft list) of the AEM User's Guide and INM 6.0c's aircraft substitution list respectively. The new reference worksheets can be accessed by clicking on their tabs as shown in the above screenshot. The "aircraft info" worksheet can also be accessed by clicking on the aircraft of interest.

4.7. Note in the example that the first DNL field is shaded BLUE indicating that the data cannot be changed and that the value has been fixed at 65 dBA.

4.8. If the model detects a 17% increase in contour area, the top row DNL 65 dBA "Change in Area" will become highlighted by turning RED thus alerting the user that the proposed action could result in a significant impact. At this stage, the comparison of baseline to alternative is beyond the scope of a simple model and a more detailed analysis using the INM would be required.

Appendix A - References

1. FAA, ATAC and Volpe Center, <u>INM Integrated Noise Model Version 6.0, User's Guide</u>, DOT/FAA/EE/99-03, September 1999.

2. Federal Interagency Committee on Noise, <u>Federal Agency Review of Selected Airport Noise Analysis Issues</u>, August 1992.

3. Connor, T.L., and Fortescue, D.N., <u>Area Equivalent Method on VISICALC</u>, FAA-E-84-8, February 1984.

4. Warren, D.G., <u>Area Equivalent Method on LOTUS l-2-3</u>, FAA-EE-84-12, July 1984.

5. Nguyen, N.C., <u>AEM - Area Equivalent Method, Version 2, User's Manual</u>, FAA-EE-90-O 1, November 1989.23

6. Studholme, E.D., Grimsley, G., Plante, J.A., Warren, D.G., <u>AEM - Area Equivalent Method, Version 3, User's Guide</u>, DOT/FAA/EE-96-04, September 1996.

Appendix B - Aircraft Reference

Aircraft Type	Aircraft Description	Takeoff Weight (lbs)	Stage
707	B707-120/JT3C	245,000	1
707120	B707-120B/JT3D-3	245,000	1
707320	B707-320B/JT3D-7	312,000	1
707QN	B707-320B/JT3D-7QN	312,000	2
717200	717-200 / BR 715	112,700	3
720	B720/JT3C	180,000	1
720B	B720B/JT3D-3	200,000	1
727100	B727-100/JT8D-7	150,000	1
727200	B727-200/JT8D-7	174,000	1
727D15	B727-200/JT8D-15	189,000	1
727D17	B727-200/JT8D-17	180,000	2
727EM1	FEDX 727-100/JT8D-7	150,000	3
727EM2	FEDX 727-200/JT8D-15	189,000	3
727Q15	B727-200/JT8D-15QN	189,000	2
727Q7	B727-100/JT8D-7QN	150,000	2
727Q9	B727-200/JT8D-9	150,000	2
727QF	UPS 727100 22C 25C	150,000	3
737	B737/JT8D-9	92,000	1
737300	B737-300/CFM56-3B-1	108,000	3
7373B2	B737-300/CFM56-3B-2	111,000	3
737400	B737-400/CFM56-3C-1	121,000	3
737500	B737-500/CFM56-3B-1	111,000	3
737700	737700/CFM56-7B	134,800	3
737D17	B737-200/JT8D-17	100,000	2
737N17	B737-200/JT8D-17 Nordam B737 LGW Hushkit	100,000	3
737N9	B737/JT8D-9 Nordam B737 LGW Hushkit	92,000	3
737QN	B737/JT8D-9QN	92,000	2
747100	B747-100/JT9DBD	625,000	2
74710Q	B747-100/JT9D-7QN	625,000	3
747200	B747-200/JT9D-7	725,000	3
74720A	B747-200/JT9D-7A	675,000	3
74720B	B747-200/JT9D-7Q	725,000	3
747400	B747-400/PW4056	788,000	3
747SP	B747SP/JT9D-7	560,000	3
757PW	B757-200/PW2037	206,000	3
757RR	B757-200/RB211-535E4	193,000	3
767300	B767-300/PW4060	355,900	3
767CF6	B767-200/CF6-80A	303,300	3
767JT9	B767-200/JT9D-7R4D	306,900	3
767400	767-400ER with CF6-80C2B(F) Engines	380,906	3
777200	Boeing 777-200 GE90-76B	484,600	3
777300	777-300 with Trent 892 Engines	564,500	0

A300	A300B4-200/CF6-50C2	324,000	3
A310	A310-300/CF6-80C2A2	302,000	3
A319	Airbus A319-131 / V2522-A5 Engines	140,200	3
A320	A320-211 CFM56-5A1	158,300	3
A32023	Airbus A320-232 / V2527-A5 Engines	158,600	3
A330	Airbus A330-301 / CF6-80 E1A2	441,000	3
A340	A340-211/CFM 56-5C2	544,500	3
A7D	A-7D,E/TF-41-A-1	36,000	0
BAC111	BAC111/SPEY MK511-14	79,000	2
BAE146	BAE146-200/ALF502R-5	84,000	3
BAE300	BAE146-300/ALF502R-5	88,000	3
BEC58P	BARON 58P/TS10-520-L	5,500	0
C130	C-130H/T56-A-15	132,000	3
C130E	C-130E/T56-A-7	132,000	0
CIT3	CIT 3/TFE731-3-100S	20,000	3
CL600	CL600/ALF502L	36,000	3
CL601	CL601/CF34-3A	43,100	3
CNA172	Cessna 172R / Lycoming IO-360-L2A	2,450	0
CNA206	Cessna 206H / Lycoming IO-540-AC	3,300	0
CNA20T	Cessna T206H / Lycoming TIO-540-AJ1A	3,300	0
CNA441	CONQUEST II/TPE331-8	9,850	0
CNA500	CIT 2/JT15D-4	14,700	3
CNA55B	Cessna 550 Citation Bravo / PW530A	14,800	0
CNA750	Citation X / Rolls Royce Allison AE3007C	35,700	3
COMJET	1985 BUSINESS JET	19,200	1
COMSEP	1985 1-ENG COMP	2,440	0
CONCRD	CONCORDE/OLY593	400,000	0
CVR580	CV580/ALL 501-D15	54,000	0
DC1010	DC10-10/CF6-6D	420,000	3
DC1030	DC10-30/CF6-50C2	517,000	3
DC1040	DC10-40/JT9D-20	502,000	3
DC3	DC3/R1820-86	26,000	0
DC6	DC6/R2800-CB17	95,000	0
DC820	DC-8-20/JT4A	250,000	1
DC850	DC8-50/JT3D-3B	255,000	1
DC860	DC8-60/JT3D-7	305,000	1
DC870	DC8-70/CFM56-2C-5	305,000	3
DC8QN	DC8-60/JT8D-7QN	305,000	2
DC910	DC9-10/JT8D-7	78,000	1
DC930	DC9-30/JT8D-9	103,000	1
DC93LW	DC9-30/JT8D-9 w/ ABS Lightweight hushkit	103,000	3
DC950	DC9-50/JT8D-17	107,000	2
DC95HW	DC9-50/JT8D17 w/ ABS Heavyweight hushkit	107,000	3
DC9Q7	DC9-10/JT8D-7QN	78,000	2
DC9Q9	DC9-30/JT8D-9QN	103,000	2
DHC6	DASH 6/PT6A-27	12,500	0
DHC6QP	DASH 6/PT6A-27 Raisbeck Quiet Prop Mod	12,500	0

13

DHC7	DASH 7/PT6A-50	38,950	3
DHC8	DASH 8-100/PW121	31,000	3
DHC830	DASH 8-300/PW123	38,700	3
EMB120	Embraer 120 ER/ Pratt & Whitney PW118	22,475	3
EMB145	Embraer 145 ER/Allison AE3007	41,800	3
EMB14L	Embraer 145 LR / Allison AE3007A1	46,300	3
F10062	F100/TAY 620-15	86,000	3
F10065	F100/TAY 650-15	88,000	3
F16A	GENERAL DYNAMICS FALCON PW200 NM	25,000	0
F16GE	GENERAL DYNAMICS FALCON F110-GE-100 NM	25,000	0
F16PW0	GENERAL DYNAMICS FALCON F100-PW-220 NM	25,000	0
F16PW9	GENERAL DYNAMICS F FALCON F100-PW-229 NM	25,000	0
F28MK2	F28-2000/RB183MK555	58,000	2
F28MK4	F28-4000/RB183MK555	66,000	2
F4C	F-4C/J79-GE-15	52,000	0
FAL20	FALCON 20/CF700-2D-2	28,660	2
GASEPF	1985 1-ENG FP PROP	2,200	0
GASEPV	1985 1-ENG VP PROP	3,000	0
GII	Gulfstream GII/SPEY 511-8	56,000	2
GIIB	GIIB/SPEY MK511-8	65,500	2
GIV	GIV/TAY 611	71,700	3
GV	Gulfstream GV/BR 710	76,925	3
HS748A	HS748/DART MK532-2	46,500	2
IA1125	ASTRA 1125/TFE731-3A	23,500	3
KC135	KC135A/J57-P-59W	285,000	0
KC135B	KC135B/JT3D-7	285,000	0
KC135R	KC135R/CFM56-2B-1	308,000	0
L1011	L1011/RB211-22B	400,000	3
L10115	L1011-500/RB211-224B	441,000	3
L188	L188C/ALL 501-D13	102,000	0
LEAR25	LEAR 25/CJ610-8	15,000	2
LEAR35	LEAR 36/TFE731-2	18,300	3
MD11GE	MD-11/CF6-80C2D1F	535,000	3
MD11PW	MD-11/PW 4460	535,000	3
MD81	MD-81/JT8D-209	126,000	3
MD82	MD-82/JT8D-217A	132,000	3
MD83	MD-83/JT8D-219	141,000	3
MD9025	MD-90/V2525-D5	151,107	3
MD9028	MD-90/V2528-D5	151,107	3
MU3001	MU300-10/JT15D-4	14,100	3
SABR80	NA SABRELINER 80	28,660	2
SD330	SD330/PT6A-45AR	21,800	3
SF340	SF340B/CT7-9B	24,548	3