Success Probability Analysis For Shuttle Based Microgravity Experiments

Results of Data Analysis

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INTRODUCTION

Presented in this report are the results of data analysis of shuttle-based microgravity flight experiments. Potential factors were identified in the previous grant period, and in this period 26 factors were selected for data analysis. In this project, the degree of success was developed and used as the performance measure.

293 of the 391 experiments in Lewis Research Center Microgravity Database were assigned degrees of success. The frequency analysis and the analysis of variance were conducted to determine the significance of the factors that effect the experiment success.

PERFORMANCE INFLUENCING FACTORS

Thaggard and Morilak (1993) compiled a list of 32 experiment and mission specific factors. For this data analysis, 26 factors were included. Modification to the original list of factors were made through the course of this study as investigators found that some data were unavailable and that some factors were redundant. Table 1.a and 1.b shows the selected factors and their explanations.

Table 1.a Performance Influencing Factors

Active	Requires crew involvement or is automated.
Altitude Requested	Altitude requested by principal investigator for optimal experiment performance.
Experiment Location	Where the experiments are located during operation on the orbiter.
Experiment Type	Type of experiment (ex hardware/instruments, biological).
Failure Detection	Where problem was detected (on-orbiter or post flight).
Inclination Requested	Inclination requested by principal investigator for optimal performance.
Interface	Service provided by the orbiter which the experiment incorporates into its design.
Iteration	Number of times the experiment has been executed on the orbit.
Level of Ground Crew Involvement	An estimate of the number of hours an orbital crew member works with an experiment divided by the experiment's total time of operation.
Level of Orbital Crew	An estimate of the number of hours a ground crew member can influence experimental operation divided by the experiment's total time of operation.
Minimum Time On-Orbit	The time the principal investigator felt was needed to run an experiment.
Number of Lockers	Number of lockers occupied by the experiment during operation.
Organization	Group which developed experiment.
Storage Location	Where the experiment was stored on-orbit prior to operation.
Type of Orbital Crew Involvement	Lists specific activities required for experiment operation.

Table 1.b Performance Influencing Factors

Crew Size	Number of crew members for a particular mission.
Flight Altitude	Altitude for a particular mission.
Flight Duration	Duration of a particular mission.
Launch Delay Cause	Examples: weather, orbiter.
Launch Delay Duration	Hours
Number of Experiments On-board	Number of experiments for a particular mission.
Orbiter Pad Weather	Weather at time of launch.
Time Between Previous Flight	Time between previous shuttle mission.
Wait Time on Pad	Includes loading time and delays
orbiter	Examples: Columbia, Challenger

PERFORMANCE MEASURE

The performance measure, the dependent variable, selected in this project was the degree of success (DoS) which incorporated many definitions form previous studies (Ridenoure, 1986; Winter and Jones, 1992). The scale for DoS in Table 2 was based on the following criteria: (1) objectives, (2) results, (3) problems encountered and (4) the minimum success requirement, achieving at least one objective.

Based on these criteria, an experiment that achieved the full objective without any problems would receive a ranking of "9". Similarly, an experiment that achieved the full objective without any problems, and also obtained data beyond the full objective would receive a "10". On the other hand, an experiment that was not attempted at all would receive a "1" or "2" depending on whether problems were related to design. An experiment would receive "1" for a design problem. Despite the subjective nature of the DoS scale, the numerical definition of experimental success offers opportunities for statistical analysis which non-continuous, categorical definitions cannot provide.

Table 2 Degrees of Success Scale

Worst	1,2	Test not attempted.
	3	Full objective not achieved. Minimum success requirements not achieved.
	4	Full objective not achieved. Minimum success requirements not achieved. Some data.
	5	Full objective not achieved. Minimum success requirements obtained. Problems encountered. (Related to design.)
	6,7	Full objective not achieved. More than minimum success requirements obtained. Problems encountered. (Not related to design.)
	8	Full objective achieved. Problems encountered.
	9	Full objective achieved. No problems.
	10	Full objective achieved.
Best		No problems. Additional results.

STATISTICAL ANALYSIS

293 of the 391 experiments in Lewis Research Center Microgravity Database (LMDB) were assigned DoS rankings. The frequency analysis and the analysis of variance were conducted to determine the significance of the factors that effect the experiment success. The General Linear Model procedure in SPSS/PC+ Version 5.0 was used to perform the analysis of variance. Table 3 shows four factors, Failure Detection, Active, Altitude Requested and Experimental Type, are significant at 0.01 level (99 percent confidence). Three factors, Level of Ground Crew Involvement, Minimum Time On-Orbit and Storage Location, are at .05 level and Level of Orbital Crew Involvement and Orbiter Pad weather at .1 level (90 percent confidence). All interactions between factors are not significant at .05.

The frequency of each DoS ranking is shown in Table 4 and Figure 1. Approximately 44% of the experiments are ranked 9, and 22% percent are ranked "8". Including the experiments ranked 10, above 70 % of the experiments achieved their full objectives. Approximately 8% of the experiments, ranked 1, 2, 3 and 4, did not meet their minimum success requirements.

Tables 5 to 13 and Figures 2 to 10 present the frequency counts and average DoS rankings for levels of each significant factor.

Table 3 Analysis of Variance Table

Factor	Degree of Freedom	Significance Level
Failure Detection	3	.0001
Active	1	.003
Altitude Requested	9	.008
Experiment Type	9	.01
Level of Ground Crew Involvement	3	.018
Minimum Time On-Orbit	7	0.025
Storage Location	5	.044
Level of Orbital Crew Involvement	3	.091
Orbiter Pad Weather	4	.094
Launch Delay Cause	3	.232
Orbiter	4	.255
Wait Time on Pad	19	.261
Launch Delay Duration	3	.312
Flight Altitude	21	.362
Interface	8	.407
Time between Previous Flight	28	.413
Flight Duration	8	.440
Number of Experiments On-Board	17	.470
Number of Lockers	7	.597
Type of Orbital Crew Involvement	28	.677
Experiment Location	10	.833
Inclination Requested	5	.868
Flight Inclination	6	.880
Iteration	8	.907
Organization	5	.946
Crew Size	5	.959

Table 4 Frequency of DoS Rankings

1	1	0.3
2	1	0.3
3	5	1.7
4	16	5.5
5	24	8.2
6	18	6.1
7	27	9.2
8	63	21.5
9	128	43.7
10	10	3.4

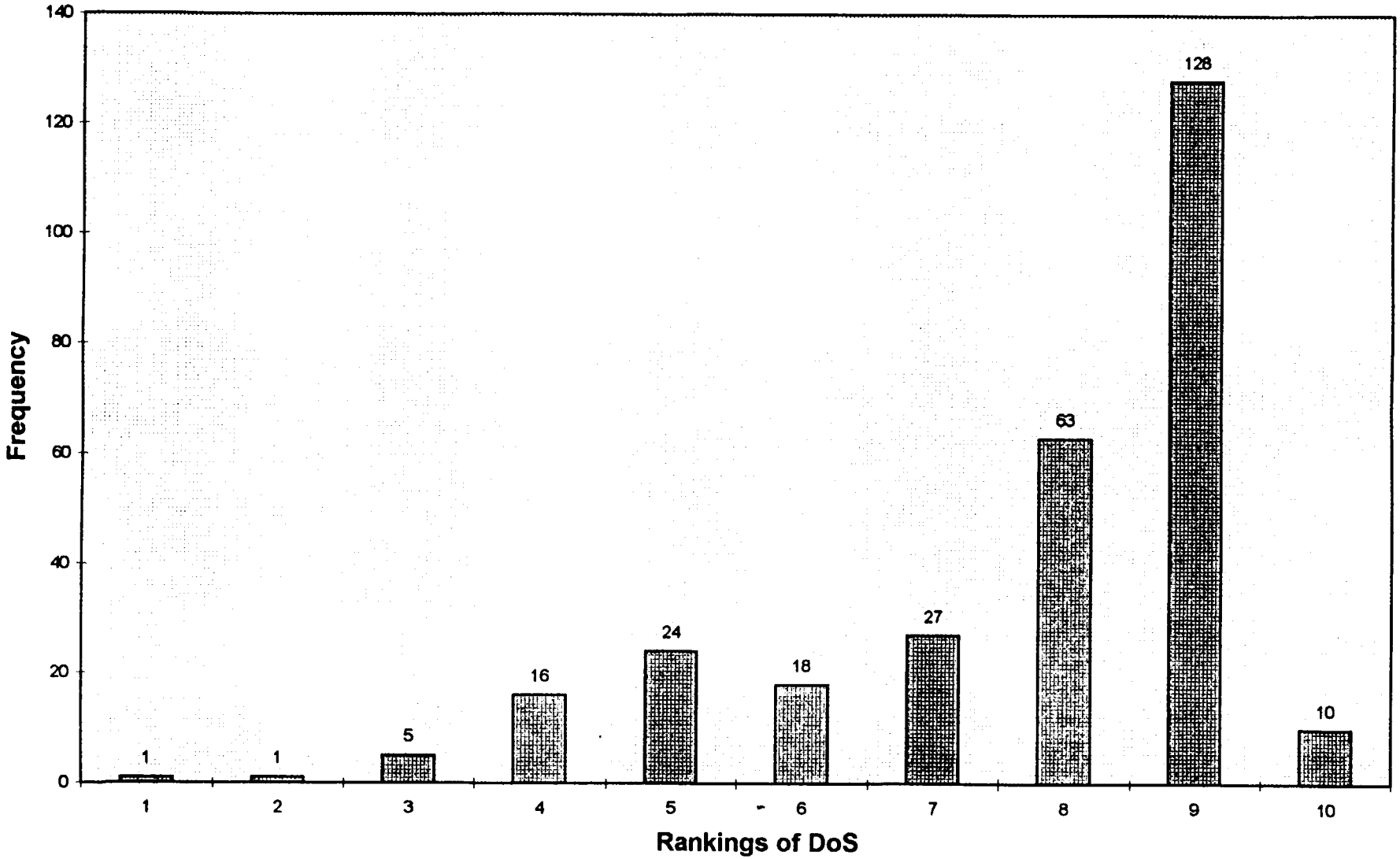

Frequency of DoS Rankings
Frequency
140
120
100
80
60
40
20
0
1
1
5
16
24
18
27
63
128
10
1
2
3
4
5
6
7
8
9
10
Rankings of DoS

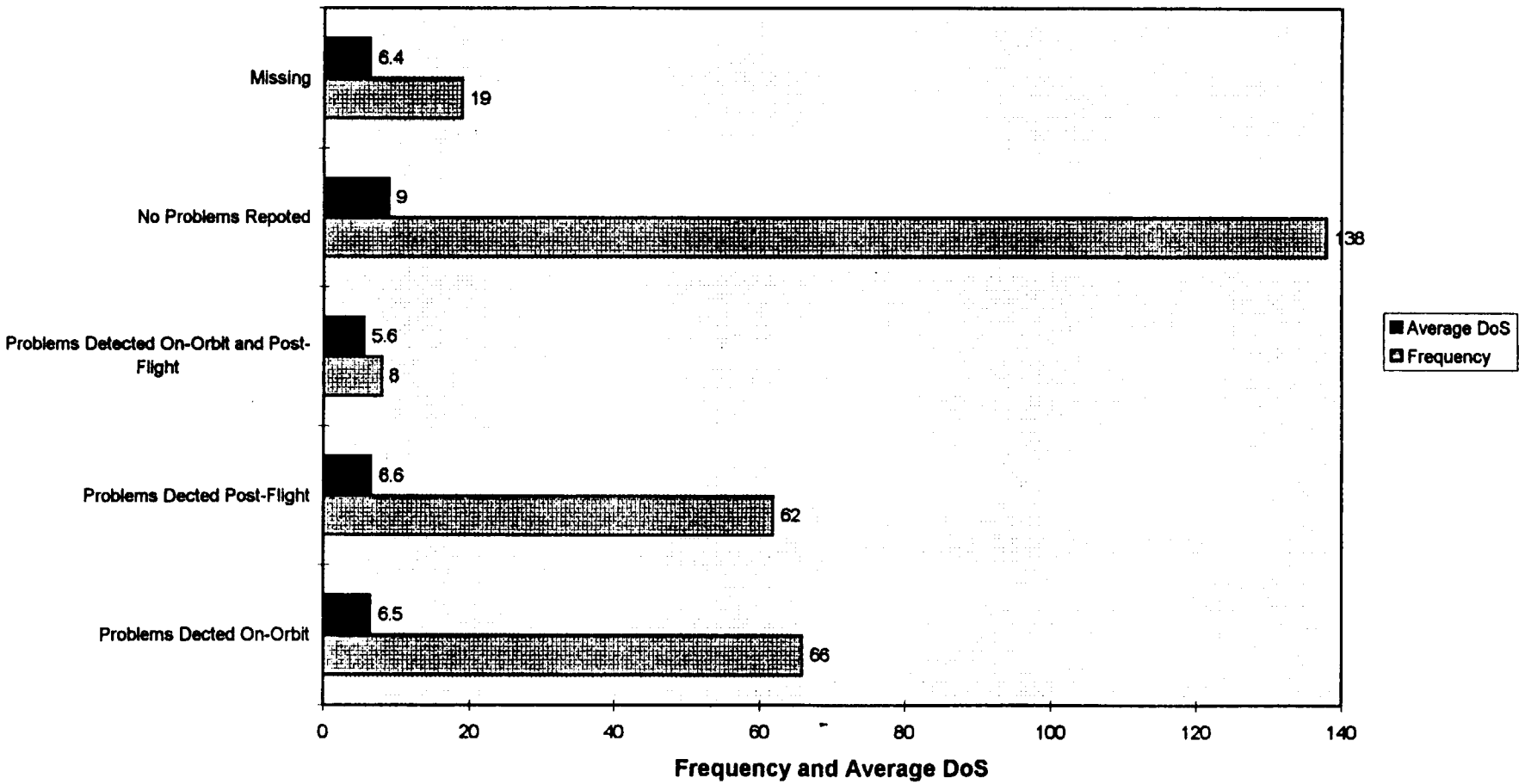
Table 5 Frequency and Average DoS for Failure Detection

Problem Detected On-orbit	66	6.5
Problem Detected Post-flight	62	6.6
Problem Detected On-orbit and Post-flight	8	5.6
No Problems Reported	138	9.0
Missing	19	6.4

Table 6 Frequency and Average DoS for Active

Passive	34	8.5
Active	259	7.6

Frequency and Average DoS for Failure Detection



Frequency and Average DoS for Crew Involvement

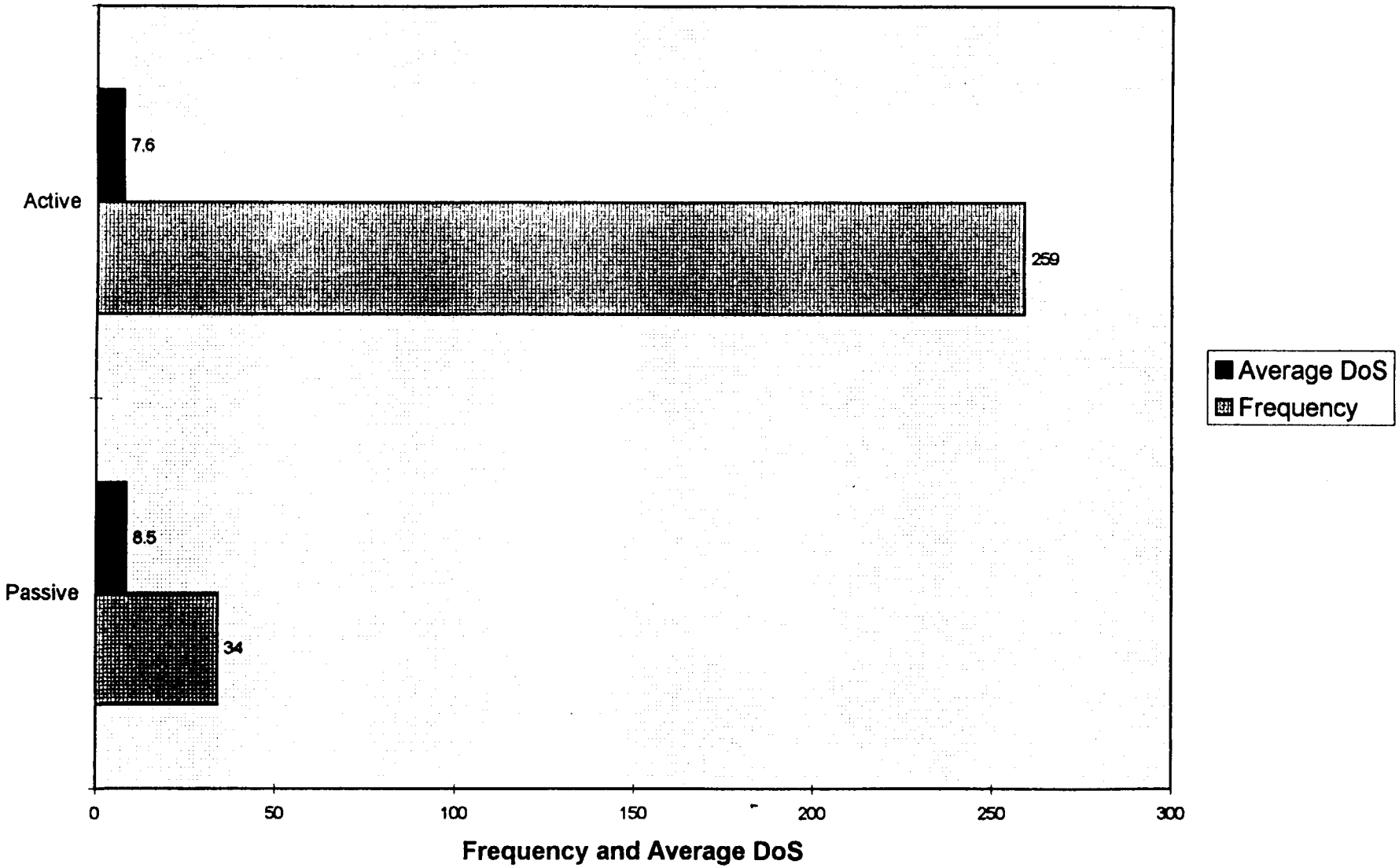


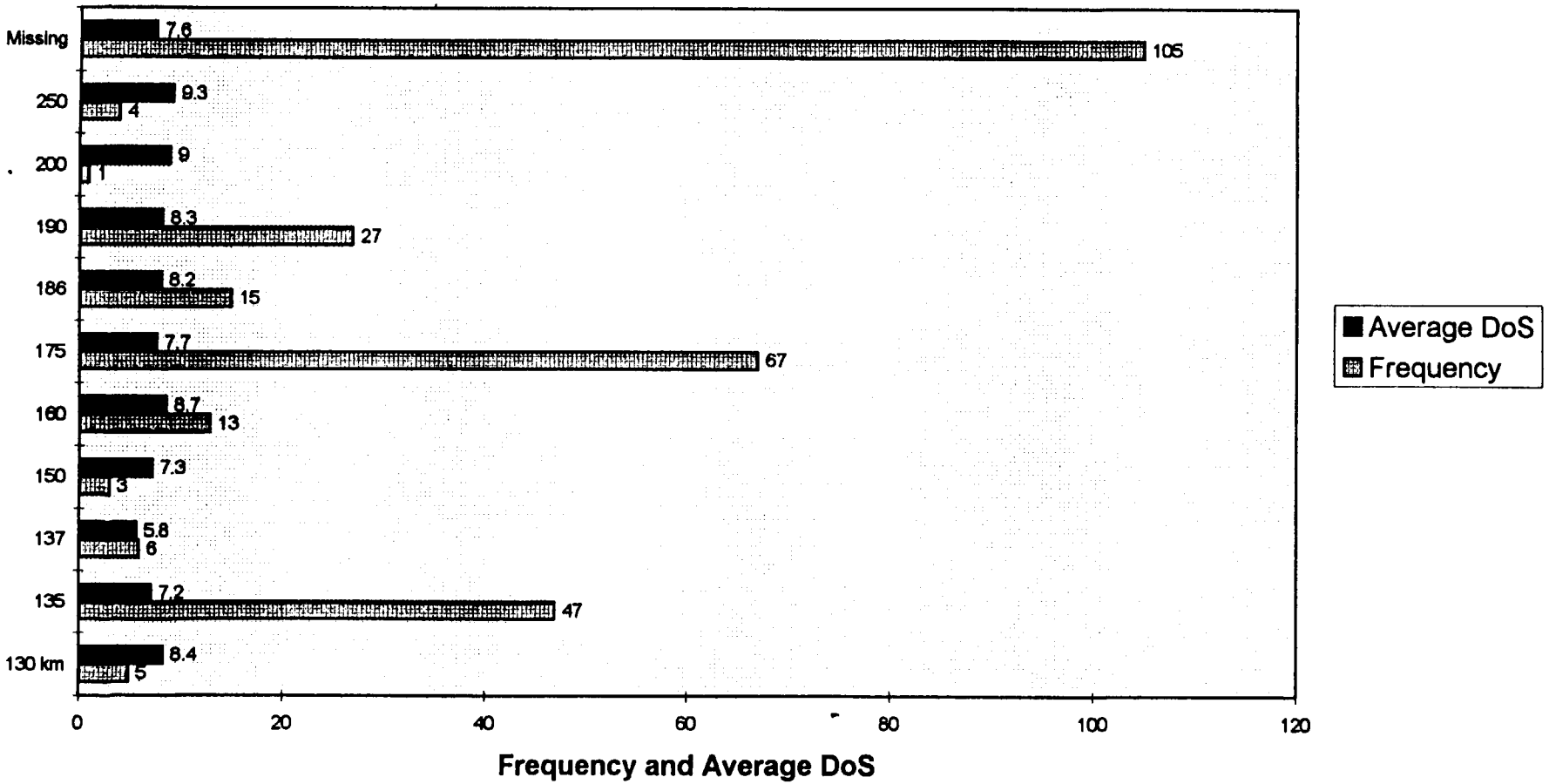
Table 7 Frequency and Average DoS for Altitude Requested

130 km	5	8.4
135	47	7.2
137	6	5.8
150	3	7.3
160	13	8.7
175	67	7.7
186	15	8.2
190	27	8.3
200	1	9.0
250	4	9.3
Missing	105	7.6

Table 8 Frequency and Average DoS for Experiment Type

Hardware/Instruments	16	7.3
Metals/Alloys	44	6.9
Biological	69	8.2
Fluids & Chemicals	37	7.6
Environments	13	8.5
Crystal Growth/Crystallography	33	7.2
Astronomy	17	7.9
Photography	11	7.9
Radiation	13	8.0
Other	40	7.7

Frequency and Average DoS for Altitute Requested



Frequency and Average DoS for Experiment Types

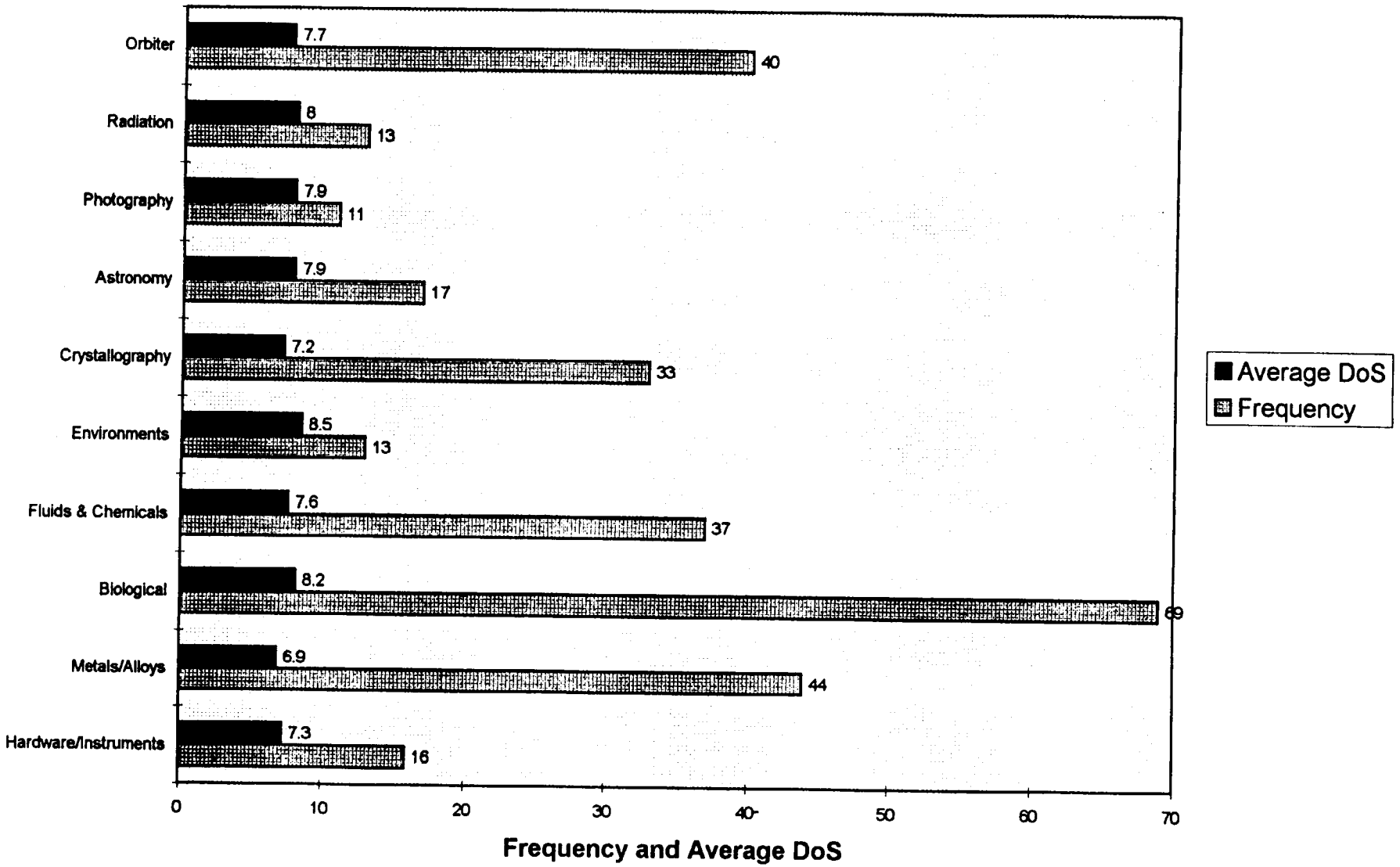


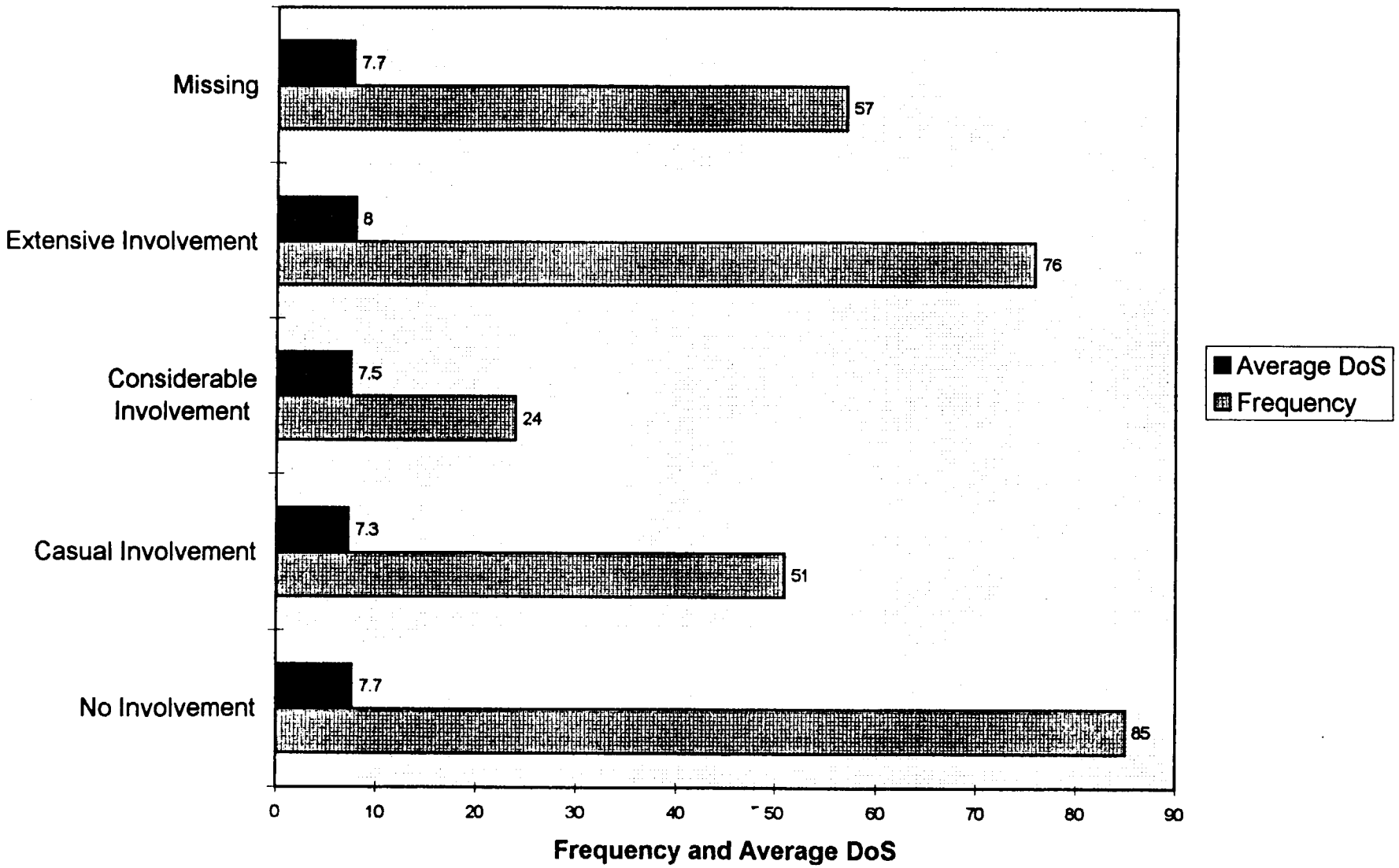
Table 9 Frequency and Average DoS for Level of Orbital Crew Involvement

Level	Frequency	Average Degree of Severity
No Involvement	85	7.7
Casual Involvement	51	7.3
Considerable Involvement	24	7.5
Extensive Involvement	76	8.0
Missing	57	7.7

Table 10 Frequency and Average DoS for Level of Ground Crew Involvement

Level	Frequency	Average Degree of Severity
No Involvement	173	7.7
Casual Involvement	36	8.1
Considerable Involvement	20	6.6
Extensive Involvement	9	8.2
Missing	55	7.7

Frequency and Average DoS for Level of Orbital Crew Involvement



Frequency and Average DoS for Level of Ground Crew Involvement

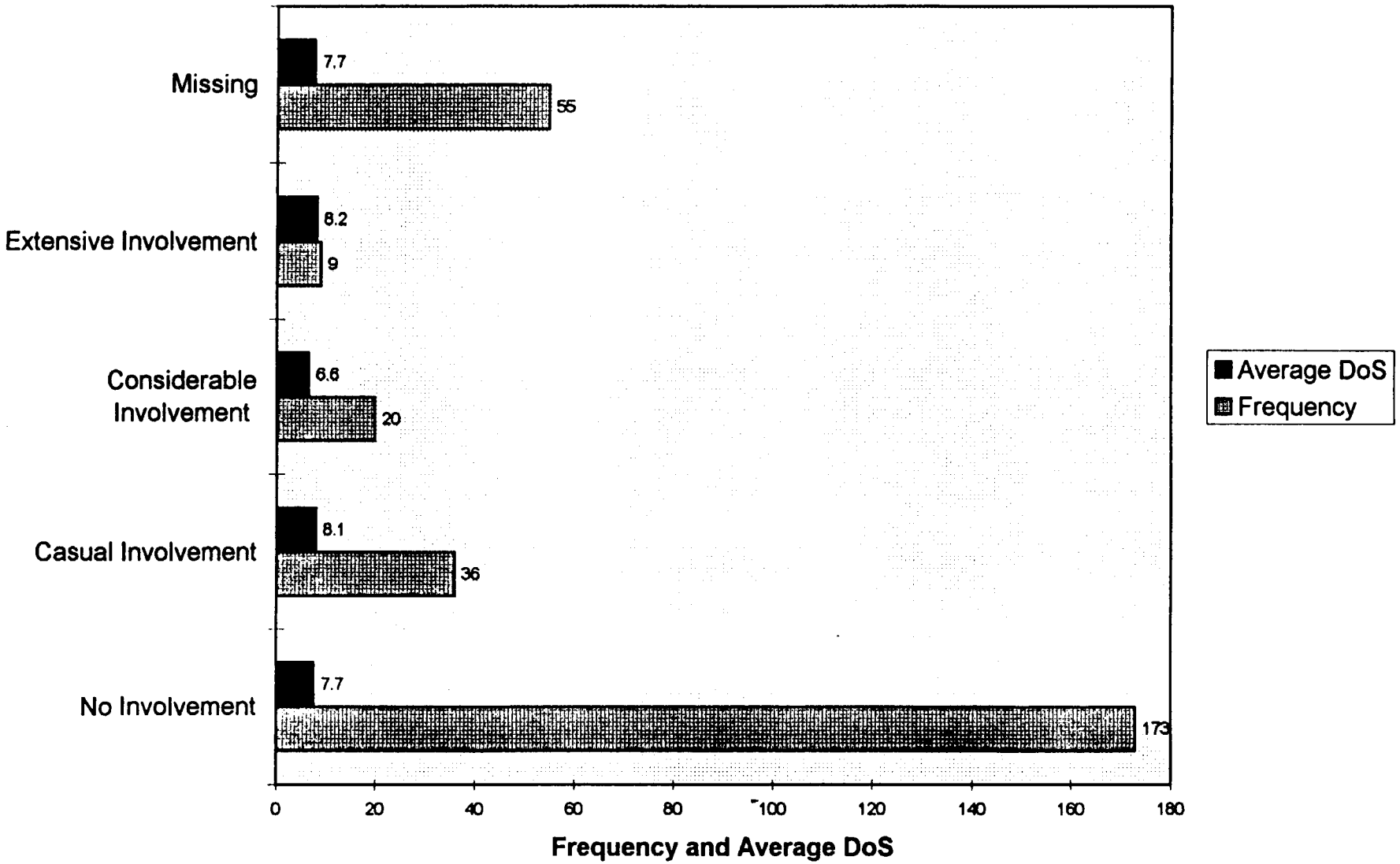
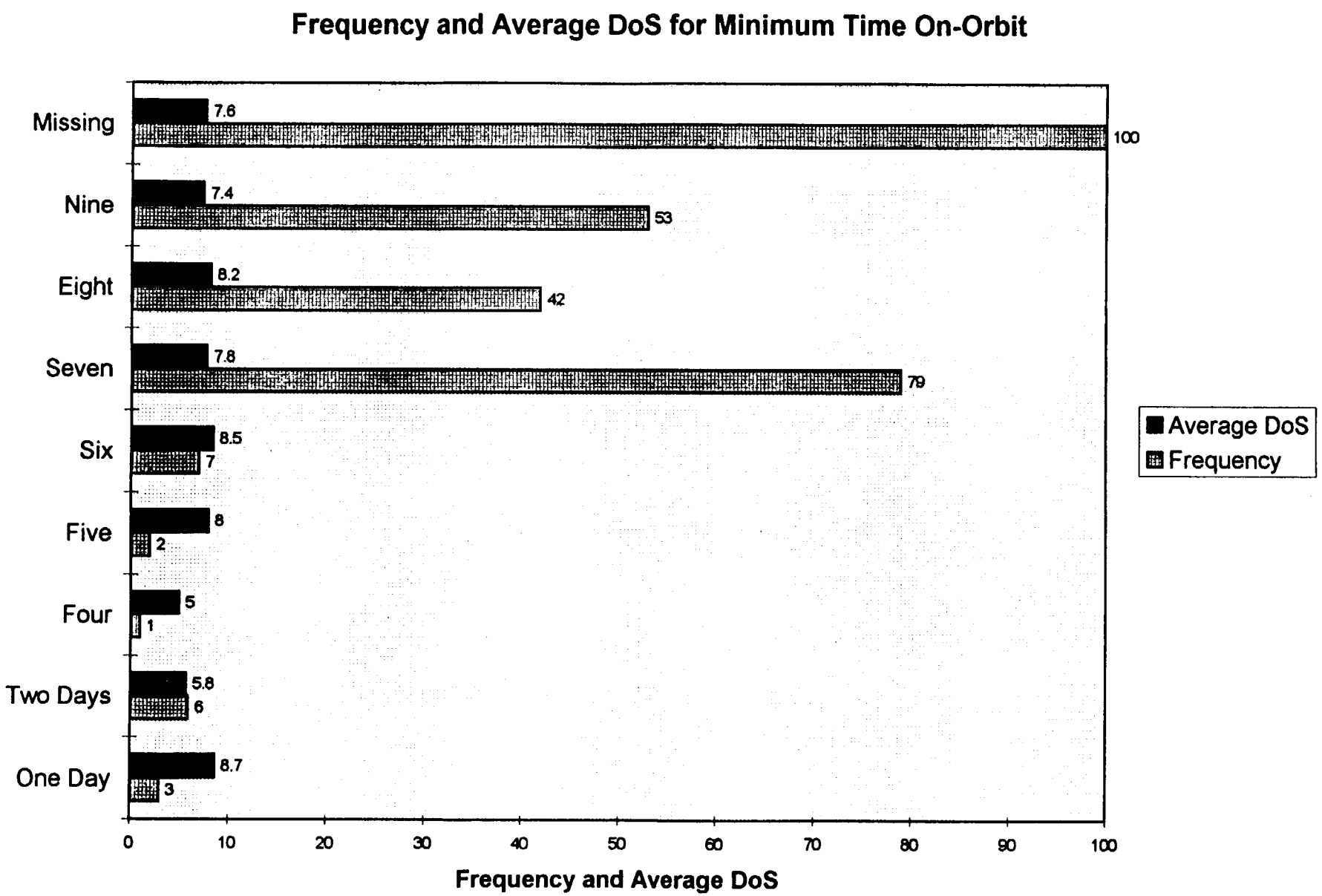


Table 11 Frequency and Average DoS for Minimum Time On-Orbit

One day	3	8.7
Two	6	5.8
Four	1	5.0
Five	2	8.0
Six	7	8.5
Seven	79	7.8
Eight	42	8.2
Nine	53	7.4
Missing	100	7.6

Table 12 Frequency and Average DoS for Storage Location

Locker	73	7.4
Rack	45	7.2
Pallet	5	8.4
Self-Contained	58	8.1
Other	17	7.6
Not Applicable	11	8.3
Missing	84	7.8


Frequency and Average DoS for Minimum Time On-Orbit
Missing
Nine
Eight
Seven
Six
Five
Four
Two Days
One Day
7.6
100
7.4
53
8.2
42
7.8
79
8.5
7
8
2
5
1
5.8
6
8.7
3
0
10
20
30
40
50
60
70
80
90
100
Frequency and Average DoS
Average DoS
Frequency

Frequency and Average DoS for Storage Location

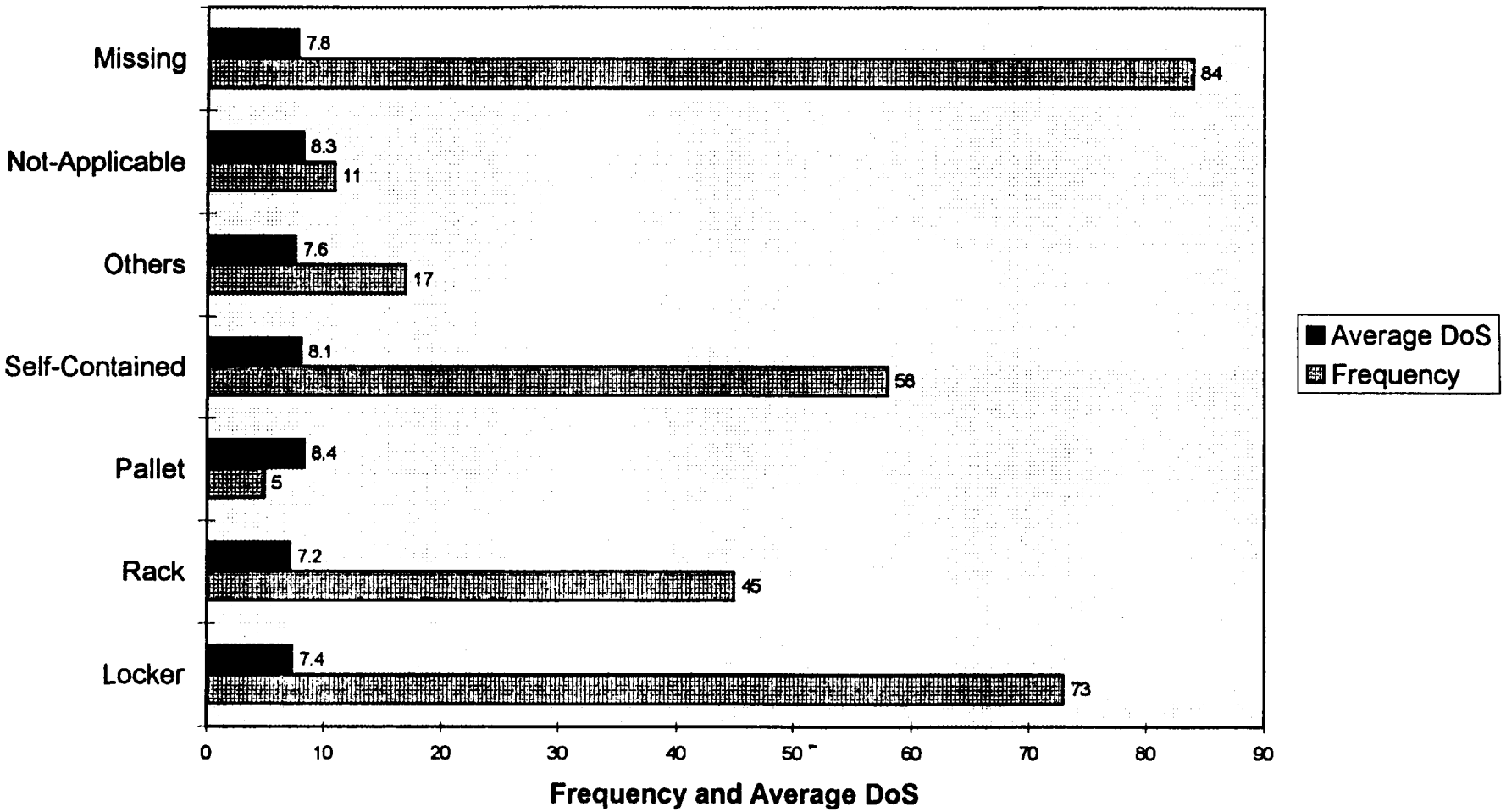
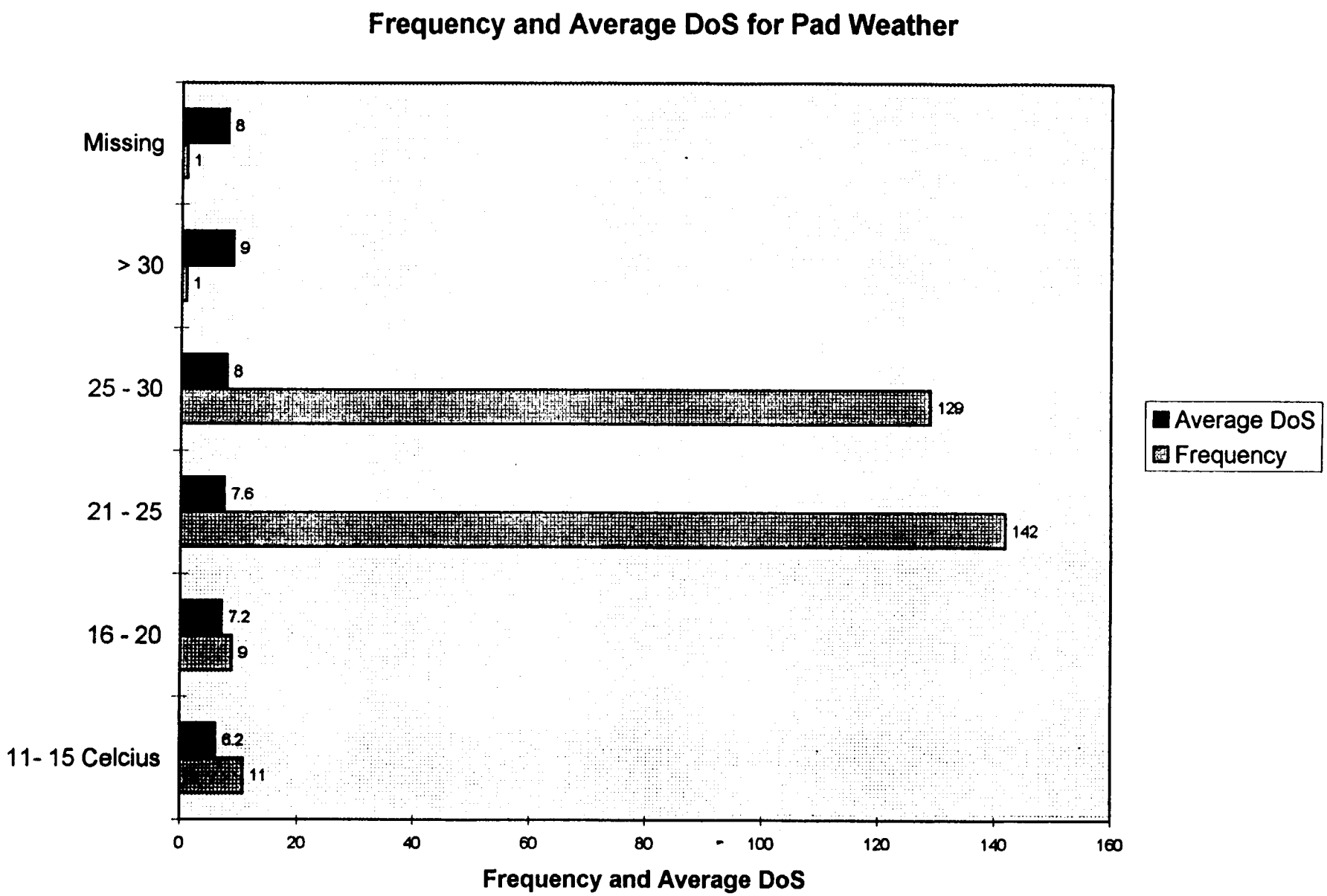


Table 13 Frequency and Average DoS for Pad Weather

11 °C - 15 °C	11	6.18
16 °C - 20 °C	9	7.2
21 °C - 25 °C	142	7.6
26 °C - 30 °C	129	7.95
> 30 °C	1	9
Missing	1	8


Frequency and Average DoS for Pad Weather
Missing
> 30
25 - 30
21 - 25
16 - 20
11- 15 Celcius
8
1
9
1
8
129
7.6
142
7.2
9
6.2
11
0
20
40
60
80
100
120
140
160
Frequency and Average DoS
Average DoS
Frequency

CONCLUSIONS

This study presents an approach to identify factors that significantly influence experiment performance. Investigators developed a Degree of Success (Dos)scale to provide a numerical representation of success. Subsequently, a Dos ranking was assigned to 293 microgravity flight experiments. 26 factors were selected for data analysis. Of these factors, 9 significant factors were identified using the analysis of variance.

This study has used the DoS scale to successfully identify significant factors. The future plan for this study is to extend the results of the present data analysis by providing an optimal level for each factor and a predictor model of experimental performance. This information will enhance the design and development of future microgravity flight experiments.