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AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

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Aircraft Structures Technical Memorandum 505

AN EXAMINATION OF THE FATIGUE METER RECORDS FROM THE RAAF ORION P-3C FLEET (U)

by

DOUGLAS J. SHERMAN

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SUMMARY

Load spectra for the Australian fleet of Orion P-3C aircraft are presented and compared with the ESDU 69023 (discrete gust) and the US MILSPEC A-8861A (power spectral) model, which are here called the baseline models. The turbulence experienced when flying over the sea is about one half of that predicted by the baseline models. The sea appears to reduce the turbulence by a greater amount, and to higher altitudes than indicated by the ESDU model. Transit flights, which involve flying at relatively high altitude over Australia, are about five times as severe as predicted by the baseline models. This supports other observations of a higher than normal incidence of high altitude turbulence (25,000 ft and above) over Australia.

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CONTENTS

1. INTRODUCTION

The Lockheed Orion P-3 is an Anti-Submarine Warfare (ASW) aircraft developed in 1958 from the Lockheed Electra. In 1968 the RAAF took delivery of ten P-3B aircraft, and in 1978-79 the RAAF took delivery of ten of the more modern P-3C's fitted with "Update II" modifications. A further ten of these were ordered in mid 1982, the last of which was delivered in May 1986. The original RAAF P-3B's have now been disposed of, six having been sold to the Portuguese Air Force with major systems updates by Lockheed to improve their ASW effectiveness.

The gust loading on the Orion is of special interest because in 1965 the Electra was one of three aircraft chosen as "satisfactory" aircraft to use as benchmarks in the development of gust loads criteria, based on power spectral concepts, for civil aircraft. (See Hoblit et al, 1966[1].) This resulted eventually in the power spectral criteria embodied in the civil code FAR25 (1980)[2], and, with a little re-analysis and some supplementary data, in the military code MIL-A-8861A (1971)[3]. It was determined that, for the Electra in typical airline service, a limit load vertical gust could be expected approximately once in 50,000 hours flying.

2. FATIGUE METERS

The Australian Orions are fitted with type M2208 (Mark 18) fatigue meters which count the number of times eight different levels of c.g. acceleration are exceeded during flying. To avoid large numbers of counts due to small fluctuations each of these eight counters have a "cocking" level and a "firing" level associated with it. The counter is cocked when the acceleration passes the "cocking" level, but it is not incremented until the acceleration returns past the "firing" level. For the fatigue meters in the Orions the various levels are:

Counter Number	Cocking level g	Firing level g	Increment from 1g g
1	+0.05	+0.45	−0.95
2	+0.45	+0.75	−0.55
3	+0.75	+1.05	−0.25
4	+1.25	+0.95	+0.25
5	+1.55	+1.25	+0.55
6	+1.95	+1.45	+0.95
7	+2.35	+1.55	+1.35
8	+2.65	+1.85	+1.65

The fatigue meter records considered in this report cover data from the P-3C fleet collected between November 1980 and June 1988. Data summaries were available for the whole fleet, for each aircraft individually, and for each of 8 different types of flying mission.

3. TYPES OF FLYING

RAAF usage is classified into one of 8 different types of flying mission. These are:

- TOF1: Crew training
- TOF2: ASW training and operations
- TOF3: Test flight
- TOF4: Patrol, search and surveillance
- TOF5: Fisheries surveillance
- TOF6: Flights with wing stores/harpoons
- TOF7: Transit, ferry
- TOF8: Air display, handling demonstration

Typical flight profiles for each of these types of flying are shown in Figures 1 to 8 respectively, which are reproduced from Lockheed (1981)[4]. The percentages of time spent on each type of flying and the mean duration of each type of mission were also given by Lockheed (1981) on the basis of a rather small data sample. The greater amount of fatigue meter data available now permits a more reliable estimate of these times, as shown in the following table:

TOF	Percentage of time...		Mean mission duration (Hours)	
	Lockheed (1981)	Fatigue meter Nov80 - Jun88	Lockheed (1981)	Fatigue meter Nov80 - Jun88
1	14.2	20.2	3.3	4.1
2	18.3	22.9	6.9	7.5
3	6.3	2.7	3.1	1.9
4	22.3	19.3	9.3	8.0
5	19.2	14.1	8.3	7.8
6	0.0	2.3	10.1	6.8
7	19.3	17.9	5.0	5.5
8	0.4	0.6	1.7	2.6

Initial calculations showed that turbulence occurrences for TOF4 and TOF5 flying were much less frequent than predicted by the "baseline" models (see next section). Enquiry revealed that these two types of flying, which were both surveillance missions, were usually flown to rather different profiles from those assumed by Lockheed, and shown in Figures 4 and 5. All surveillance flying is flown to a common pattern which involves a certain fraction of time in transit, followed by a search flight at an altitude which is typically 5,000 ft, broken by intermittent descents to a low altitude (perhaps as low as 200 ft) to inspect ships or other targets found during the search flight. Table A1 shows typical fractions of time spent in transit, search and low level inspection for several different routes.

From Table A1, new flight profiles were derived for representative average TOF4 and TOF5 missions:

	TOF4 Hours	TOF5 Hours
Transit	2.8	1.4
Search (7000 ft)	0.8	0.4
Search (5000 ft)	0.0	5.0
Search (3000 ft)	0.0	0.2
Search (1500 ft)	3.2	0.0
Low Level	1.2	0.8
Total	8.0	7.8

4. GUST LOAD PREDICTIONS

There are two gust load models which ARL presently uses as "baselines" against which to compare in-service gust data such as the fatigue meter records. These are:

(a) ESDU 69023[5] - a discrete gust model,

(b) MIL-A-8861A[3] - a power spectral model.

Sherman (1988)[6] has shown that whilst these two models produce similar predictions in some parts of the flight envelope, there are other conditions where their predictions may differ by factors of 10 or 20 or more. The models agree where the data bases on which they were derived were adequate to define the occurrence of turbulence. In general, this was low level flying, and small gusts. The rarer, large gusts, especially at higher levels, were not adequately represented in the data bases, and the large differences between the two models in these cases, is an indication of the genuine uncertainty in estimating their occurrence. Since much of the Orion flying is at low levels, we may expect the two baseline models to give reasonably good predictions.

The fatigue meters do not record the altitude or airspeed at which gusts were experienced, so we have to compare the gust loads with those that would be predicted for a particular flight profile. Based on Figures 1 to 8, and the assumed typical TOF4 and TOF5 missions shown above, a set of assumed profiles has been put together for each type of flying as shown in Table A2. In Table A2 and several of the subsequent tables the following abbreviations are used for the mode of flying:

Crs = Cruise
C&D = Climb and Descent
Sea = Over sea

The mean duration of each mission, other than TOF4 and TOF5, has been taken as the value shown in the corresponding figure—which was based on Lockheed's (1981) small sample—but the fraction of time spent on each type of flying has been taken as the value derived from the total fatigue meter data used in this report. For the assumed profiles, the expected numbers of gust loads have been predicted by both of the baseline methods.

The power spectral method purports to be a prediction solely of the gust loads, which are assumed to be equally divided between upgusts and downgusts. The ESDU 69023 code is based on counting accelerometer data, largely from civil transport aircraft, and so includes both gust loads and manoeuvre loads *typical of civil transport use*. Thus the number of positive loads predicted is higher than the number of negative loads. It is usually assumed that the pilot avoids manoeuvres which cause negative load increments (loads below 1g), so these negative load increments are mainly caused by gusts. The results presented in the next section (see Figures 9 to 17) show that generally the exceedance curves predicted by the two methods match fairly well on the left side of the graphs (loads below 1g) and that on the right side the ESDU 69023 code generally predicts somewhat higher numbers of loads than MIL-A-8861A.*

* The gust load predictions reported here were made with the ARL computer program "EXCG". This program has been recently modified to allow for downwash at the tail when computing lift curve slopes. This revised program was used for the present report, whereas the old program, which ignored downwash, was used for the Caribou fleet (Sherman, 1988).

5. RESULTS

Table A3 shows the load spectra measured by the fatigue meters and predicted by the two baseline methods for each type of flying (lines prefixed by 1 to 8) and for all types of flying together (lines prefixed by "A"). These spectra are graphed in Figures 9 to 17 respectively.

For flying at a given altitude, the aircraft's airspeed has a considerable effect on the load (acceleration) caused by a given vertical gust (the load is approximately proportional to the airspeed) but it has no effect on the probability of encountering gusts of a given magnitude per unit flight distance. Table A4 shows the distance flown at each altitude, classified by mode of flying (cruise, climb & descent, flight over the sea). These distances are a measure of the exposure of the aircraft to gusts at each altitude.

In order to measure the relative damage caused by different segments of flying, the expected numbers of load exceedances at each of the three fatigue meter levels below 1g (i.e. at the levels where gusts are expected to dominate the loading) were computed using the ESDU 69023 code. These predicted load exceedances are shown in Tables A5 to A7, and compared with the total *observed* numbers of exceedances for each type of flying.† The predictions and observations are, *in some cases*, considerably different: the differences indicate where changes to the ESDU 69023 model might make it reflect more nearly the Australian experience.

Similarly, Tables A8 to A10 show expected numbers of exceedances computed by the power spectral code MIL-A-8861A. Because this code combines exceedances due to upgusts and downgusts, the total for each type of flying is divided by 2 in order to compare with the load exceedances observed by the negative increment counters of the fatigue meters. Again, some considerable differences may be observed between predictions and observations, and these differences suggest modifications to the MIL-A-8861A model.

6. DISCUSSION

Inspection of Figure 17 suggests that, overall, the two baseline models produce fairly similar results, and those results are reasonably close to the loads experience of the Orion fleet, although the smaller gusts are over-estimated by a factor of almost 2.

Manoeuvre loads are significantly greater than those predicted for a transport aircraft by ESDU 69023, but this is to be expected for an aircraft used in a military role.

Individual types of flying (Figures 9 to 16) show some bigger discrepancies. In particular, the baseline models considerably over-estimate the gust loads experienced in types of flying 4, 5 and 8, and they considerably under-estimate those experienced in type of flying 7.

There is a certain amount of judgement involved in choosing the representative flight profiles shown in Figures 1 to 8, and a further degree of judgement in reducing these profiles to the cases shown in table A2. Because of this, we cannot expect too close an agreement between predictions and observations. However, with the help of Tables A5 to A7 we can suggest some modifications to the ESDU 69023 discrete gust

† Note that the marginal sums of exceedances for each type of flying are the numbers of exceedances for that type of flying in 1000 hours of total flying in the proportions shown in Table A2: they are not the exceedances per 1000 hours of a particular type of flying.

model, and with the help of Tables A8 to A10 we can suggest some modifications to the MIL-A-8861A power spectral model.

We will consider several types of flying individually, not in numerical order, but roughly in order of the degree of discrepancy between prediction and observation.

(a) Type of flying 5 - Fisheries surveillance

Fisheries surveillance involves flying at fairly low altitude over the sea. The ESDU model predicts lower turbulence over sea than over land. The difference is a factor of 3 to 4 at 1000 ft, but reduces to a factor of 1.2 at 5000 ft, and disappears at 7000 ft.

Table A5 shows that the model predicts that 531, or more than three quarters, of the exceedances of the 0.25g increment level occur during flight at 1500 ft over the sea. These exceedances would have to be reduced by a factor of about 2.5, and the loads due to the other segments of flight over the sea would have to be reduced by a similar factor in order to correctly predict the loads experienced. Similarly Table A6 shows that load increments of 0.55g are predicted to occur about 1.5 times as often as actually experienced, and Table A7 shows that load increments of 0.95g are predicted to occur about 1.2 times as often as experienced.

For the speeds flown by the Orion during this type of flying, the derived equivalent gust velocity is about 12 m/s per g, so an increment of 0.25g corresponds to vertical gusts at flight level of about 3 m/s, and the higher acceleration increments correspond to vertical gusts of around 6 m/s and 12 m/s.

It appears that flight over the sea does not reduce the probability of encountering a rare severe storm as much as it reduces that of encountering mild turbulence.

The power spectral model specified by MIL-A-8861A does not allow for the type of terrain (land or sea) or mode of flying (climb or cruise): all flight at 1500 ft is considered identical. Tables A8 to A10 show that, for flying over a smooth sea, the power spectral model over-estimates the occurrence of turbulence by a factor of about 4 at the 0.25g level, by a factor of about 1.5 at the 0.55g level and by a factor of 2 at the 0.95g level. To significantly reduce the model's prediction of gusts reaching right up to 12 m/s it will be necessary to reduce the power spectrum parameter P_1 by a factor of 3 to 4, and the parameter P_2 by a factor of about 2.

In summary, for this type of flying, the gust loads predicted by the two baseline methods have to be reduced by the following factors in order to be in agreement with the observed Orion gust loading:

Level		Reduction Factor	
g-increment	Vert. gust	ESDU 69023	MIL-A-8861A
0.25 *g*	3 m/s	2.5	4
0.55 *g*	6 m/s	1.5	1.5
0.95 *g*	12 m/s	1.2	2

(b) Type of flying 4 - Patrol, search and surveillance

Here, too, the models over-estimate the occurrence of turbulence for flight over the sea, especially in the case of the milder, more frequent gusts. The bulk of the turbulence occurrences are predicted to occur during the segment of flying at 5000 ft, and the ESDU gust model predicts only a small difference between flight over sea or land at these heights. It seems that the sea reduces the turbulence occurrences by a greater factor, and to greater heights than suggested by that model.

For these altitudes and speeds, the derived equivalent gust velocity is about 12 to 13 m/s per g. The amount of turbulence predicted by the two baseline gust models has to be reduced by the following factors:

Level		Reduction Factor	
g-increment	Vert. gust	ESDU 69023	MIL-A-8861A
0.25 g	3 m/s	3	4
0.55 g	6 m/s	1.5	2
0.95 g	12 m/s	1	2

(c) Type of flying 8 - Air display, handling demonstration

The loads in this type of flying are clearly dominated by the segment of high speed cruise at 1000 ft and 380 knots. The duration of this high speed segment in each display is variable, and, according to advice from a squadron pilot at Edinburgh, is probably over-estimated by the Lockheed flight profile shown in Figure 8.

For the assumed flight profile, the value of the derived equivalent gust velocity to cause a 1g acceleration increment is only 6 m/s. The turbulence predicted by the baseline models has to be reduced by the following factors:

Level		Reduction Factor	
g-increment	Vert. gust	ESDU 69023	MIL-A-8861A
0.25 g	1.5 m/s	1.3	1.3
0.55 g	3 m/s	2	2
0.95 g	6 m/s	10	10

This represents an unusually tight agreement between the two models, and reverses the trend noted for the other types of flying, in that the predicted numbers of the larger gusts need to be reduced by large factors, and the smaller gusts are not much affected. Probably, minor turbulence has little effect on the performance of air displays, but in the rare cases when storms occur at the scheduled time of the display, the display will be deferred for the mutual convenience of everyone, or if it is performed in stormy weather, the airspeed will be reduced nearer to the turbulence penetration speed.

(d) Type of flying 7 - Transit, Ferry

This type of flying is one for which the actual turbulence experienced is considerably more severe than either of the models predict. Therefore we cannot use the segment-wise calculation of expected numbers of exceedances in order to indicate which segments of the model are likely candidates for modification.

Because of geographic constraints, it is likely that most transit flights will occur over mainland Australia, rather than over the sea. Most of the flying time in these transit flights is at a cruise altitude of about 25,000 ft. Sherman (1981)[7] has noted that the main exception to the applicability of the ESDU 69023 model to the Australian environment was a higher incidence of turbulence for high altitude flying (over about 30,000 ft), and cited the concurrence of the jet stream and mountain ranges as a likely reason for this.

If all the increase is to be attributed to the 25,000 ft cruise, for which the derived equivalent gust velocity to cause a 1g increment is about 11 m/s, the turbulence predicted by the two models would have to be increased by the following factors:

Level		Multiplication Factor	
g-increment	Vert. gust	ESDU 69023	MIL-A-8861A
0.25 *g*	3 m/s	6	5
0.55 *g*	6 m/s	9	5
0.95 *g*	11 m/s	40	1

The big difference between the factors for the largest gusts, indicates the large uncertainty in the models for this case. For this altitude and gust speed, the power spectral model appears the more correct.

(e) Other types of flying

Types of flying 1, 2, 3 and 6 show as much variation between the two baseline models as between the models and the load history experienced. On the whole, the numbers of the more severe loadings are better predicted by the MIL-A-8861A model than by the ESDU 69023 model, but this is not universal.

7. CONCLUSIONS

When the load spectra experienced by the Orion aircraft during different types of flying missions are compared with the spectra predicted by the two "baseline" models ESDU 69023 and MIL-A-8861A, it is found that:

- For patrol or fisheries surveillance missions, the turbulence experienced in flying over the ocean is about half that predicted by the baseline models. The sea appears to reduce the turbulence by a greater amount, and to higher altitudes than indicated by the ESDU model. This is in accord with the conclusions drawn from HICAT data by Ashburn, Waco and Melvin (1970)[8].

- For transit missions, which are mainly at high altitude, the turbulence may be five times as severe as the baseline model predictions. This supports other observations of a higher than normal level of turbulence at high altitudes over Australia.

- For other types of flying the turbulence experienced is generally as close to one of the baseline models as the scatter of the baseline models from each other. However, in a number of cases this scatter between the baseline models—which indicates genuine uncertainty in them—is unacceptably large.

REFERENCES

1. Hoblit F.M., N. Paul, J.D. Shelton & F.E. Ashford *1966* Development of a power-spectral gust design procedure for civil aircraft. Report No. FAA-ADS-53, prepared for FAA by Lockheed-California. (NTIS Accession No. AD-651-152)
2. FAR25 *1980* Federal Aviation Regulations Part 25. See especially Amendment 25-54 dated 14 October 1980, pp151-152, and Figures 1 and 2.
3. MIL-A-8861A *1971* Airplane strength and rigidity - Flight loads. U.S Military Specification prepared for USAF. 31 March 1971.
4. Lockheed *1981* RAAF service life extension program. Lockheed Report No. LR 29854, August 1981.
5. ESDU *1979* Average Gust Frequencies – Subsonic Transport Aircraft. London: Engineering Sciences Data Unit. Data Item 69023 with amendments A, B and C. July 1979.
6. Sherman D.J. *1988* An examination of the fatigue meter records from the RAAF Caribou fleet. ARL Structures Tech. Memo. 489. (July 1988)
7. Sherman D.J. *1981* Aircraft measurements of the frequency of turbulence encounters in Australia. ARL Structures Note 471. (March 1981)
8. Ashburn E.V., Waco D.E. and Melvin C.A. *1970* High altitude gust criteria for aircraft design. USAF Air Force Flight Dynamics Laboratory, Technical Report AFFDL-TR-70-101. (NTIS Accession Number AD-873-415)

TABLE A1

PROFILES OF SURVEILLANCE FLYING

Route No.	Per cent of time spent in... Transit	Search	Low level	Ave search Altitude	% total Time
		TOF 4 - Patrol surveillance			
1	35	50	15	7000	11
2	35	50	15	1500	46
		TOF 5 - Fisheries surveillance			
3	14	82	4	7000	1.2
4	20	73	7	5000	1
5	15	59	26	5000	2.5
6	18	65	17	3000	5
7	20	74	6	5000	1
8	11	85	4	5000	1
9	29	65	6	7000	2
10	29	66	5	5000	5
11	50	36	14	5000	3
12	9	74	17	5000	1

TABLE A2

HOURS FLOWN IN EACH TYPE OF FLYING PER 1000 TOTAL HOURS.

Classified by altitude, mode and airspeed

Alt Feet	Mode	CAS Knot	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Total
250	Sea	220			2.2	9.9	3.5				15.6
500	C&D	165	55.9								55.9
500	C&D	200			.5	.3	.2				1.0
500	C&D	210		3.2				.3	1.2	.2	4.9
500	C&D	220	3.1								3.1
500	Sea	210		47.7			17.6				65.3
500	Sea	220			2.2						2.2
1000	Crs	380								.3	0.3
1000	Sea	300						1.9			1.9
1500	Sea	230				9.9	56.4				66.3
2000	Crs	165	52.8								52.8
3000	Crs	165	18.7								18.7
3000	C&D	220	9.3							.3	9.6
3000	C&D	260			2.2					.4	2.6
3000	Sea	210		47.7		5.0					52.7
4000	C&D	220			2.9						2.9
4000	Sea	240	62.2								62.2
5000	C&D	220				9.6				.5	10.1
5000	Sea	220				123.7					123.7
6000	Crs	220			2.2						2.2
6000	C&D	260								.4	0.4
6000	Sea	220			1.8						1.8
6000	Sea	250						4.9			4.9
7000	Sea	230				9.9	14.1				24.0
10000	Crs	220			5.8						5.8
10000	C&D	210						1.2			1.2
10000	Sea	200								3.9	3.9
10000	Sea	230				24.7					24.7
10000	Sea	260						.6			0.6
15000	C&D	200		19.1			8.6		9.5		37.2
15000	C&D	210			.9						0.9
15000	C&D	260						.3	7.1		7.4
15000	Sea	210						1.5			1.5
15000	Sea	260		19.1	1.8						20.9
20000	Sea	210						6.2			6.2
20000	Sea	220			4.5						4.5
25000	Crs	230							161.2		161.2
25000	Sea	240		92.2			40.6				132.8
35000	Sea	240						6.1			6.1
Totals			202.0	229.0	27.0	193.0	141.0	23.0	179.0	6.0	1000.0

NOTE: Modes are Crs = Cruise, C&D = Climb & Descent, Sea = Over sea

TABLE A3

(a) EXCEEDANCES PER HOUR OBSERVED BY ORION FATIGUE METERS

	G increment									
TOF	-.95	-.55	-.25	.25	.55	.95	1.35	1.65	Hours	%
1:	2.74e-3	.12	3.88	18.48	1.81	.25	.05	19.7e-3	9491.1	20.2
2:	1.48e-3	.09	3.10	20.49	1.94	.11	13.2e-3	3.1e-3	10784.9	22.9
3:	1.56e-3	.17	5.37	18.04	2.30	.32	.07	19.5e-3	1282.0	2.7
4:	0.88e-3	.04	1.62	12.69	1.13	.08	11.1e-3	1.8e-3	9061.5	19.3
5:	0.60e-3	.04	1.93	11.52	.98	.06	7.3e-3	2.1e-3	6619.3	14.1
6:	4.68e-3	.14	5.02	22.87	2.56	.18	.03	6.6e-3	1067.8	2.3
7:	1.31e-3	.06	1.81	7.17	.50	.04	6.2e-3	1.7e-3	8421.6	17.9
8:	18.70e-3	1.52	28.97	74.12	11.79	2.41	1.14	.67	267.4	0.6
A:	1.64e-3	.08	2.83	15.22	1.44	.13	.03	10.1e-3	46995.6	100.0

(b) EXCEEDANCES PER HOUR PREDICTED BY ESDU DATA ITEM 69023

	G increment							
TOF	-.95	-.55	-.25	.25	.55	.95	1.35	1.65
1:	1.46E-03	9.14E-02	8.02E+00	1.60E+01	1.73E-01	2.64E-03	6.20E-05	3.49E-06
2:	3.60E-04	2.91E-02	2.45E+00	5.03E+00	5.25E-02	6.18E-04	6.63E-06	2.00E-07
3:	1.32E-03	8.04E-02	5.66E+00	1.04E+01	1.43E-01	2.36E-03	5.35E-05	3.04E-06
4:	7.76E-04	5.88E-02	5.36E+00	8.93E+00	9.66E-02	1.28E-03	1.72E-05	6.03E-07
5:	7.71E-04	5.62E-02	4.92E+00	1.09E+01	1.20E-01	1.67E-03	2.50E-05	9.55E-07
6:	2.16E-03	9.90E-02	4.71E+00	9.31E+00	2.04E-01	4.61E-03	1.89E-04	1.70E-05
7:	1.07E-04	1.01E-02	4.66E-01	6.56E-01	1.24E-02	1.33E-04	1.41E-06	4.62E-08
8:	1.47E-01	3.23E+00	3.30E+01	7.43E+01	7.75E+00	3.57E-01	3.30E-02	7.25E-03
A:	1.62E-03	7.00E-02	4.45E+00	8.70E+00	1.40E-01	3.49E-03	2.25E-04	4.50E-05

(c) EXCEEDANCES PER HOUR PREDICTED BY MIL-A-8861A

(positive and negative gusts combined)

	G increment					
TOF	.00	.25	.55	.95	1.35	1.65
1:	1.83E+03	1.28E+01	1.38E-01	4.27E-03	2.50E-04	3.07E-05
2:	1.24E+03	1.18E+01	1.02E-01	3.36E-03	2.77E-04	5.04E-05
3:	1.30E+03	1.59E+01	1.74E-01	5.27E-03	3.27E-04	4.50E-05
4:	1.25E+03	1.30E+01	1.44E-01	4.25E-03	1.95E-04	2.03E-05
5:	1.41E+03	1.50E+01	1.26E-01	2.88E-03	1.83E-04	2.93E-05
6:	8.18E+02	2.50E+01	6.04E-01	1.25E-02	7.92E-04	1.19E-04
7:	1.53E+02	1.11E+00	2.77E-02	2.54E-03	2.67E-04	4.97E-05
8:	1.23E+03	6.97E+01	5.11E+00	2.28E-01	1.59E-02	3.20E-03
A:	1.18E+03	1.15E+01	1.51E-01	5.11E-03	3.48E-04	5.78E-05

TABLE A4

NAUTICAL MILES FLOWN IN EACH TYPE OF FLYING PER 1000 HOURS

Classified by altitude, and mode

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Total
250	Sea			492	2185	772				3449
500	C&D	9986	672	90	60	40	65	251	35	11199
500	Sea		10090	496		3722				14308
1000	Cru								119	119
1000	Sea						559			559
1500	Sea				2325	13250				15575
2000	Cru	8972								8972
3000	Cru	3214								3214
3000	C&D	2140		604					174	2918
3000	Sea		10458		1096					11554
4000	C&D			675						675
4000	Sea	15789								15789
5000	C&D				2269				125	2394
5000	Sea				29239					29239
6000	Cru			537						537
6000	C&D								110	110
6000	Sea			426			1336			1762
7000	Sea				2518	3586				6104
10000	Cru			1476						1476
10000	C&D						298			298
10000	Sea				6567		183		903	7653
15000	C&D		4770	233		2150	100	4668		11921
15000	Sea		6167	575			401			7143
20000	Sea			1323			1739			3062
25000	Cru							54106		54106
25000	Sea		32242			14191				46433
35000	Sea						2523			2523
Totals		40101	64399	6927	46259	37711	7204	59025	1466	263092

TABLE A5

PREDICTED & OBSERVED EXCEEDANCES OF 0.75g LEVEL PER 1000 HOURS

(Predicted by ESDU 69023)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Total
250	Sea			6	28	10				44
500	C&D	320	46	5	3	2	4	17	5	402
500	Sea		162	10		60				232
1000	Crs								139	139
1000	Sea						52			52
1500	Sea				93	531				624
2000	Crs	270								270
3000	Crs	62								62
3000	C&D	154		67					28	249
3000	Sea		273		29					302
4000	C&D			27						27
4000	Sea	814								814
5000	C&D				67				8	75
5000	Sea				702					702
6000	Crs			12						12
6000	C&D								8	8
6000	Sea			9			45			54
7000	Sea				50	71				121
10000	Crs			12						12
10000	C&D						1			1
10000	Sea				62		3		10	75
15000	C&D		10	1		4	1	18		34
15000	Sea		35	3			1			39
20000	Sea			2			1			3
25000	Crs							49		49
25000	Sea		36			16				52
35000	Sea						1			1
Predicted		1620	562	154	1034	694	109	84	198	4455
Observed		783	712	147	313	272	114	324	165	2831

TABLE A6

PREDICTED & OBSERVED EXCEEDANCES OF 0.45g LEVEL PER 1000 HOURS

(Predicted by ESDU 69023)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Total
250	Sea			0.06	0.27	0.10				0.43
500	C&D	2.26	0.39	0.04	0.02	0.02	0.04	0.15	0.07	2.99
500	Sea		1.39	0.10		0.51				2.00
1000	Crs								18.0	18.0
1000	Sea						1.35			1.35
1500	Sea				1.02	5.83				6.85
2000	Crs	1.58								1.58
3000	Crs	0.37								0.37
3000	C&D	1.80		1.08					0.71	3.59
3000	Sea		2.42		0.25					2.67
4000	C&D			0.27						0.27
4000	Sea	12.4								12.4
5000	C&D				0.68				0.13	0.81
5000	Sea				7.19					7.19
6000	Crs			0.13						0.13
6000	C&D								0.28	0.28
6000	Sea			0.10		1.87	0.74			2.71
7000	Sea				0.71	1.01				1.72
10000	Crs			0.20						0.20
10000	C&D						0.00			0.00
10000	Sea				1.19		0.07		0.22	1.48
15000	C&D		0.20	0.01		0.09	0.02	0.63		0.95
15000	Sea		1.41	0.13			0.02			1.56
20000	Sea			0.05			0.01			0.06
25000	Crs							1.04		1.04
25000	Sea		0.84			0.37				1.21
35000	Sea						0.02			0.02
Predicted		18.41	6.65	2.17	11.33	9.80	2.27	1.82	19.41	71.86
Observed		24.68	19.66	4.72	7.55	6.21	3.26	10.11	8.64	84.84

TABLE A7

PREDICTED & OBSERVED EXCEEDANCES OF 0.05g LEVEL PER 100000 HOURS

(Predicted by ESDU 69023)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Total
250	Sea			0.08	0.33	0.12				0.53
500	C&D	1.87	0.41	0.03	0.02	0.01	0.04	0.15	0.13	2.66
500	Sea		1.45	0.12		0.54				2.11
1000	Crs								84.9	84.90
1000	Sea						3.35			3.35
1500	Sea				1.49	8.47				9.96
2000	Crs	0.71								0.71
3000	Crs	0.17								0.17
3000	C&D	2.77		2.16					1.77	6.70
3000	Sea		2.64		0.28					2.92
4000	C&D			0.36						0.36
4000	Sea	24.0								24.00
5000	C&D				0.90				0.27	1.17
5000	Sea				9.49					9.49
6000	Crs			0.17						0.17
6000	C&D								0.77	0.77
6000	Sea			0.12			1.35			1.47
7000	Sea				0.99	1.40				2.39
10000	Crs			0.20						0.20
10000	C&D						0.00			0.00
10000	Sea				1.49		0.15		0.32	1.96
15000	C&D		0.09	0.01		0.04	0.05	1.17		1.36
15000	Sea		2.99	0.28			0.02			3.29
20000	Sea			0.03			0.00			0.03
25000	Crs							0.59		0.59
25000	Sea		0.66			0.29				0.95
35000	Sea						0.01			0.01
Predicted		29.52	8.24	3.56	14.99	10.87	4.97	1.91	88.16	162.22
Observed		55.32	34.05	4.26	17.02	8.51	10.64	23.40	10.64	163.85

TABLE A8

PREDICTED EXCEEDANCES OF 1g PLUS OR MINUS 0.25g PER 1000 HOURS

(Predicted by MIL-A-8861A)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Totals
250	Sea			121	539	190				850
500	C&D	899	132	14	9	6	13	49	15	1137
500	Sea		1980	121		730				2831
1000	Cru								328	328
1000	Sea						476			476
1500	Sea				179	1020				1199
2000	Cru	149								149
3000	Cru	45								45
3000	C&D	129		61					24	214
3000	Sea		403		42					445
4000	C&D			32						32
4000	Sea	1360								1360
5000	C&D				104				11	115
5000	Sea				1340					1340
6000	Cru			15						15
6000	C&D								11	11
6000	Sea			12			65			77
7000	Sea				84	120				204
10000	Cru			37						37
10000	C&D						2			2
10000	Sea				204		10		29	243
15000	C&D		18	1		8	1	40		68
15000	Sea		84	8			2			94
20000	Sea			7			3			10
25000	Cru							109		109
25000	Sea		82			36				118
35000	Sea						2			2
Predicted		2582	2699	429	2501	2110	574	198	418	11511
Div by 2		1291	1350	215	1251	1055	287	99	209	5756
Observed		783	712	147	313	272	114	324	165	2831

TABLE A9

PREDICTED EXCEEDANCES OF 1g PLUS OR MINUS 0.55g PER 1000 HOURS

(Predicted by MIL-A-8861A)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Totals
250	Sea			1.0	4.3	1.5				6.8
500	C&D	4.5	.9	.1	.1	.0	.1	.3	.2	6.2
500	Sea		13.1	1.0		4.9				19.0
1000	Cru								29.1	29.1
1000	Sea						12.2			12.2
1500	Sea				1.4	8.1				9.5
2000	Cru	.6								.6
3000	Cru	.4								.4
3000	C&D	1.6		1.0					.5	3.1
3000	Sea		4.5		0.5					5.0
4000	C&D			.4						0.4
4000	Sea	20.7								20.7
5000	C&D				1.2				.2	1.4
5000	Sea				15.9					15.9
6000	Cru			.2						.2
6000	C&D								.3	.3
6000	Sea			.2			1.2			1.4
7000	Sea				1.3	1.9				3.2
10000	Cru			.6						.6
10000	C&D						.0			.0
10000	Sea				3.2		.2		.4	3.8
15000	C&D		.4	.0		0.2	.0	.9		1.5
15000	Sea		1.8	.2			.0			2.0
20000	Sea			.2			.1			.3
25000	Cru							3.8		3.8
25000	Sea		2.7			1.2				3.9
35000	Sea						.1			.1
Predicted		27.8	23.4	4.9	27.9	17.8	13.9	5.0	30.7	151.4
Div by 2		13.9	11.7	2.5	14.0	8.9	7.0	2.5	15.4	75.7
Observed		24.7	19.7	4.7	7.6	6.2	3.3	10.1	8.6	84.8

TABLE A10

PREDICTED EXCEEDANCES OF 1g PLUS OR MINUS 0.95g PER 100000 HOURS

(Predicted by MIL-A-8861A)

Alt Feet	Mode	TOF1	TOF2	TOF3	TOF4	TOF5	TOF6	TOF7	TOF8	Totals
250	Sea			1.2	5.2	1.8				8.2
500	C&D	4.6	1.0	0.1	0.1	0.0	0.1	0.4	0.2	6.5
500	Sea		15.3	1.2		5.6				22.1
1000	Cru								131.	131.0
1000	Sea						20.4			20.4
1500	Sea				1.8	10.5				12.3
2000	Cru	0.3								0.3
3000	Cru	0.7								0.7
3000	C&D	5.5		3.8					1.9	11.2
3000	Sea		12.8		1.4					14.2
4000	C&D			1.2						1.2
4000	Sea	75.2								75.2
5000	C&D				3.8				0.6	4.4
5000	Sea				49.1					49.1
6000	Cru			1.0						1.0
6000	C&D								1.5	1.5
6000	Sea			0.8			5.9			6.7
7000	Sea				6.1	8.7				14.8
10000	Cru			2.4						2.4
10000	C&D						0.1			0.1
10000	Sea				0.1		0.9		2.0	3.0
15000	C&D		2.3	0.2		1.0	0.3	7.1		10.9
15000	Sea		16.2	1.5			0.3			18.0
20000	Sea			1.0			0.3			1.3
25000	Cru							38.0		38.0
25000	Sea		29.4			12.9				42.3
35000	Sea						0.5			0.5
Predicted		86.3	77.0	14.4	67.6	40.5	28.8	45.5	137.2	497.3
Div by 2		43.2	38.5	7.2	33.8	20.3	14.4	22.8	68.6	248.7
Observed		55.3	34.1	4.3	17.0	8.5	10.6	23.4	10.6	163.9

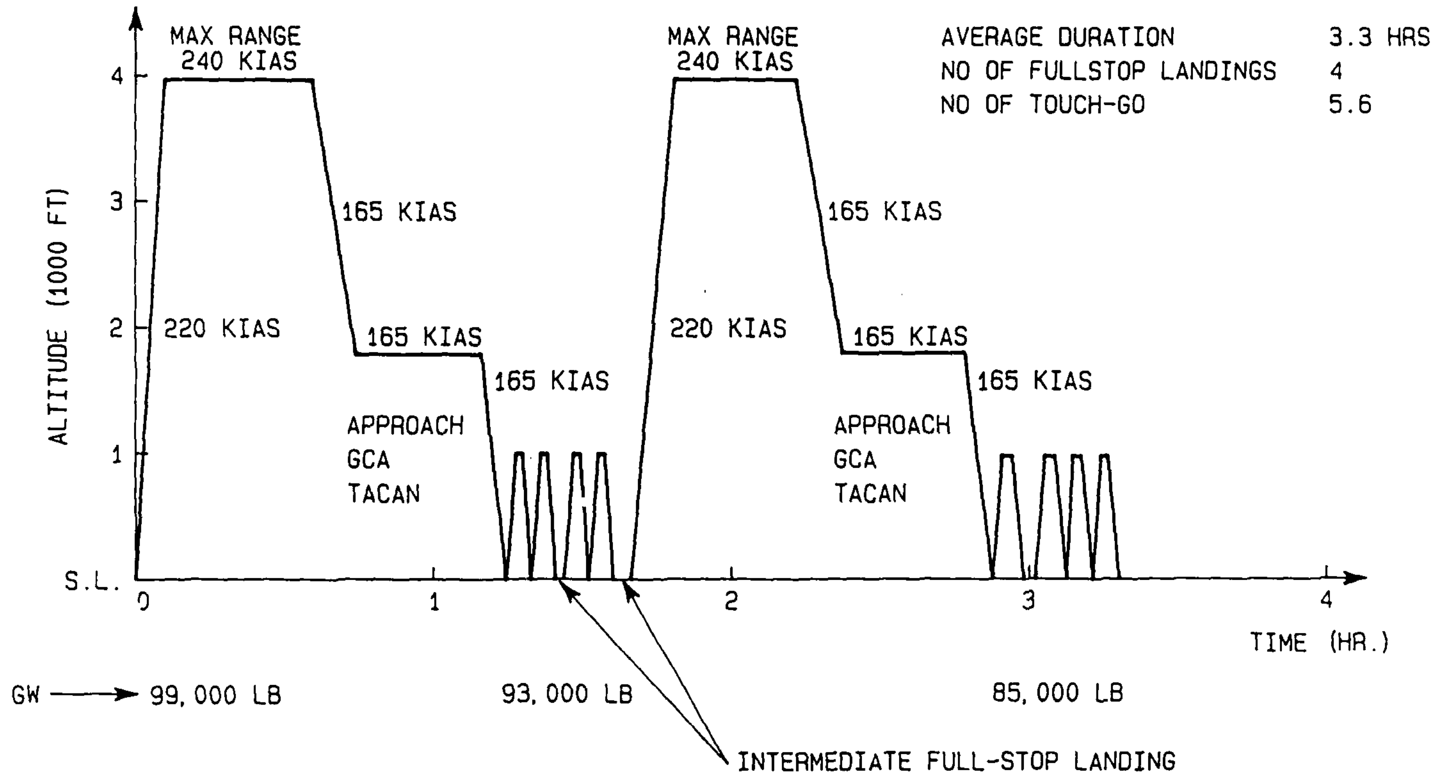


FIGURE 1 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 1 - CREW TRAINING

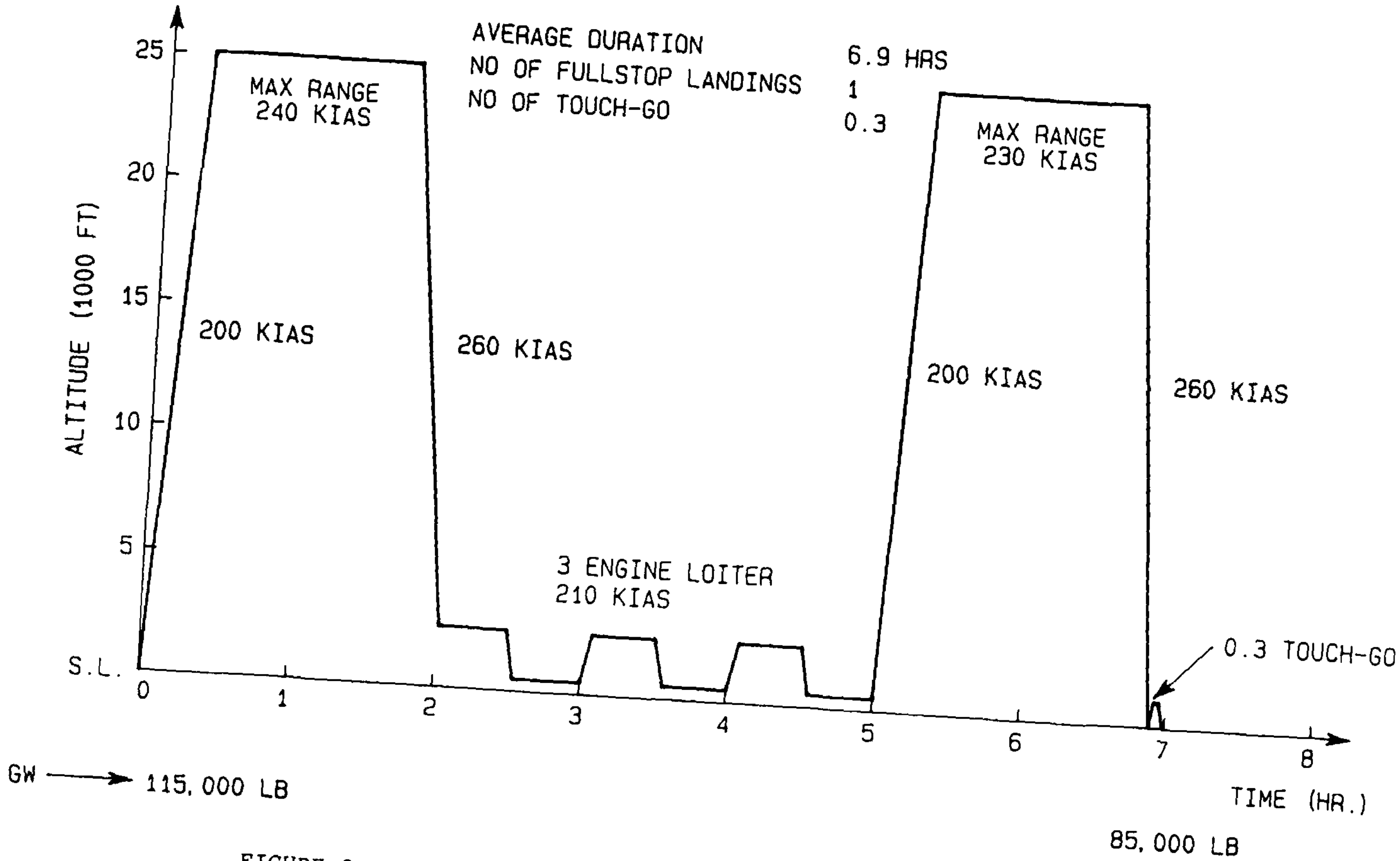


FIGURE 2 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 2 - ASW TRAINING AND OPERATIONAL

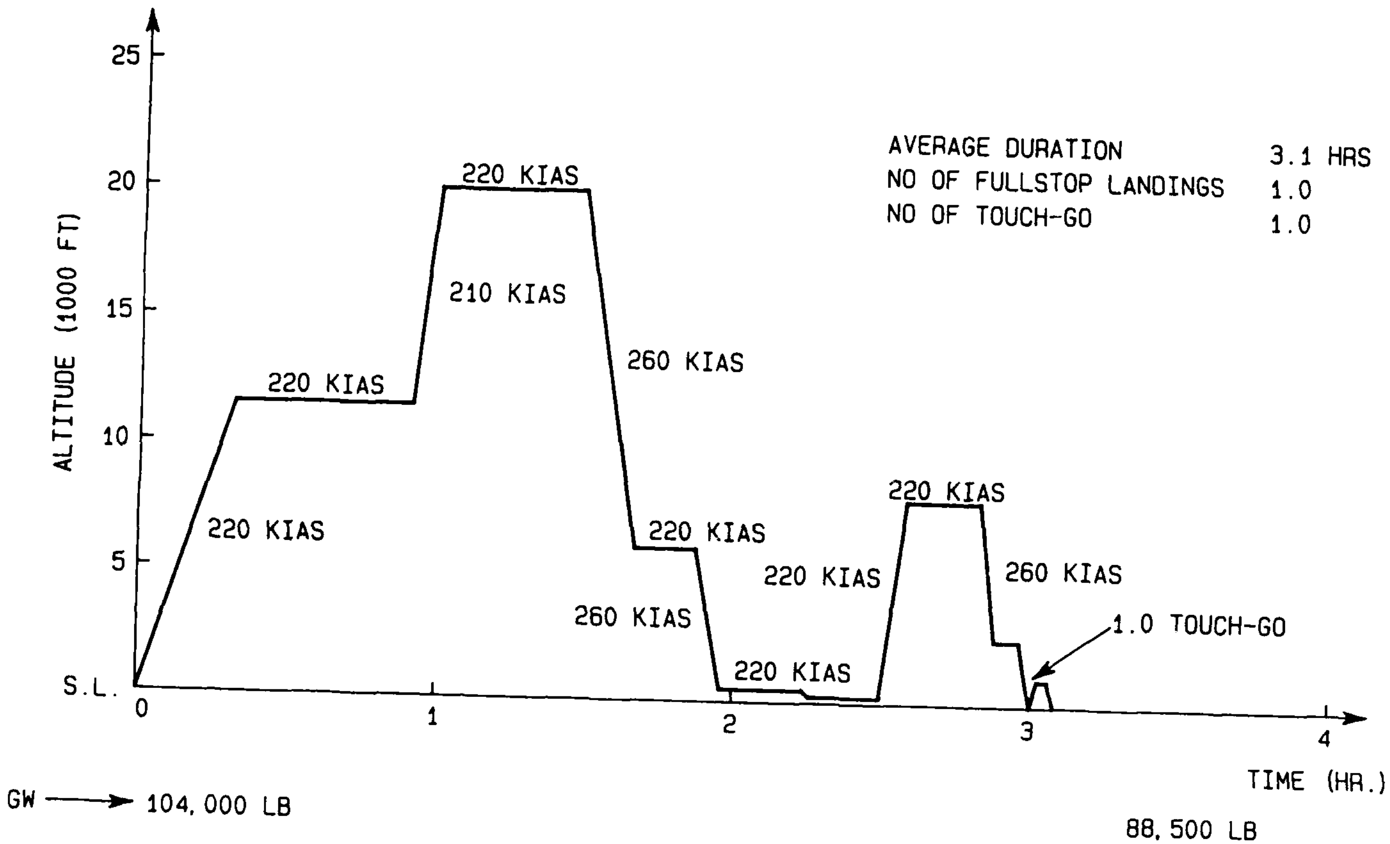


FIGURE 3 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 3 - TEST FLIGHT

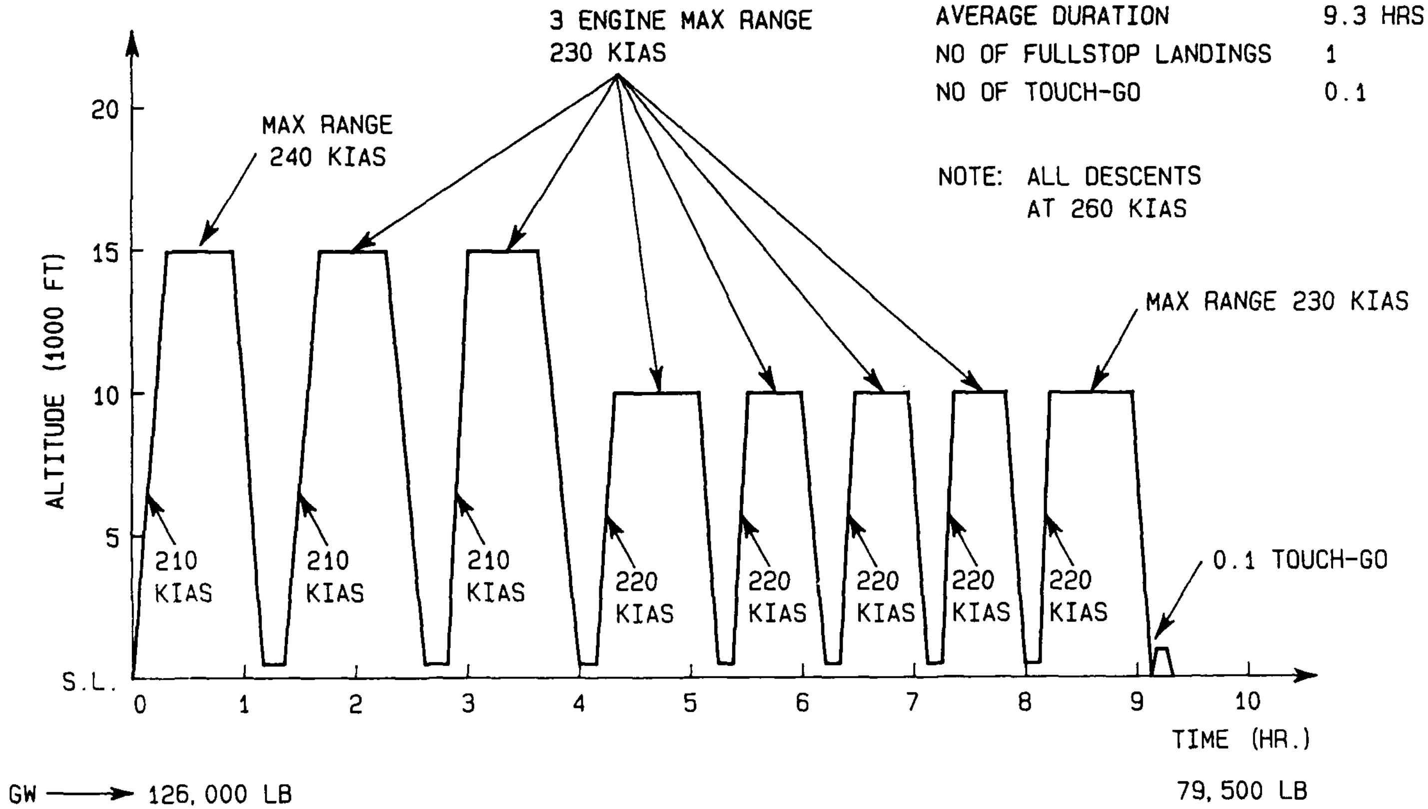


FIGURE 4 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3
TYPE OF FLYING 4 - PATROL, SEARCH AND SURVEILLANCE

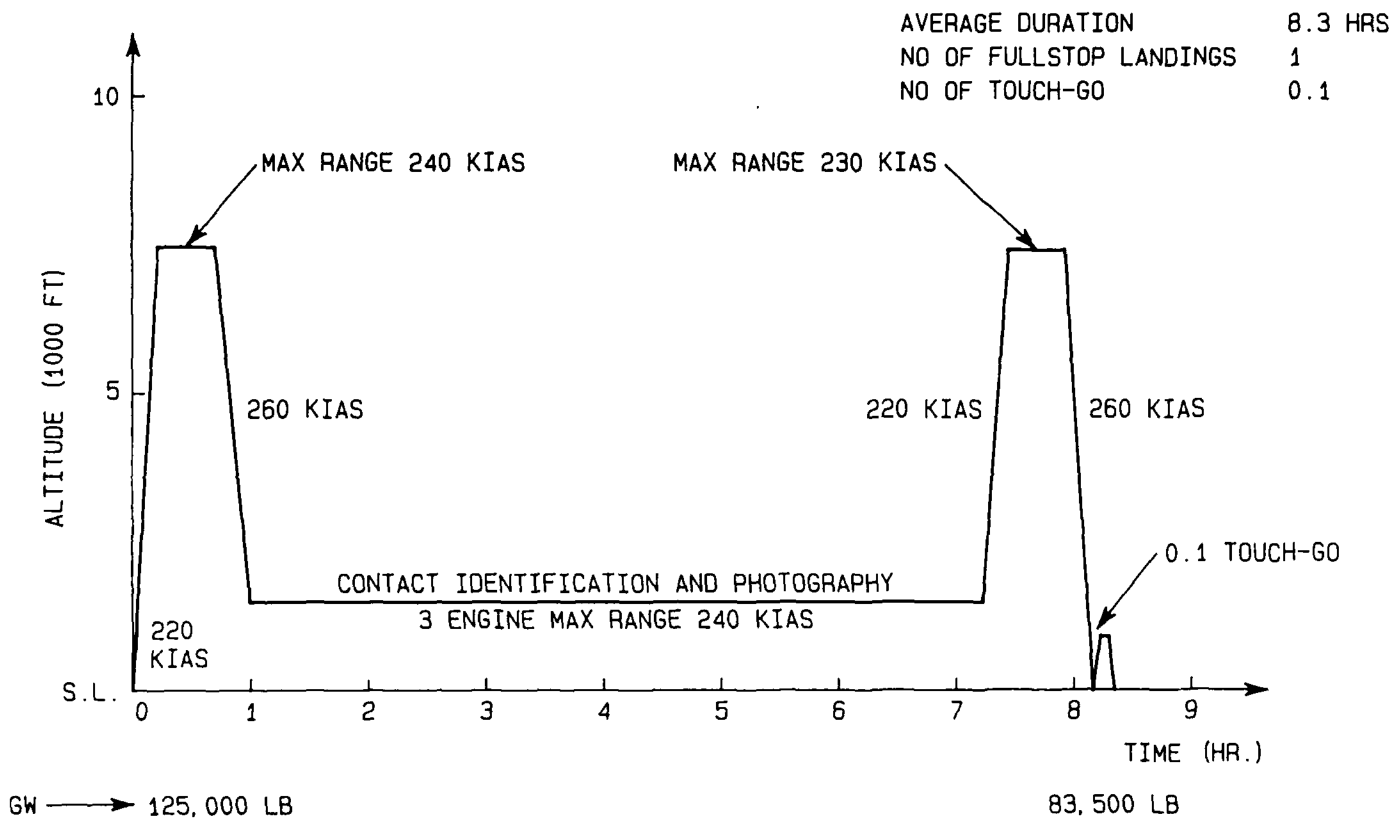
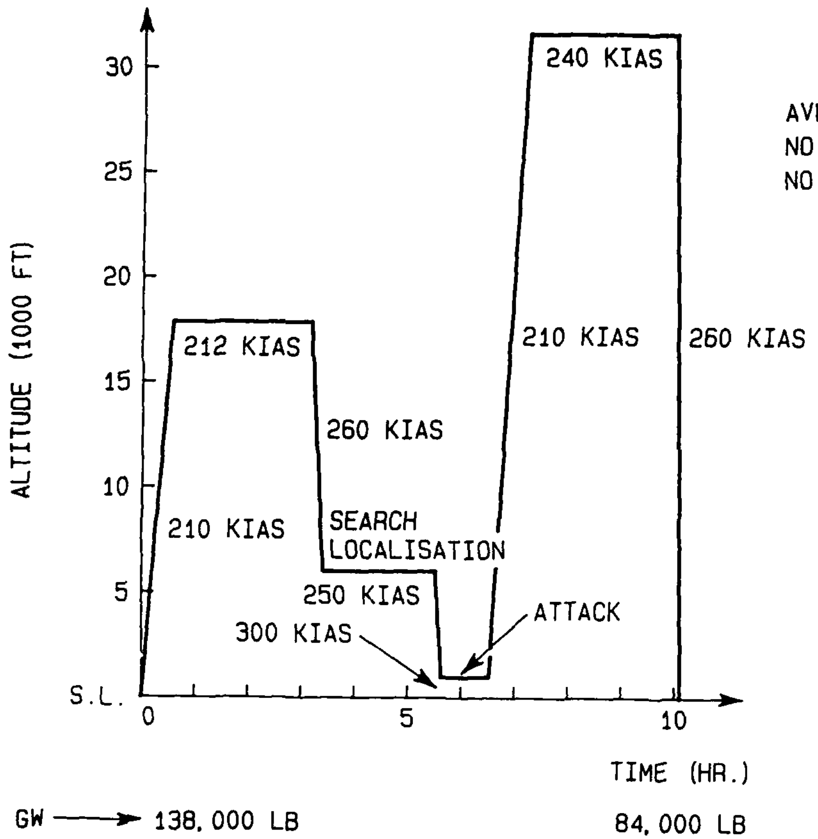


FIGURE 5 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 5 - FISHERIES SURVEILLANCE



AVERAGE DURATION	10.1 HRS
NO OF FULLSTOP LANDINGS	1.0
NO OF TOUCH-GO	0

6 HARPOON MISSLES ARE CARRIED. THEY ARE LAUNCHED DURING THE ATTACK PHASE OF THE MISSION.

FIGURE 6 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 6 - FLIGHT WITH WING STORES/HARPOONS

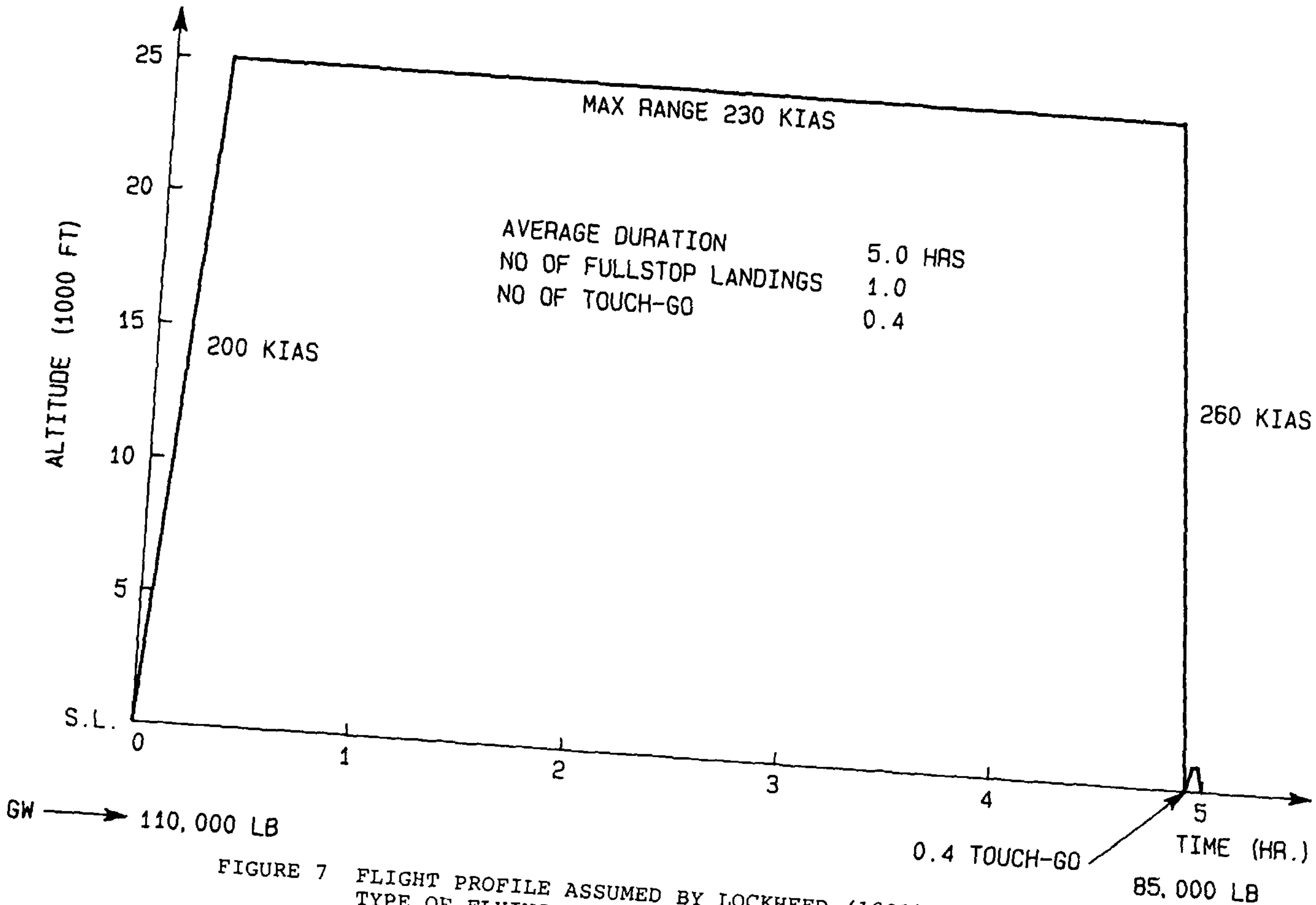


FIGURE 7 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3
TYPE OF FLYING 7 - TRANSIT, FERRY

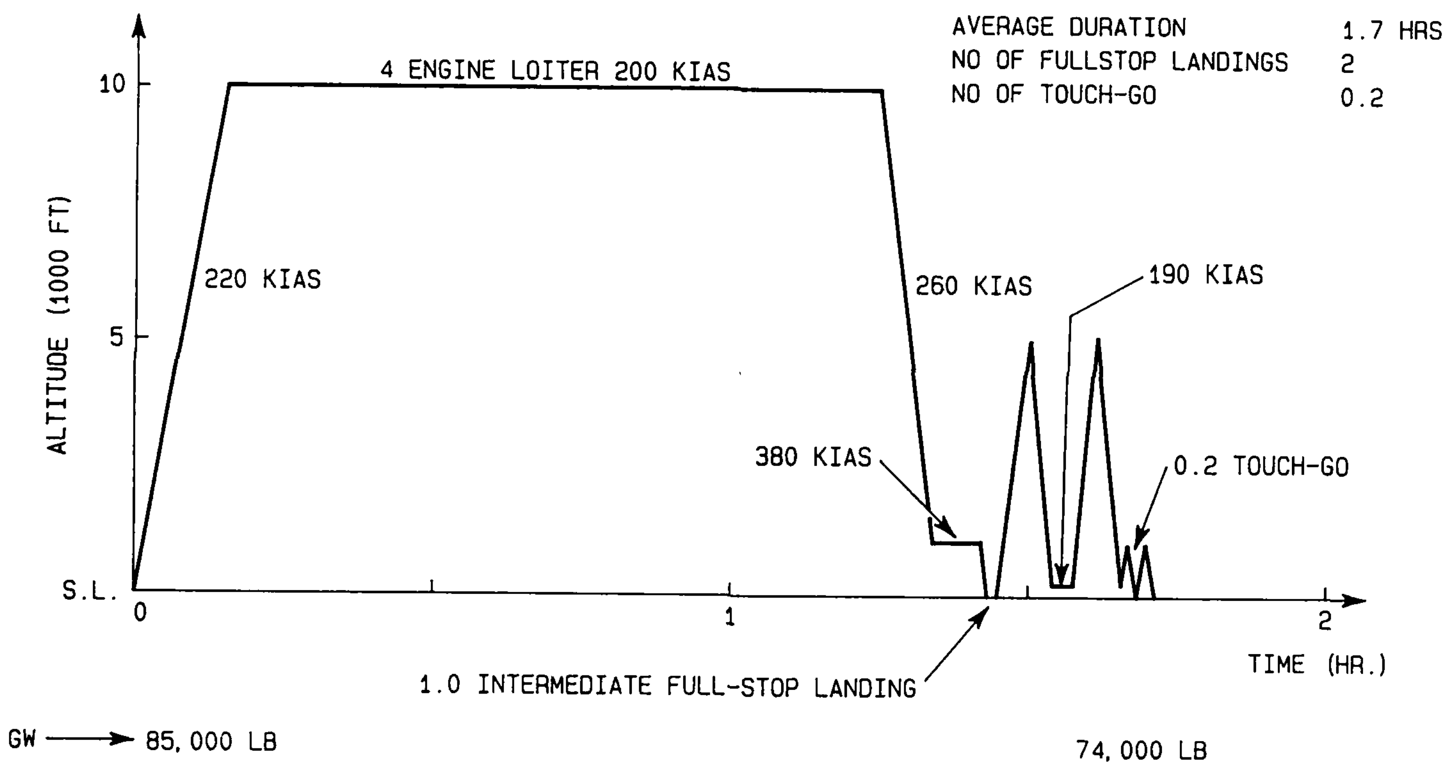


FIGURE 8 FLIGHT PROFILE ASSUMED BY LOCKHEED (1981) FOR RAAF P-3 TYPE OF FLYING 8 - AIR DISPLAY, HANDLING DEMONSTRATION

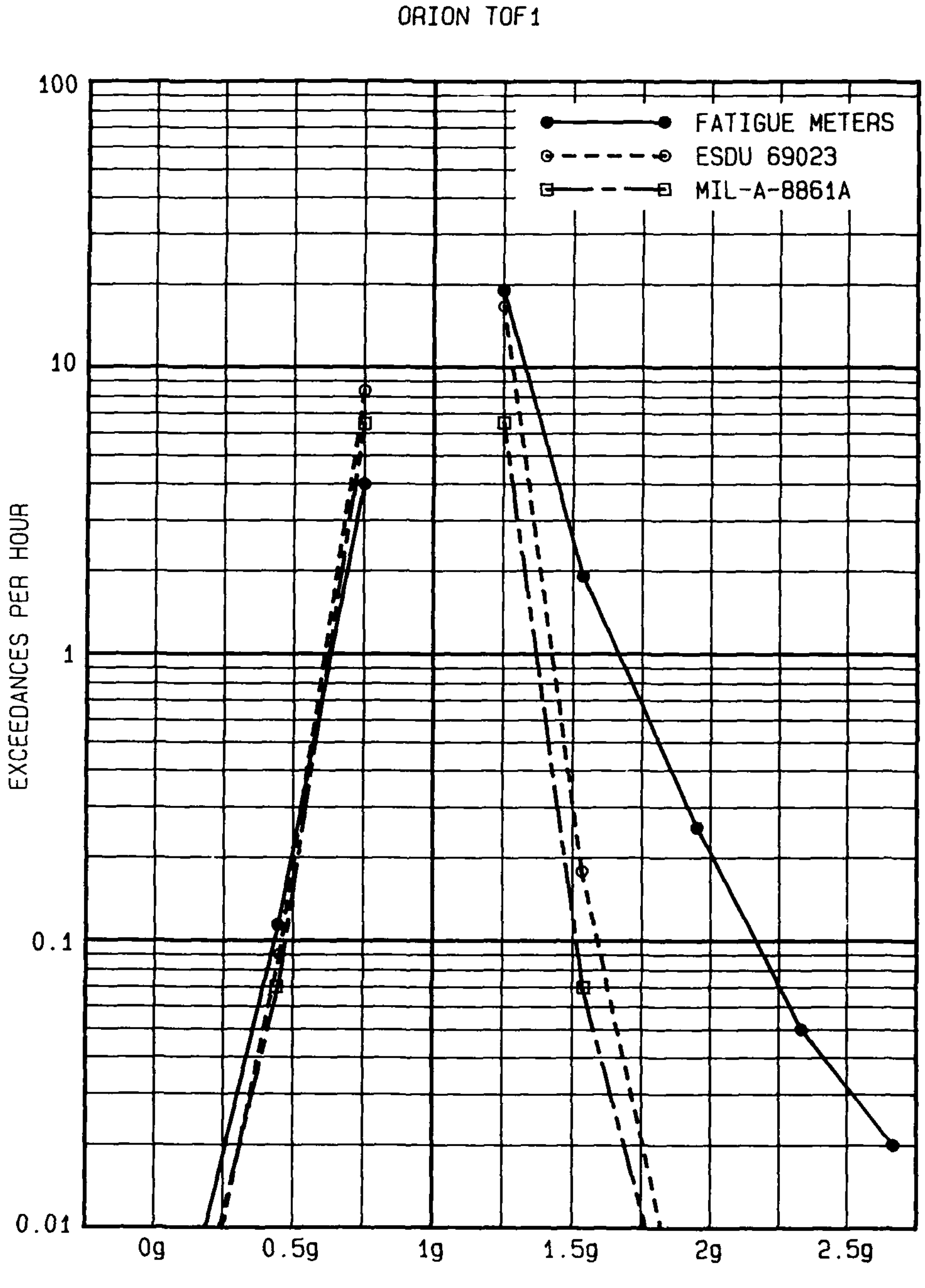


FIGURE 9 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 1

ORION TOF2

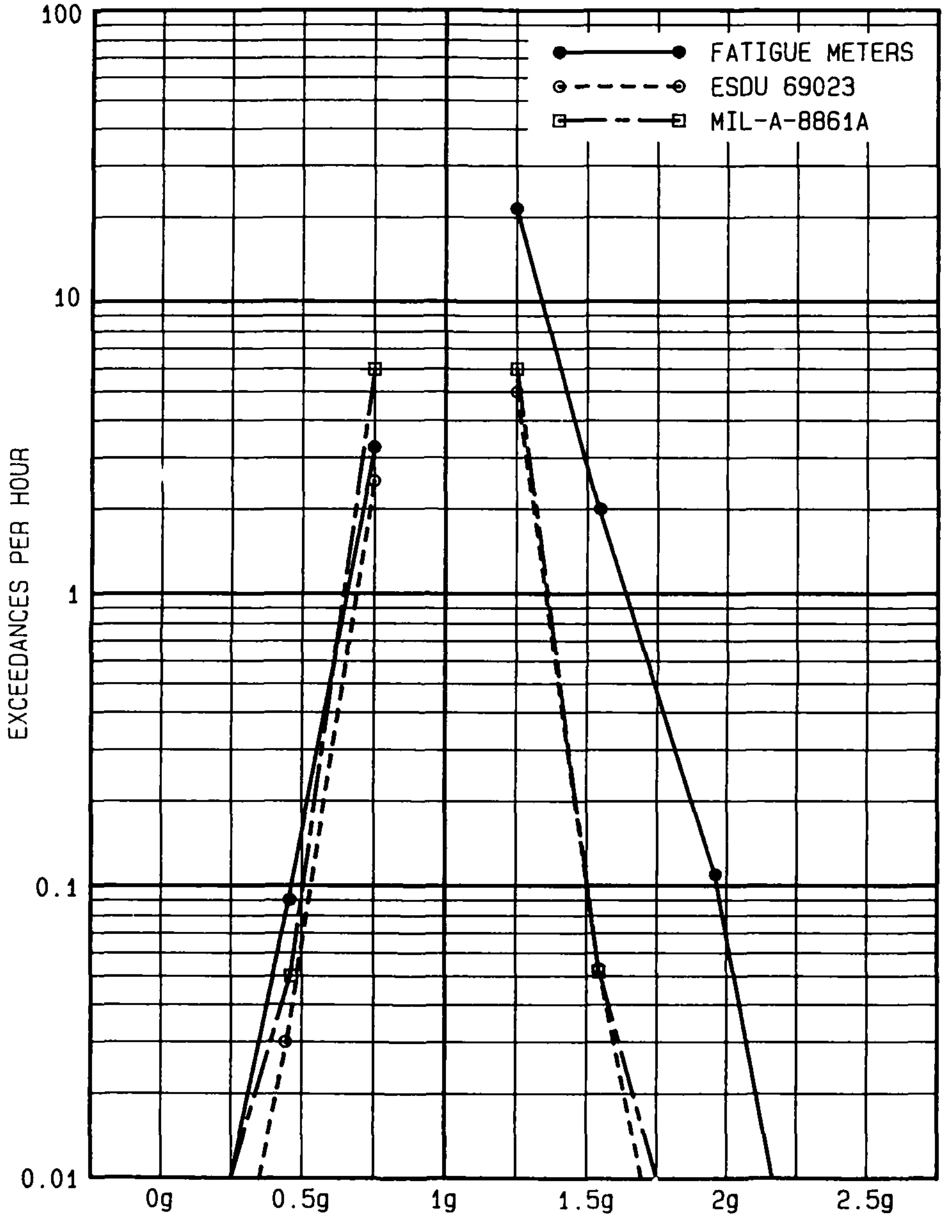


FIGURE 10 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 2

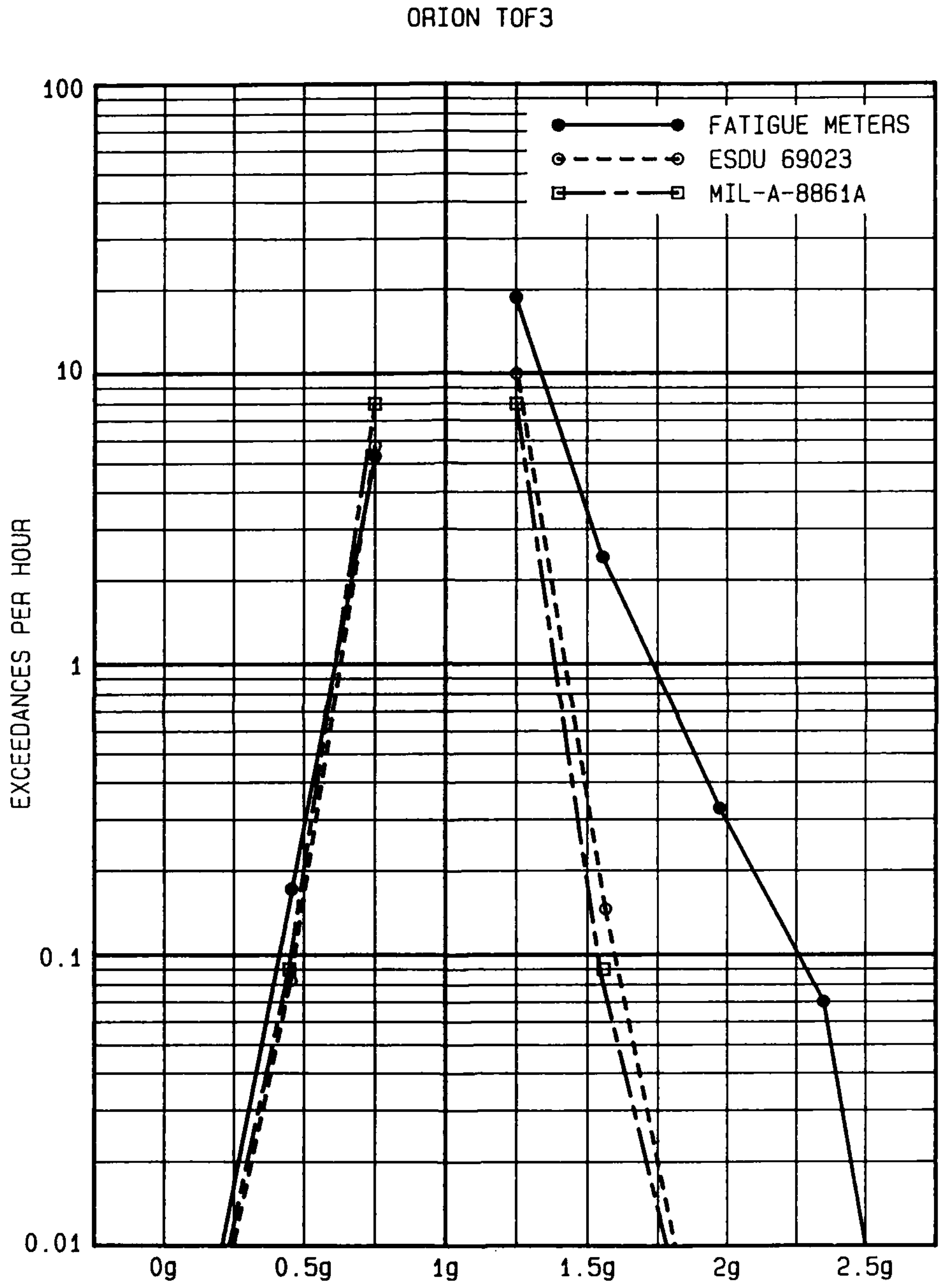


FIGURE 11 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 3

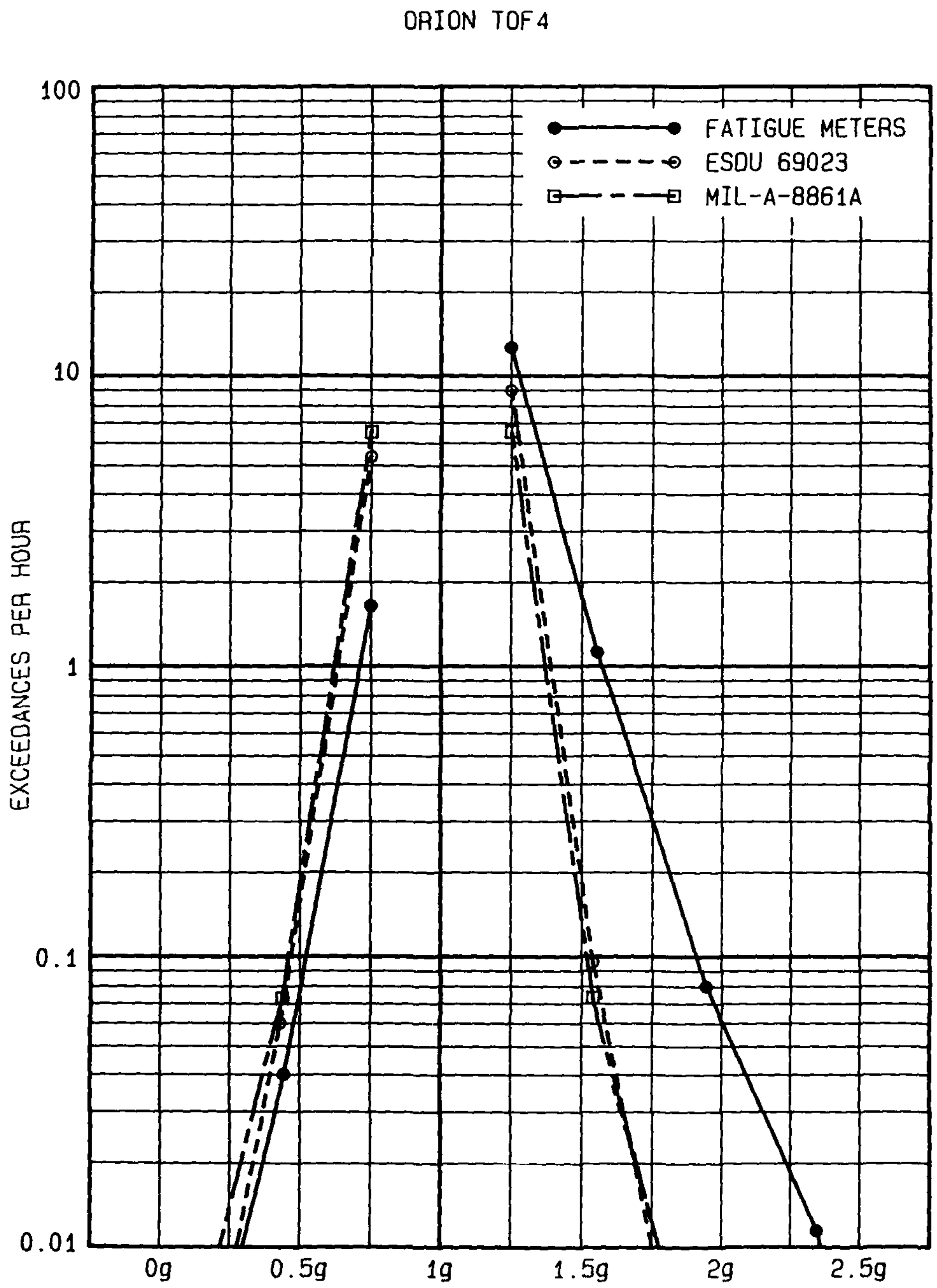


FIGURE 12 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 4

ORION TOF5

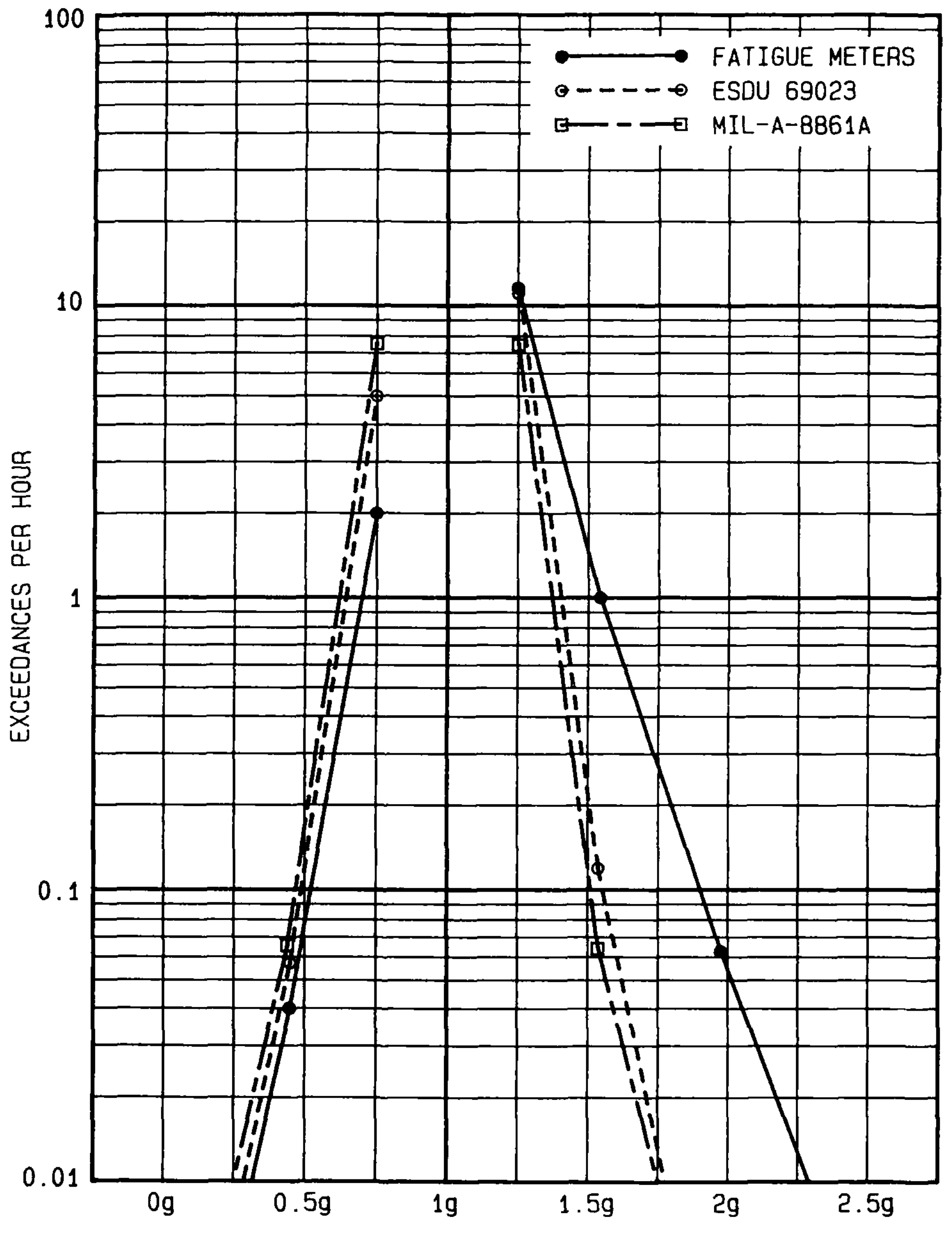


FIGURE 13 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 5

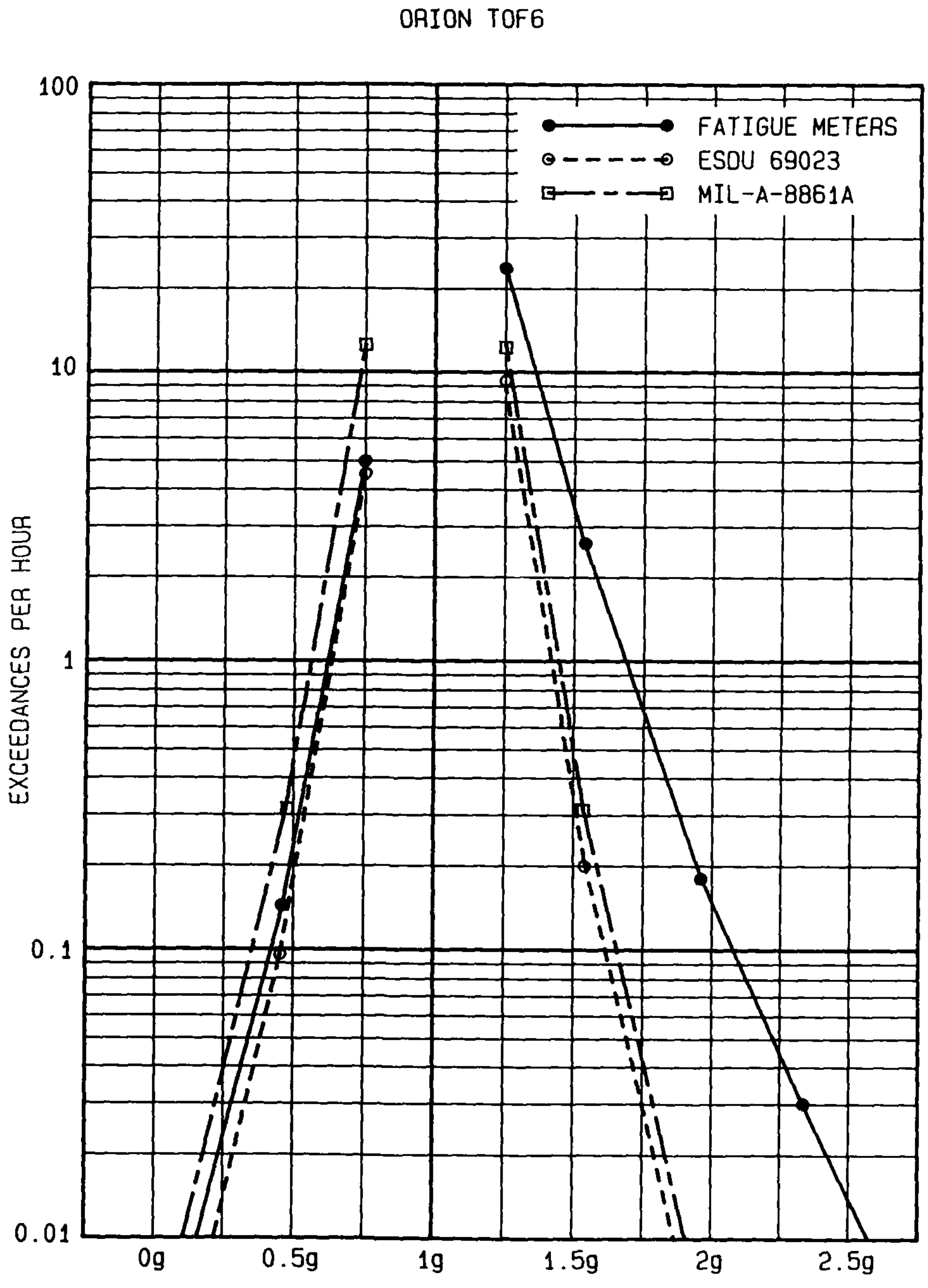


FIGURE 14 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 6

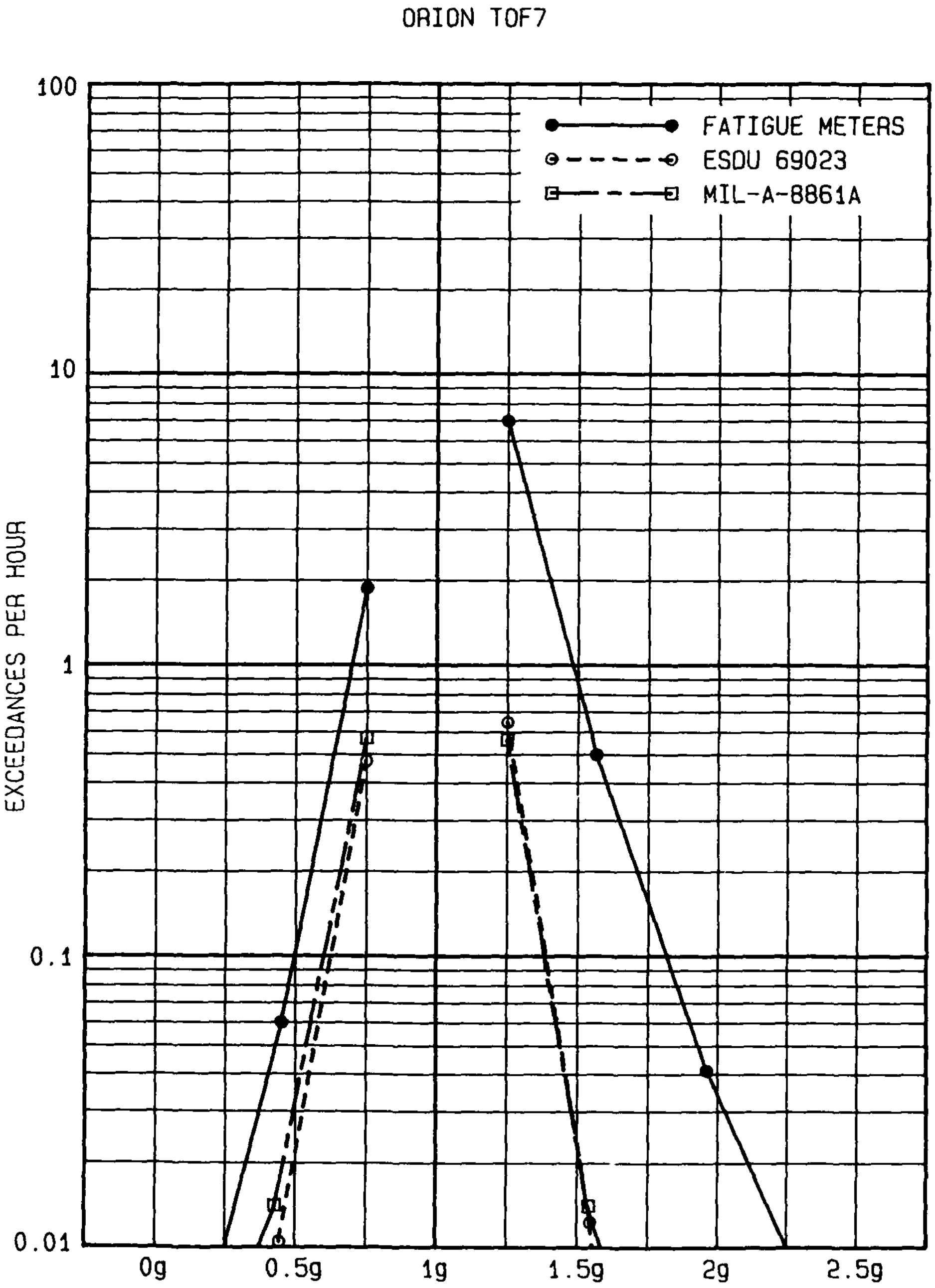


FIGURE 15 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 7

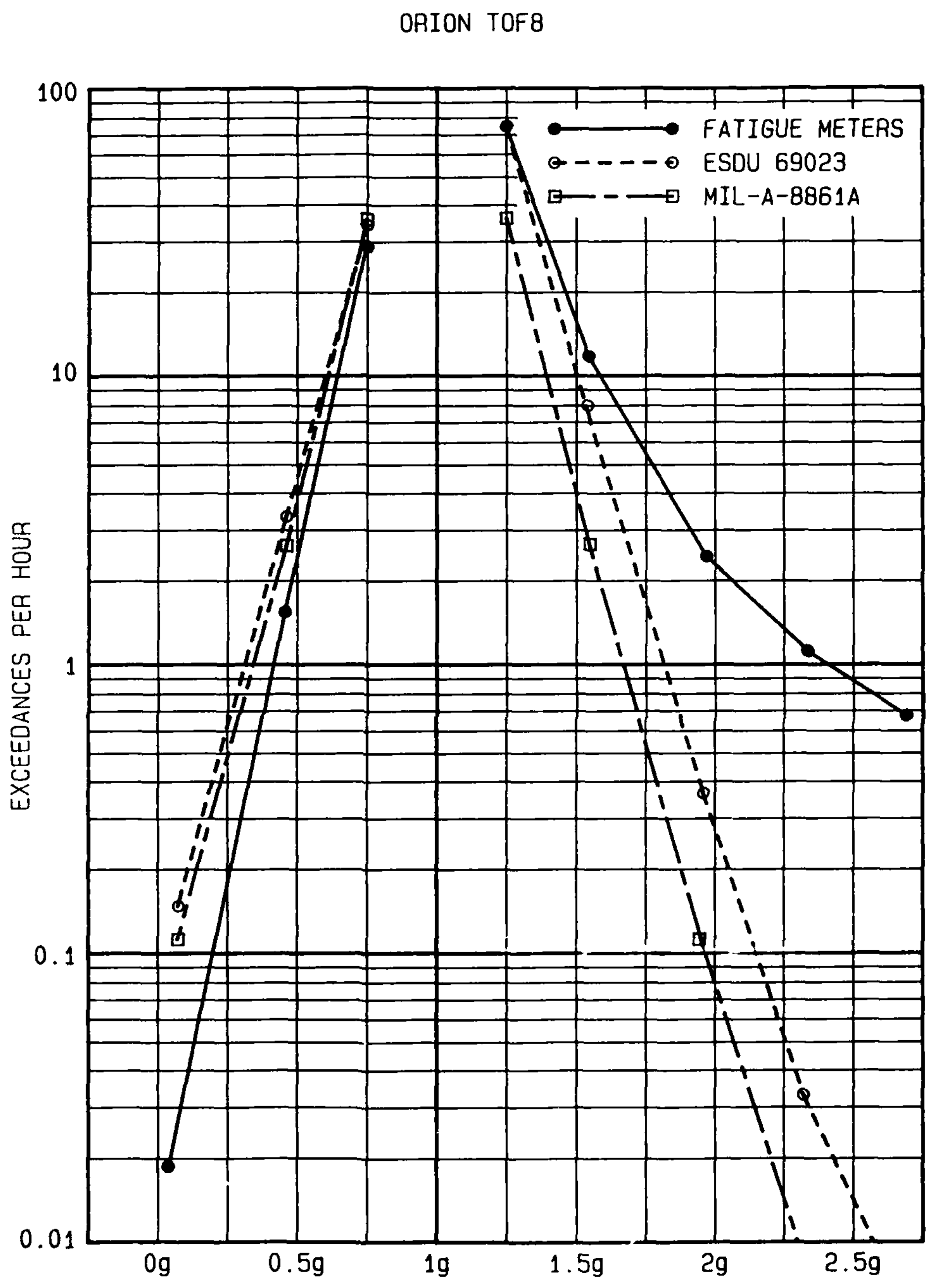


FIGURE 16 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR TYPE OF FLYING 8

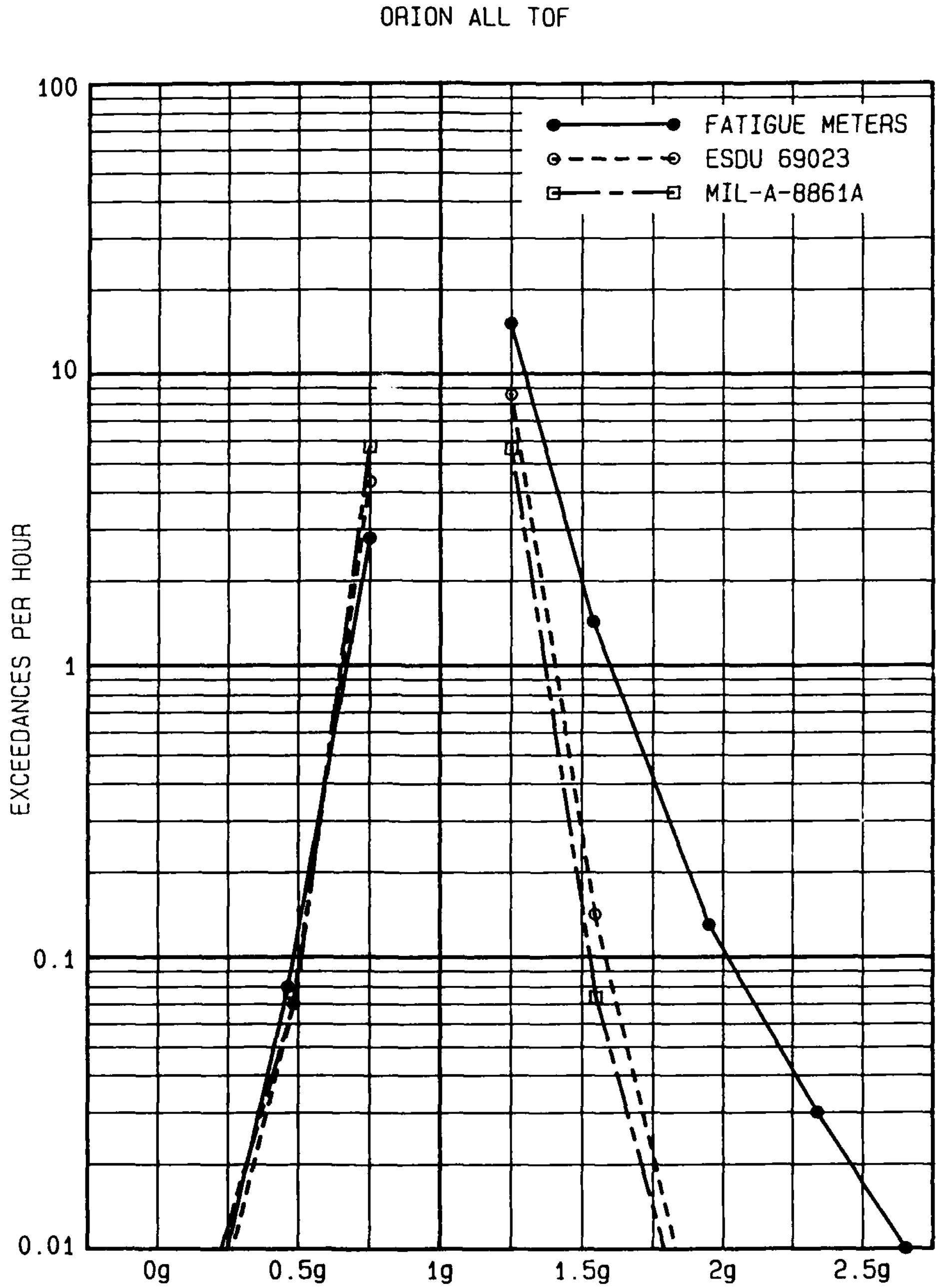


FIGURE 17 RAAF ORION LOAD SPECTRA OBSERVED BY FATIGUE METERS AND PREDICTED BY ESDU 69023 AND MIL-A-8861A MODELS FOR ALL TYPES OF FLYING

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Load spectra for the Australian fleet of Orion P-3C aircraft are presented and compared with the ESDU 69023 (discrete gust) and the US MILSPEC A-8861A (power spectral) model, which are here called the baseline models. The turbulence experienced when flying over the sea is about one half of that predicted by the baseline models. The sea appears to reduce the turbulence by a greater amount, and to higher altitudes than indicated by the ESDU model. Transit flights, which involve flying at relatively high altitude over Australia, are about five times as severe as predicted by the baseline models. This supports other observations of a higher than normal incidence of high altitude turbulence (25,000 ft and above) over Australia.

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