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AGRICULTURAL AVIATION USER REQUIREMENT PRIORITIES

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16. Abstract

Reported herein are the results of a research project that has as its purpose the development of agricultural aviation user requirement priorities. The work was performed for the Langley Research Center of the National Aeronautics and Space Administration under Contract Number NAS1-14758. The raw data utilized in the project was obtained from the National Agricultural Aviation Association. A specially configured poll, developed by the Actuarial Research Corporation was used to solicit responses from NAAA members and others.

The primary product of the poll is the specification of seriousness as determined by the respondents for some selected agricultural aviation problem areas identified and defined during the course of an intensive analysis by the Actuarial Research Corporation.

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TABLE OF CONTENTS

I INTRODUCTION

A. Purpose 1
B. Report Contents 1

II THE PROBLEM

A. Background 3
B. Problem Areas 4
C. Approach 7

III SUMMARY OF RESULTS

A. General 9
B. Tabulations 9
C. Problem Priorities 15
D. Group Comparisons 19

IV APPLICATIONS

A. General 27
B. Weighting Factor Relationships 27
C. Generic Packaging 29

V CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions 32
B. Recommendations 32

References 33

APPENDIX A. The Magnitude Estimation Scaling Procedure A-1

APPENDIX B. Technical Approach

1. Development of the Polling Format B-1
2. Data Collection Procedures B-6
3. Data Analysis Procedures B-8

Annex 1. Definitions of the Problem Statements B-17
Annex 2. Polling Format Instructions and Typical Listing of Problem Statements B-22
Annex 3. Polling Format Biographical Questionnaire B-27

TABLES

I	Summary of Responses	9
II	Response Sources	10
III	Occupational Categorization of Respondents	11
IV	Distribution of Crop Servicing	14
V	Other Services Performed	14
VI	Problem Area Weights Based on all Respondents	16
VII	Generic "Packaging" of Problem Areas	31
B-I	Summary of Booklet and Reference Item Distribution	B-9
B-II	Item Order of the Problem Statements in the Test Booklets	B-26

FIGURES

1	Distribution of Respondent Agricultural Aviation Experience	12
2	Distribution of Respondent Agricultural Flight Hours	13
3	Ag Aviation Problem Priorities	17
4	Comparison of Group Responses - Occupational Categories	20
5	Comparison of Group Responses - Operators of A/C under 4500 lbs. GW and 4500-1200 lbs. GW	22
6	Comparison of Group Responses - Wheat, Cotton and Rice Applicators	24
7	Comparison of Group Responses - Fixed-Wing and Helicopter Operators	25
8	Research Task Cost Assessment	28
9	Generic "Packaging"	30
B-1	Functional Categorization	B-3
B-2	Total Flight Hours	B-11
B-3	Display of Ag Flight Hours vs Years of Experience	B-12
B-4	Display of Ag Flight Hours vs Years of Experience, Pilots Only	B-13

I. INTRODUCTION

A. Purpose

Reported herein are the results of a research project that has as its purpose the development of agricultural aviation user requirement priorities. The work was performed for the Langley Research Center of the National Aeronautics and Space Administration (NASA) under Contract Number NAS 1-4758. The raw data utilized in the project was obtained from the National Agricultural Aviation Association (NAAA). A specially configured poll, developed by the Actuarial Research Corporation was used to solicit responses from NAAA members and others.

The results of this study are unique in that the priorities:

1. Represent a synthesis of the primary technical problems affecting agricultural aviation operations;

2. Reflect the collective perceptions of a sizeable body of the agricultural aviation industry's primary operating or user segment, i.e., the aerial application service owner/operators and pilots;

3. Are expressed as quantitative, relative weighting factors; and

4. Have been derived by the application of a mathematically defensible, psychometric polling technique, Magnitude-Estimation Scaling (MAG-ES).

The weighting of the priorities provides greatly increased sensitivity in identifying significant problem areas and in allocating research resources. Remedial research programs selected on this basis should be far more responsive to the ultimate beneficiary, the agricultural aviation community.

B. Report Contents

The main body of this report contains three primary sections:

1. SECTION II - The Problem

The background and the rationale underlying the survey are discussed in detail.

2. SECTION III - Summary of Results

The results of the survey are summarized and analyzed. Where appropriate, the significance of the findings are noted and explained. Included are tabulations indicating the number and sources of the survey responses, as well as data describing the collective qualifications of the respondents.

3. SECTION III - Applications

Instructions relative to interpreting and utilizing the information are presented.

II. THE PROBLEM

A. Background

That agricultural aviation (Ag Avn) has made a tremendous contribution to the United States' position of preeminence in world food production goes without question. The scope of operations including the dispensing of seeds, fertilizers, insecticides, herbicides, and fungicides is of significant magnitude and is growing every year at an estimated 10 percent. (Ref. 1) In 1975 alone, for example, some two million flight hours were spent in servicing 200 million acres.[1/] (Ref. 2) On the basis of these data it has been concluded that at least "...65 percent of the nation's foodstuffs are now tended by aircraft." (Ref. 1)

Diminution of the role played by aircraft in agriculture is not expected. Burgeoning world populations, changing climatic patterns, natural disasters, etc., all portend serious global shortages of food for the foreseeable future. As the major source of agricultural products, the United States must increase farm production yields and efficiency in the years to come. The importance of agricultural aviation as a factor in meeting these future demands is generally acknowledged.

A latent problem exists, however, that may hinder the full realization of aviation's potential as an agricultural tool. The development of new systems, i.e., the aircraft, dispensing and support subsystems, has been basically one of gradual product improvement. As a result, a recognizable technological lag exists in the Ag Avn industry. Unless significant improvements can be achieved in the next decade, the ability of the industry to meet the challenge of a world-wide food crisis may be severely limited.

1/ It is estimated that only 15 percent of the nation's 350 million tillable acres are being serviced by agricultural aircraft. In view of the discrepancy the figure cited in Reference 2 probably indicates multiple applications on a much smaller amount of land. (Ref. 3)

Recognizing the problem, NASA is in the process of instituting a comprehensive research program oriented towards agricultural aircraft systems. NASA believes its vast technological resources can be applied effectively to the task of providing improvements in such areas as performance, safety, economy, functional effectivity, human factors, etc. It is anticipated that the resulting research will focus on various system elements, e.g., the dispensing equipment, in addition to the airframe and power plant.

Current activities associated with the proposed program are directed toward planning and the identification of research objectives. This study provides essential guidance and assistance in this effort.

B. Problem Areas

Research usually is initiated for the purposes of:

1. Determining the theoretical bases for unexplained phenomena,
2. Exploiting emerging technology,
3. Providing remedial solutions to identified problem areas, and/or
4. Satisfying recognized consumer or user requirements for improvements.

While the proposed NASA program presumably will be responsive to all these purposes, it is reasonable to expect that the latter will create the greatest demand for research resources. This is a logical assumption if one considers the uniqueness of a program dedicated to Ag Avn, one for which no precedent exists.

The practical recourse, therefore, is to query the user community as to what constitutes its most pressing problems. After all, it is intuitively obvious that the users are the most qualified to make authoritative statements about the deficiencies (mechanical, operational, or otherwise) associated with the systems they employ.

The determination of research priorities from a comprehensive list of candidate areas for improvement, however, is an exceedingly complex problem in itself. Whereas the objectives associated with the first three purposes noted tend to be self evident, user requirement issues, generally speaking, are less definable and more beclouded with controversy.

A number of factors contribute to this dilemma:

First, the operators of a system as large as Ag Avn serve different markets and as a result, as subgroups, may have different requirements. For example, it would be expected that applicators who service grain crops such as wheat have specific needs that vary widely from those servicing cotton or rice and vice versa. In other words, mission dissimilarities could conceivably demand different equipment, materials, and modes of operation. The characteristics of the problems arising from such diverse applications, therefore, are bound to vary significantly from both qualitative and quantitative points of view.

Second, the system components of interest to the users, i.e., the aircraft, the dispensing and ground service equipment, the chemicals, the operational procedures, are highly dissimilar elements, and in effect are the classic case of "apples and oranges." As such, the recombination of unlike elements on a common measure normally defies ordinary statistical treatment.

Third, within any one user group, the rice applicators, for example, considerable internal disagreement may exist relative to the nature of various attendant problems and to the emphasis that should be placed on remedial programs. The usual conflicts may be attributed to a variety of factors

such as differences in frequency of problem occurence, exposure time to various operating difficulties, size of operations, specific material failures, the local environment, economics, etc.

Finally, controversy is even more difficult to resolve when one considers the degree of variation in human characteristics that exists normally within any one group of individuals, regardless of any common professional bonds. Here such factors as a dominant or a retiring personality, career experience, and financial security play a significant role. For example, a dominant personality who tends to control the situation by the strength of his personality, may be less qualified technically than his peers. Any conclusions formulated in his presence usually become heavily weighted with his personal biases and hence, may be inappropriate. Furthermore, when one or more dominant personalities are present, discussions all too frequently degenerate into polemics and unproductive debate.

Assuming that somehow a comprehensive listing of user requirements can be assembled despite the aforementioned difficulties, another major problem confronts the planner; i.e., establishing research priorities in light of a probable ceiling on fiscal resources. A major difficulty normally arises from the fact that the subject matter generally is assembled in highly qualitative form. As such it is an extremely difficult task to make systematic relative value judgments concerning which issues should receive attention.

Complicating this task is the human characteristic of preferring to make determinations based on quantitative assessment. The decision maker tends to believe that numerical substantiation is more objective and hence, more defensible. In other words numbers seem to relieve one of the burdens of relying on purely subjective reasoning.

In order to provide some degree of quantification users often are asked to rank order (i.e., 1, 2, 3...) issues based on the frequency of occurrence, as a means of indicating priorities. This method has only marginal utility in a quantitative sense. First of all, problems are rarely arrayed with only unit values separating each item. Any one problem area may be either many times more pressing or perhaps equal to the next issue on the list. In other words, a sense of magnitude is lacking in conventional rank ordering. Without some indication of relative emphasis, realistic research resource allocation becomes extremely difficult.

C. Approach

A unique methodology, Magnitude-Estimation Scaling (MAG-ES), provides a means of establishing useful and meaningful quantitative priorities without incurring the difficulties enumerated above. MAG-ES is a psychometric polling procedure that has been successfully used in assigning quantified values to qualitative subject matter once thought to be incommensurable. (Ref. 4) Furthermore, it has been demonstrated that MAG-ES has the capability to bridge the gap between subjective reasoning and quantification in a sound, mathematically defensible manner. (Ref. 5) The results obtained from past applications have proven realistic, consistent, and above all, useful. (Refs. 6, 7, 8)

MAG-ES can:

1. Provide a quantitative insight into the unique requirements of the overall Ag Avn community, as well as specialized user groups,

2. Combine highly dissimilar elements on a common scale,

3. Order the viewpoints of all interested, authoritative parties without polemics and unproductive debates, and

4. Provide a more objective assessment without the undue pressures from vested interests, strongly biased individuals, or dominant personalities. A description of MAG-ES and the approach used in applying the technique to the problem of deriving useful priorities is contained in Appendix A.

III. SUMMARY OF RESULTS

A. General

Polling of Ag Avn industry members was conducted by the National Agricultural Aviation Association (NAAA). Magnitude-Estimating Scaling (MAG-ES) polling formats prepared by the Actuarial Research Corporation (ARC) were used. A detailed description of the procedures for developing and implementing the polling format is given in Appendix B.

The polling was conducted by NAAA representatives at a series of 15 state and regional NAAA conventions held during the period 3 January - 15 March, 1977. Additional polling formats were mailed to NAAA members in those states not holding annual meetings.

B. Tabulations

1. Responses

A total of 717 returns were received for processing from both NAAA conventions and the mail-out. Some responses could not be utilized for a variety of technical reasons. Table I summarizes the rationale for eliminating the 92 responses.

Table I Summary of Responses

Number of Returns (gross)		717
Less:		
Helicopter Operator/Pilot	40	
Incomplete responses	25	
Respondent followed wrong procedures	24	
Illegible responses	1	
Quebec, Canada, operator	2	
		-92
Net Responses Used		625

ARC was instructed to focus its examination of problem areas solely on the fixed-wing segment of the industry. The polling format, therefore, was so oriented and configured. Returns indicating the respondents to be operators and/or pilots of helicopters only were purposefully removed from consideration at this time. Those respondents indicating both fixed-wing and helicopter backgrounds were included in the data pool.

Although the operating problems encountered in Eastern Canada are likely to be similar to those in various parts of the U.S., a sound rationale for incorporating the two responses from Quebec could not be established readily. Furthermore, the number of responses, only two, was insufficient to justify separate treatment or consideration as a group.

The useable responses from the conventions and mail-out are shown in Table II.

Table II Response Sources

Sources	
o State/Regional Conventions	484
o Mail-outs	
- 771 Mailed	
- 149 Returned (gross) - Used	141
Total	625

The rate of response for the mail-out was 19.3%.

2. Respondent Profiles

A vital element of this study is the necessity for limiting the inquiry to those having intimate knowledge of Ag Avn operations. Ideally every respondent should be classified as an "expert", but this level of experience is difficult to delimit or describe, let alone attain uniformly in practice.

Since the polling was conducted by the NAAA, the opportunity for screening the respondents was beyond the control of ARC. From the background information in the descriptive portion of the polling format,[2/] however, it was possible, post-polling, to review the qualifications and summarize experience levels.

One important indicator of qualification is that of the occupational categories of the respondents. Table III summarizes this issue.

Table III Occupational Categorization of Respondents

Category	Number of Respondents	Percentage of Total
Owner-Operator[3/] / Pilot	429	69%
Pilot only	109	17%
Owner/Operator/Pilot/Allied Industry[4/]	52	8%
Owner-Operator (non-pilot)	22	4%
Pilot/Allied Industry	8	-
Owner-Operator/Allied Industry	3	-
Others 5/	2	-
Total	625	

Figure 1 summarizes the overall agricultural aviation experience in years of the respondents. They average 13.8 years of experience. The multimodal distribution can be attributed to the probable natural tendancy of the respondent to recall such information on a convenient 5, 10, 15...etc., year-group basis.

Figure 2 depicts the distribution of agricultural flight hours for those respondents who are or have been aviators, some 95.7% of the total.

2/ See Appendix B, Annex 2, for a copy.
3/ The Owner-Operator is defined as the owner-entrepreneur and/or manager of an aerial application service.
4/ An Allied Industry member is a supplier of chemicals, equipment, materials, and/or services (e.g., aircraft maintenance, etc.).
5/ "Other" refers to respondents who failed to indicate a category but included sufficient additional information to permit retention.

Figure 1

DISTRIBUTION OF RESPONDENT

AGRICULTURAL AVIATION EXPERIENCE

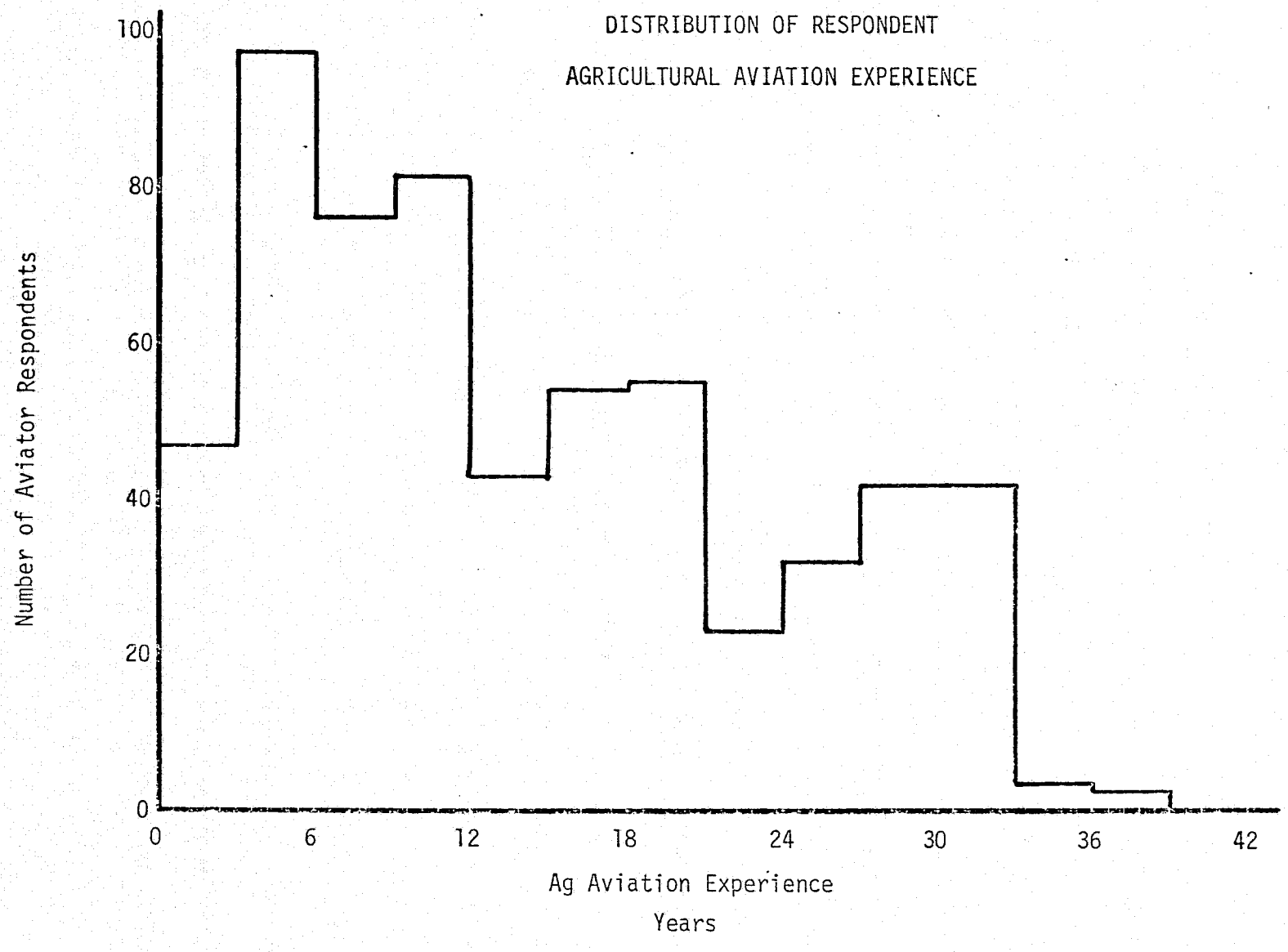
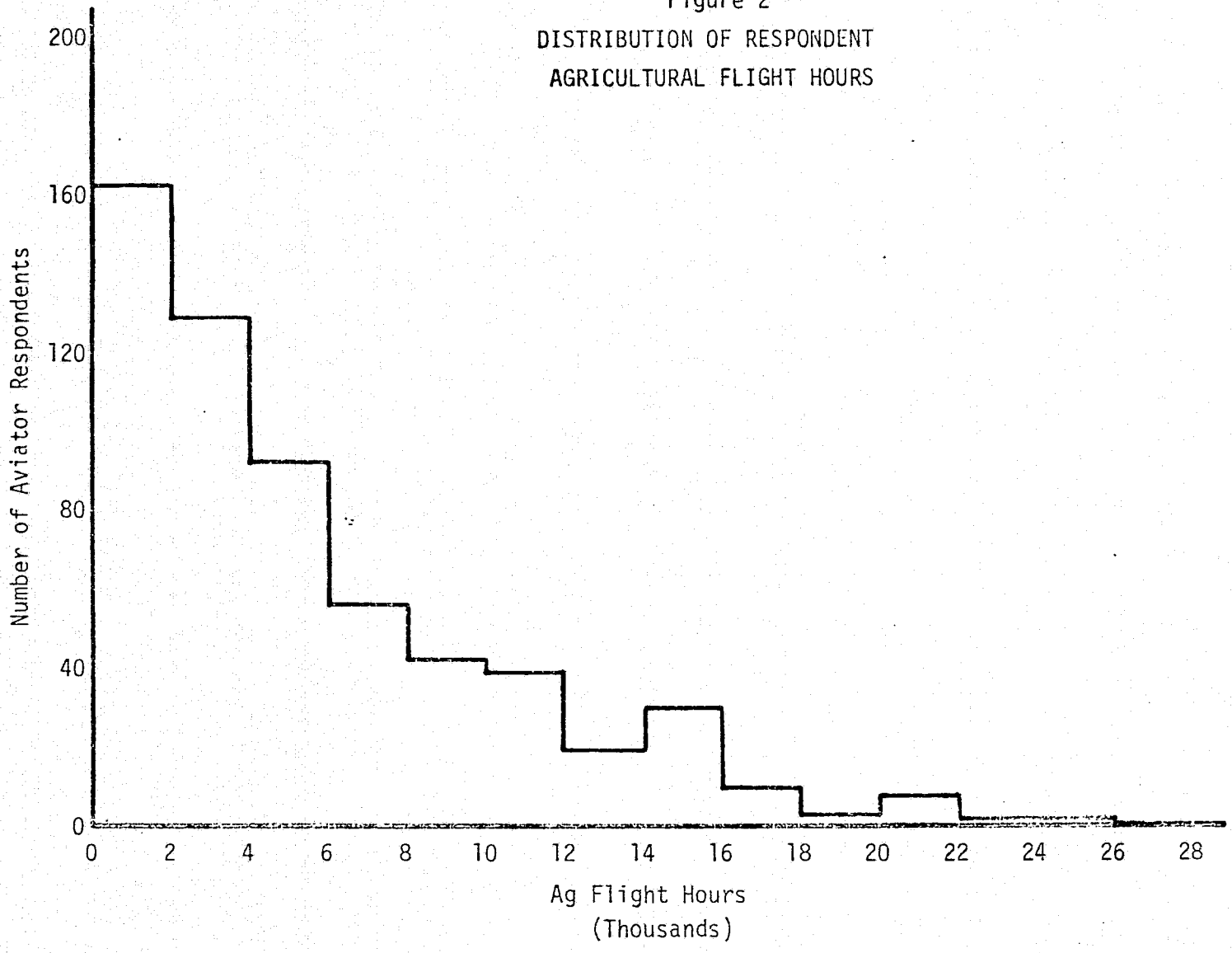


Figure 2
DISTRIBUTION OF RESPONDENT
AGRICULTURAL FLIGHT HOURS



That their collective experience is considerable is attested by the fact that the average agricultural flight hours are 5250 per person. The average total flight time (i.e., all piloting experience including Ag Avn) for the group is 8055 hours per person, a significant indicator of experience in itself.

3. Miscellaneous Data

Two additional pieces of general information were extracted from the biographical questionnaire portion. One body of data describes the percentage of respondents servicing a particular crop. This information is reflected in Table IV.

Table IV Distribution of Crop Servicing

Percentages of Respondents

Alfalfa, clover	43%	Grapes	4%
Berries	4%	Milo, sorghum	45%
Citrus orchards	6%	Range land	30%
Corn, field	59%	Rice	16%
Corn, sweet	18%	Soybeans	55%
Cotton	44%	Sugar cane	6%
Forests (Wood Products)	10%	Tobacco	9%
Fruit orchards	16%	Vegetables	27%
Grain (wheat, oats, rye, barley, etc.)	77%	Other	19%

The other body of information as shown in Table V indicates the percentage of subjects who perform other types of services.

Table V Other Services Performed

Percentages of Respondents

Pest Control (non-crop)	28%
Fire Fighting:	
Water	4%
Chemical	3%
Aerial Seeding	80%
Night Operations	15%
Rights-of-way (herbicides)	17%
Other	12%

Note that 80% of the applicators engage in aerial seeding operations. Pest control (non-crop) refers to the application of insecticides for general infestations such as fire ants and gypsy moths.

With respect to the type of dispensing, only five respondents indicated almost exclusive, i.e., 90% to 100%, specialization in dry material application, suggesting that the industry is almost totally oriented toward wet, or liquid, application.

C. Problem Priorities

The primary product of the poll is the specification of seriousness as determined by the respondents for some 41 selected Ag Avn problem areas for daytime operations with fixed-wing aircraft. The problems were identified and defined during the course of an intensive analysis described in Appendix B.

The results summarized in Table VI are significant in that the perceptions of the combined body of 625 respondents are reflected in a quantified, coherent form. Figure 3 graphically represents the information contained in Table VI with the problems being arrayed in descending order of "seriousness". The scale of weights forms the ordinate or vertical axis.[6/]

The weighting factors are significant in that all problem areas, despite generic dissimilarities, are now related to each other in ratio form. For example, "drift"[7/] (item number 22) with a weight of 6.6 has been

6/ Although retained for relative ranking purposes, the reader is cautioned that any finite significance in the first decimal place cannot be empirically established. In fact, each number could be rounded to the nearest whole or half number with little loss in generality or practicality.

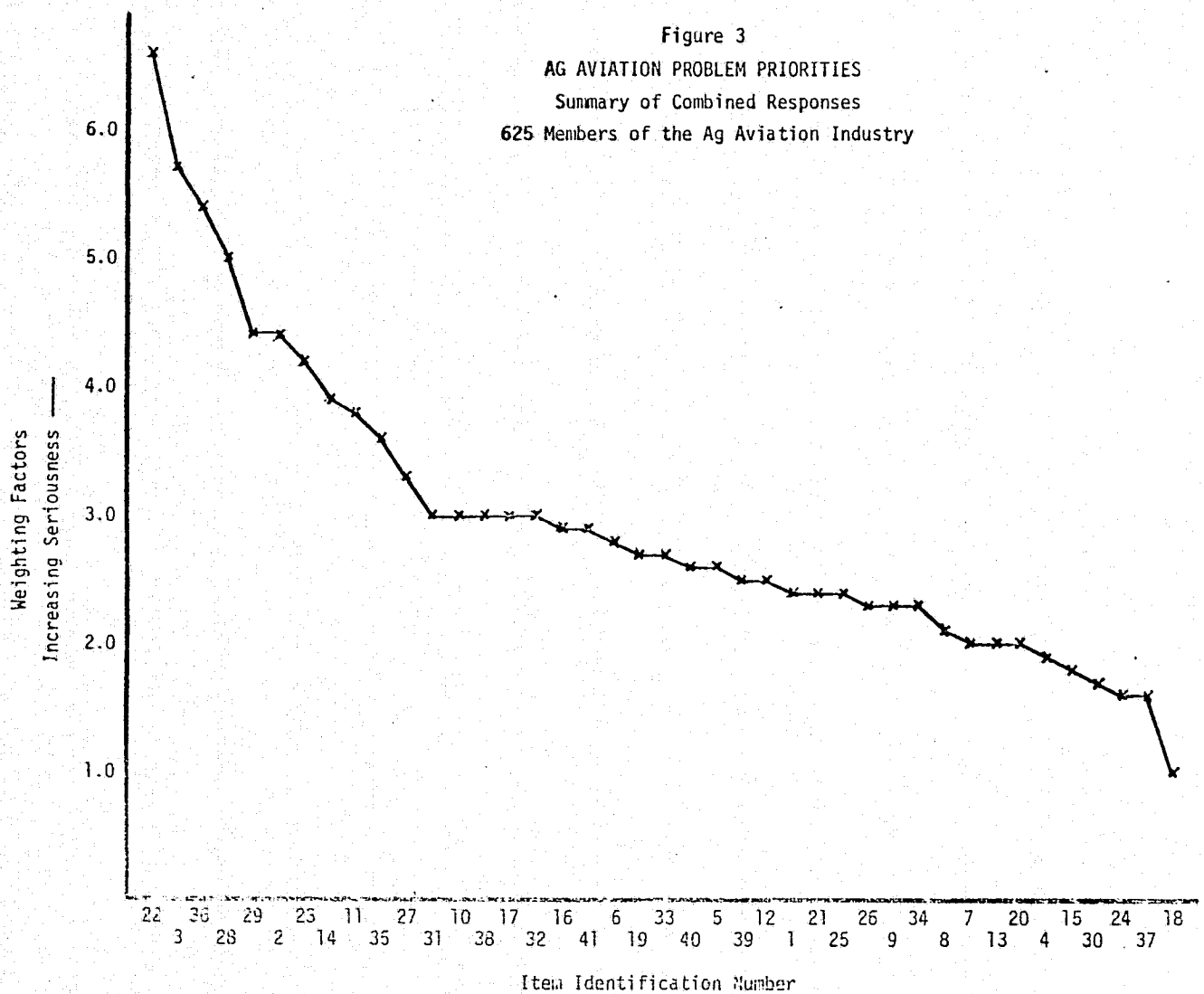
7/ Definitions of the items may be found in Annex 1 to Appendix B.

Table VI

Problem Area Weights Based on All Respondents

Weight	No.	Item
2.4	1.	"In-the-field" repair and service of A/C
4.4	2.	Length of engine and accessory time-between-overhaul (TBO)
5.7	3.	Engine reliability
1.9	4.	"Wash-down" of A/C, inside and out
2.6	5.	Corrosion inspection and control
2.8	6.	Availability of replacement A/C engine
2.0	7.	"In-the-field" repair and service of dispersal systems
2.1	8.	"Flush-out" of dispersal system
2.3	9.	"Change-over" detoxification
3.0	10.	Ground handling of payload--proportioning, mixing, transfer, weighing, speed of operation
3.8	11.	Protecting ground crew from toxic materials
2.5	12.	Adjusting dispersalsystems to meet new application requirements
2.0	13.	Rough-terrain TO and landing capability of the A/C
3.9	14.	Short take-off and landing capability of the A/C
1.8	15.	Cruise speed
2.9	16.	Climb-out/dive-in capability of the A/C
3.0	17.	Steep, short-radius turn capability of the A/C
1.0	18.	Stall warning
2.7	19.	Swath guidance
2.0	20.	Monitoring of individual nozzles/gates in flight
2.4	21.	Monitoring flow rate
6.6	22.	Drift
4.2	23.	Uniform dispersal pattern--providing even lateral (side to side) distribution in a swath
1.6	24.	Selecting dispenser turn-on/off points
2.4	25.	Effects of varying ground speed on dispersal
2.3	26.	Confirming uniformity and concentration of application post flight
3.3	27.	Determining uniformity of coverage and dosage of application during flight
5.0	28.	Capability of cockpit area to survive a crash
4.4	29.	Fire prevention and protection
1.7	30.	Maintaining A/C control during dump
3.0	31.	The accumulation of dust and chemicals on windscreen
3.0	32.	Cockpit visibility (unobstructed view)
2.7	33.	Location and design of cockpit flight and emergency controls
2.3	34.	Stick force effort during maneuvers
3.6	35.	Cockpit comfort
5.4	36.	Protecting pilot from toxic substances
1.6	37.	Mid-air collisions
3.0	38.	Ground obstacle detection and avoidance
2.5	39.	Fuel consumption
2.6	40.	External A/C noise
2.9	41.	Flexibility of A/C to meet different AG requirements

Figure 3
AG AVIATION PROBLEM PRIORITIES
Summary of Combined Responses
625 Members of the Ag Aviation Industry



judged by the respondents to be 2.2 times more serious than, for example, item 31 (Accumulation of dust and chemicals on windscreen) weighted at 3.0,[8/] or 6.6 times more serious than "stall warning" (item 18). Similarly, item 13 (Rough terrain take-off and landing capability ...) weighted at 2.0 is only 40 percent as serious as item 28.

The 6.6 weighting of seriousness for drift is 18% higher than the next ranked problem, item 3 -- engine reliability. As may be observed in the next section, Section D, Group Comparisons, the two items are reversed in order among some of the subgroups that are examined. Yet taken in the aggregate, drift remains the most serious problem according to the members of the industry participating in the poll.

It should be mentioned that drift is a problem resulting from a number of separate phenomena such as aerodynamic interference, boom location, droplet size, wing tip vortices, atmospheric and chemical parameters, etc. The owner/operators and pilots, however, are primarily concerned with only the net effects on their operations. This perception was made abundantly clear during the interviews leading to the development of the polling format. Hence, the term, "drift", was used in lieu of the more precise but less communicative underlying technical causes of the problem.

The lowest ranked item (18), "Stall warning", should be interpreted as being only the least significant of the problem areas presented. This statement does not intend to preclude the existence of lesser problems. It must be remembered that all weights are relative, and as such the value of any weighting factors as an <u>absolute</u> is meaningless.

8/ The same inference can be made for items 10, 38, 17, 32 -- all weighted 3.0.

D. Group Comparisons

While the combined statement of priorities may be assumed rightfully to be representative of the entire industry, it also is intuitively obvious that certain disparities in perception, internal conflicts and disagreements exist among various identifiable segments. The reasons for the lack of unanimity are manifold, e.g., vested interests, different types of crops being serviced, experience levels, and types of aircraft used, to name but a few.

The purpose of examining various subgroups is to detect areas of disagreement and to ensure that the legitimate requirements of these segments are pinpointed and not submerged.

The reader is cautioned that the scale of the ordinate or vertical axis has been changed to percentages as opposed to weighting factors since the latter are not germane in this examination. The entries reflect the percentage of a group's total response devoted to each respective item.

1. Occupational Category Comparisons

Three primary occupational categories of respondents (re: Table III) are compared in Figure 4. The items have been arrayed in the same overall order of decreasing seriousness as was used in Figure 3. The perceptions of the pilots and operator/pilots tend to be in closer agreement than do the owner-operators. Without information to the contrary it must be assumed that the latter is not an aviator.

Note that although a difference in magnitude exists, the owner-operators and owner-operator/pilots agree that drift is by far the most serious problem. The perception is probably motivated by the degree of economic risk

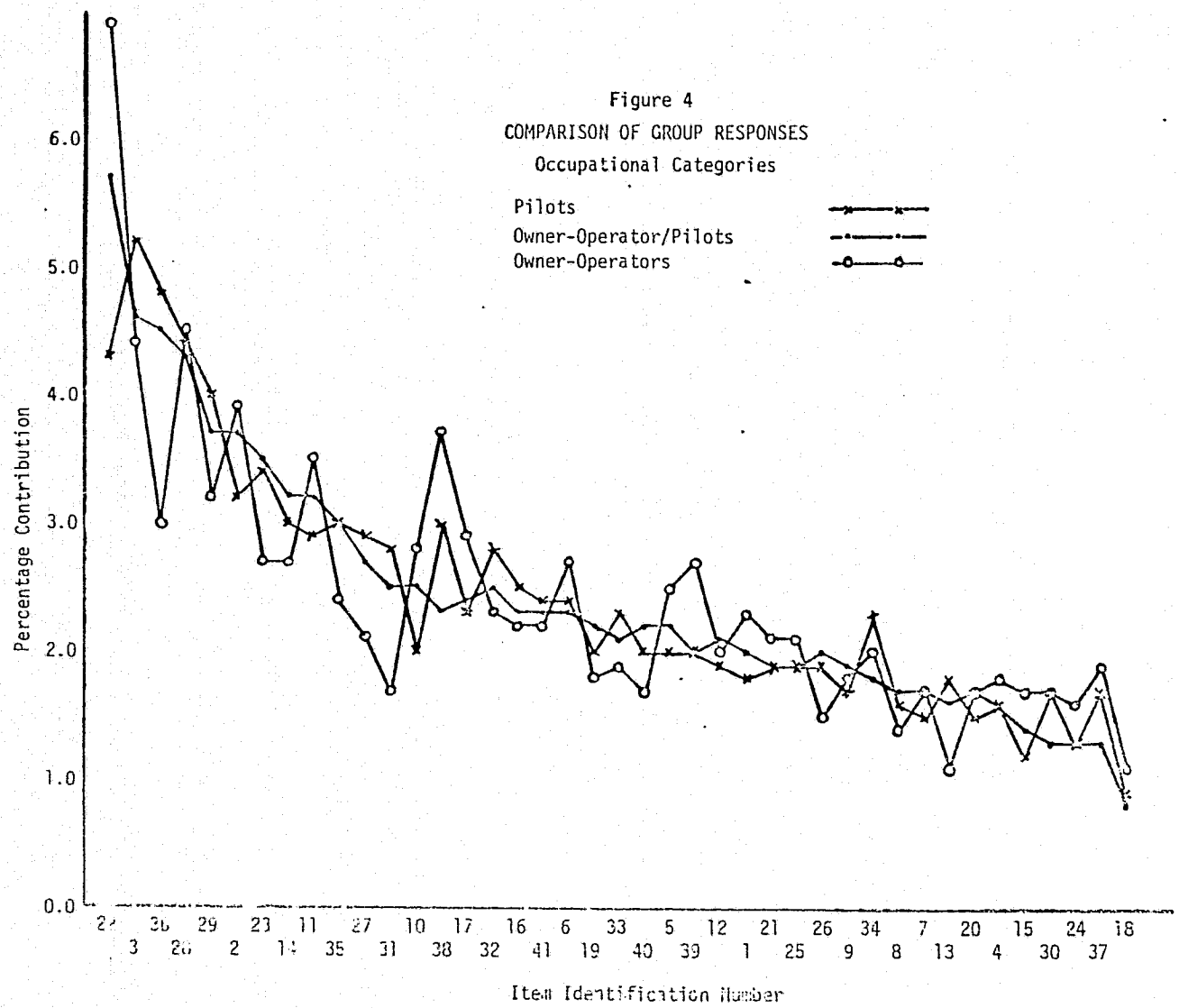


Figure 4
COMPARISON OF GROUP RESPONSES
Occupational Categories
Pilots
Owner-Operator/Pilots
Owner-Operators
Percentage Contribution
6.0
5.0
4.0
3.0
2.0
1.0
0.0
36 29 23 11 27 10 17 16 6 33 5 12 21 26 34 7 20 15 24 18
3 2 35 31 38 32 41 19 40 39 1 25 9 8 13 4 30 37
Item Identification Number

incurred by this problem area. Note also that the non-flying owner-operator tends to have less concern for those items having to do primarily with the flying aspects of the industry, namely:

Item 36 - Protecting pilot from toxic substances
Item 35 - Cockpit comfort
Item 27 - Determining uniformity of coverage in flight
Item 31 - Accumulation of dust on windscreen

Again an explanation for a high rating on item 38, ground obstacle detection and avoidance, by the owner-operator may be economically inspired. In other words an accident attributed to this factor would mean the loss of capital equipment, the loss of operating revenue, and the probability of higher insurance premiums.

2. Influence of Aircraft Size

Figure 5 compares the responses of applicators who operate aircraft in two primary weighting categories, i.e., below 4500 lbs. GW and from 4,500 to 12,000 lbs. GW. The lower weight class was designed to include the Piper and Cessna lines while the larger aircraft are meant to include Grumman and Rockwell products.[9/]

Marked disparities are not evident from this comparison, although slight differences exist with respect to items 2 and 6, both of which are engine problems. The heavier aircraft utilize long-out-of-production radial engines, the availability of which is an acknowledged problem in the industry. The light class, however, uses horizontally opposed engines that are still being manufactured. The lesser concern by the operators of the light class is clear.

9/ This classification of aircraft size by weight does not take into consideration an apparently widespread operational practice of taking-off in a grossly overloaded condition.

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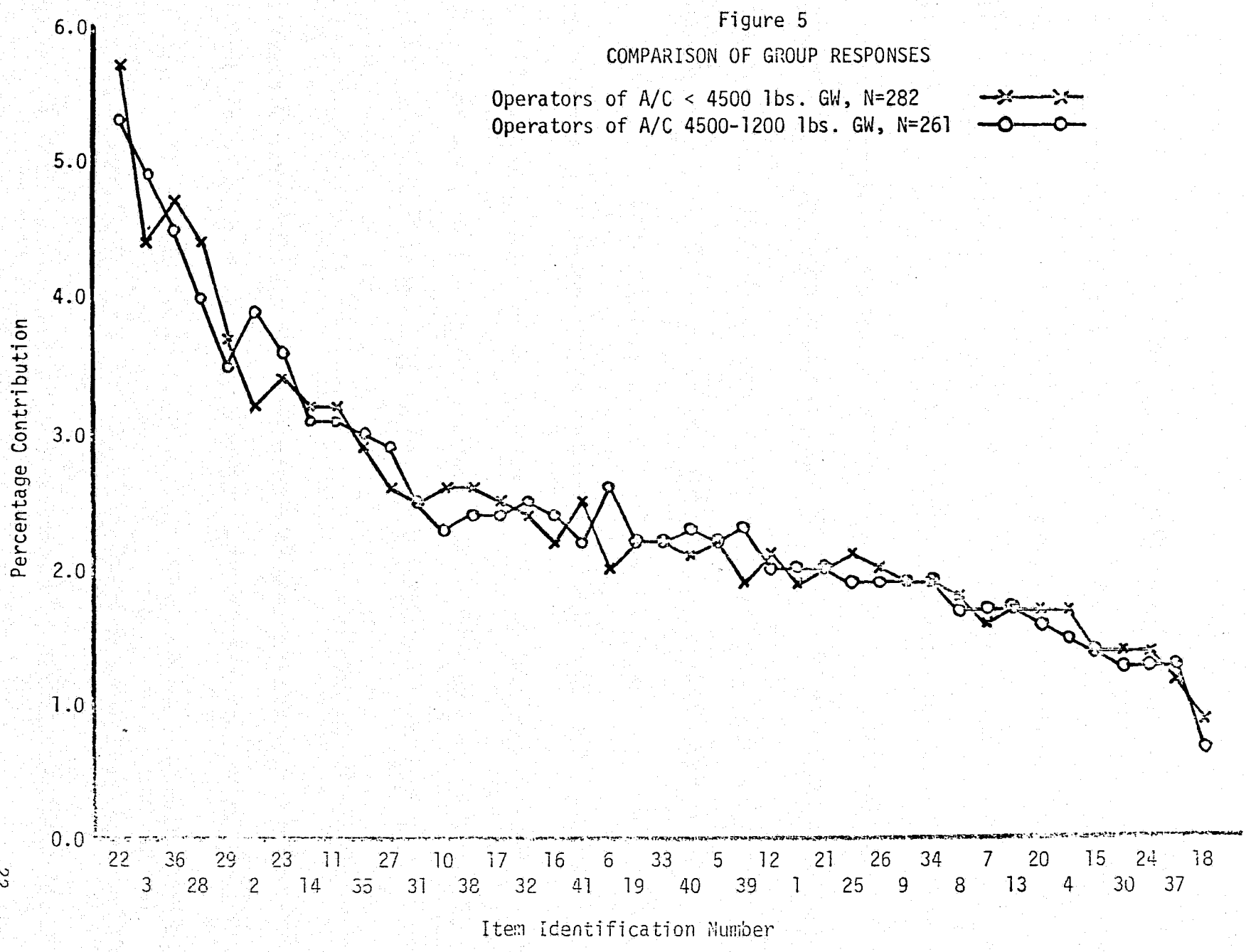
Figure 5

COMPARISON OF GROUP RESPONSES



Some 51 subjects reported operating both classes of aircraft. The responses appear to be a mean value between the other two and were, therefore, omitted for clarity.

3. Influence of Crop Type

By a procedure described in Appendix B, it was possible to make a gross separation of those applicators who service wheat, cotton, and rice. A comparison of the respective responses is shown in Figure 6.

The presentation suggests strong evidence that crop type may have significant influence on the applicator's perception of specific problem areas. Unfortunately determining explanations for each of the items for which marked disparities exist is not possible, however, since the operators also engage in servicing other crops to some unknown degree. As mentioned in the section on tabulations, each operator services approximately five different crops.

4. Helicopter Operators

As mentioned earlier those respondents indicating helicopter only experience were eliminated from computations in view of the fixed-wing orientation of the polling format. A comparison was made between the overall responses of fixed and rotary-wing operators to determine if significant differences could be detected.

Figure 7 indicates the validity of separating the two issues. Great differences in perception exist. The low ratings by the helicopter operators for items 14 (STOL capability), 17 (Steep, short radius turn capability), and 34 (High stick force during maneuvers) are realistic responses when

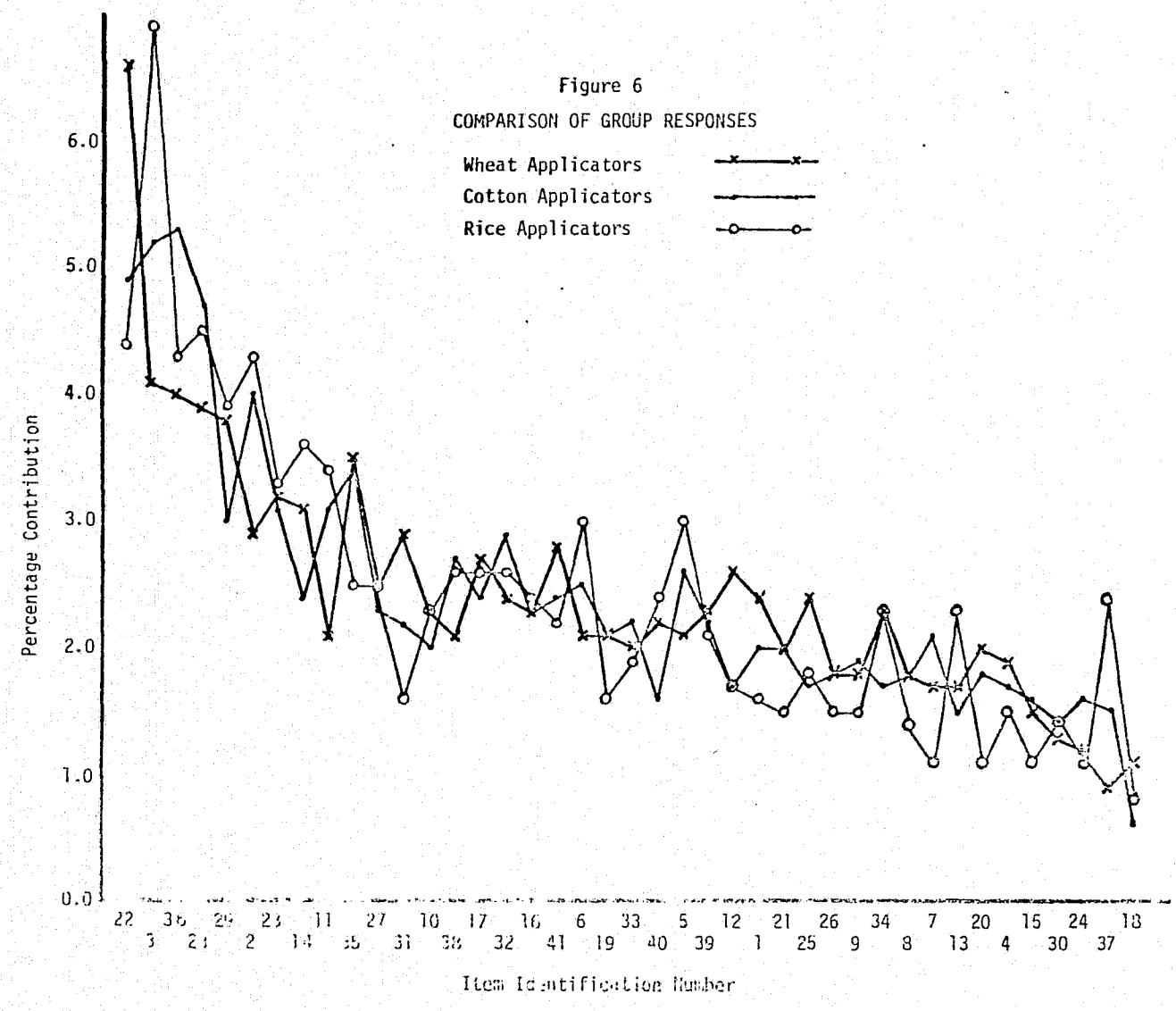


Figure 6

COMPARISON OF GROUP RESPONSES

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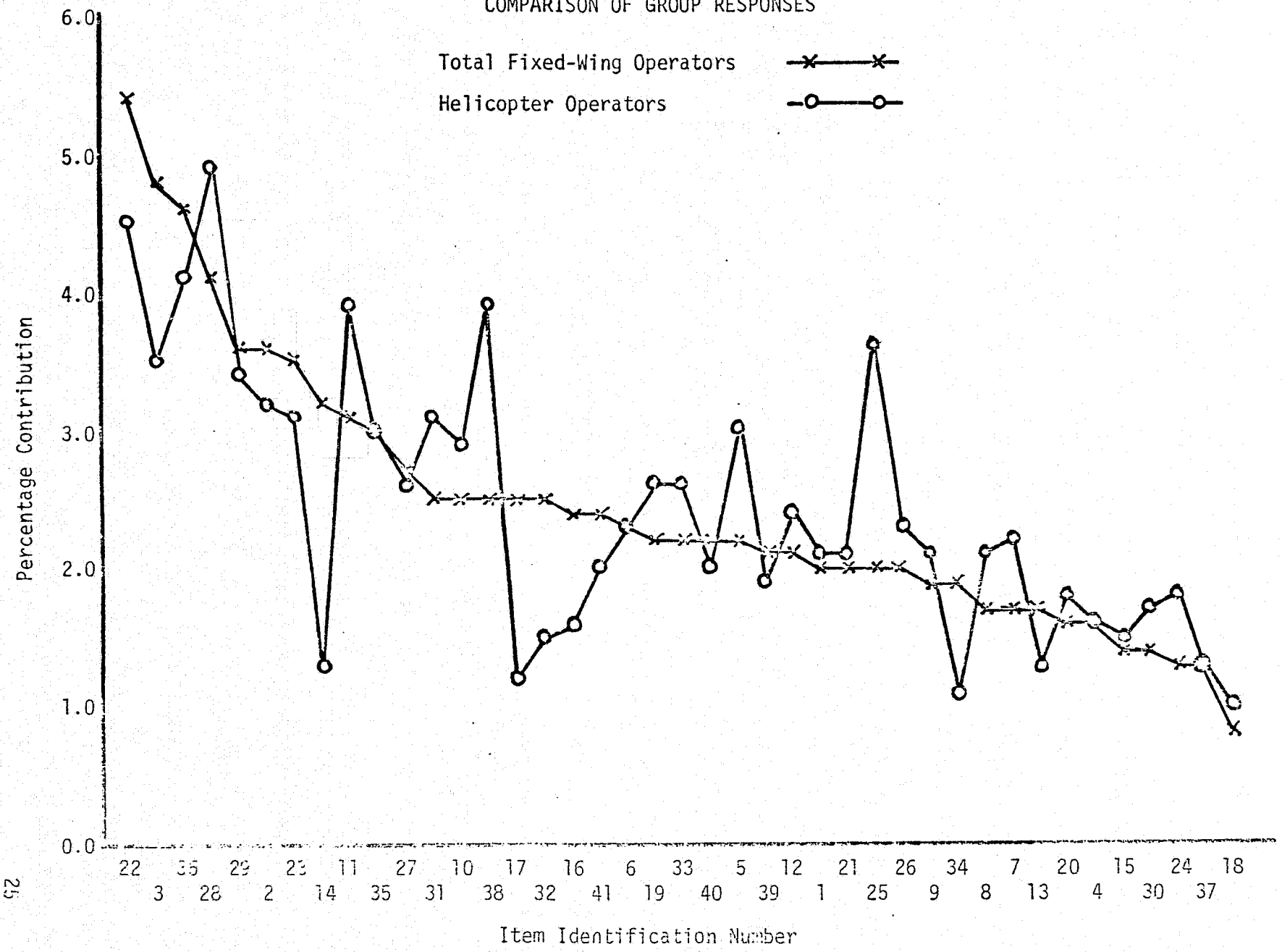
Figure 7

COMPARISON OF GROUP RESPONSES



one considers the rotary-winged vehicle's characteristics vis-a-vis fixed-wing. For example, helicopters have a vertical take-off and landing capability. Current machines have boosted control systems which relieve pilot effort considerably.

IV. APPLICATIONS

A. General

The Ag Avn user requirement or problem area priorities as derived by the MAG-ES polling exercise provides the planner with unusual capabilities for establishing future remedial research programs. This section describes briefly how the data may be utilized to its best advantage.

The planner should view the quantitative presentation of the priorities as documented evidence and guidance to be used in the overall decision process. Obviously there are many other factors that must be considered during the analysis. For example, the group Comparison section clearly indicates that differences in perception do occur within subgroups of respondents. Many of these apparent disagreements are based on legitimate, specific requirements that should be taken into consideration. Likewise, depending on circumstances, it may be appropriate to place more credence on the owner-operator responses with respect to issues having strong economic implications, or conversly, more weight to the pilot's input for such items as aircraft comfort, safety and crashworthiness.

In essence the priorities should be viewed as guidance and tempered as necessary with other relevant factors.

B. Weighting Factor Relationships

As mentioned briefly in Section III. C, the 41 problem statements, regardless of inherent dissimilarities, are now intimately related to each other quantitatively. Ratios of relative seriousness can be established between any pair of items. In other words an item may be "x" times more

serious than a lower ranked problem or "y" percent less serious than a higher ranking. The weights in effect convey a sense of magnitude.[10/]

The weighting factors provide the research planner with the capability of assessing the relative magnitude of each problem area as a means of assigning research resources. The 41 statements, however, can only convey a gross aggregation of Ag Avn problem areas.

To derive more utility from the results, it is suggested that the planner determine what research tasks might be associated with such problems as item 22, Drift. For example, an analysis of the drift problem must include examination of subitems as shown in Figure 8. The cost for performing each task then can be estimated and arrayed as shown.

Figure 8 Research Task Cost Assessment

ID No.	Item	Wt.	Research Task	Task Cost	Total Cost	Cost Rank (Examples only)
22	Drift	6.6	Aerodynamic interference	X1		
			Boom location	X2		
			Aircraft speed	X3		
			Boom size	X4		
			Chemical parameters	X5	$(\Sigma X_n=)X$	3
			Droplet size control	X6		
			Tip vortices	X7		
			Atmospheric parameters	X8		
3	Engine reliability	5.6	Metallurgy	Y1		
					$(\Sigma Y_n=)Y$	2
			Bearing technology	Y2		
			.			
			.			
36	Protecting pilot	5.4	.	Z1	Z	1
			.	.		
			.	.		

The fact that item 22 is weighted above the others should not be confused with the cost ranking. The cost for any lower weighted item may be many times more expensive.

10/ It must be remembered that the weights are relative factors. The concept of an absolute level of seriousness actually has no meaning.

It should be noted, also, that a research task such as "aerodynamic interference" may also provide solutions to other problem areas, e.g., item 23, uniform dispersal pattern--.

C. Generic Packaging

One of the most useful features of the MAG-ES derived weighting factors is "additivity", i.e., the factors may be added or subtracted from a mathematically defensible standpoint. This capability permits the combination of highly dissimilar subjects, the classic "applies and oranges" case, on the same measurement scale. Furthermore, additivity also permits the grouping or "packaging" of generically similar items. Problem areas may be grouped conveniently according to some common denominator. Figure 9 depicts the concept whereby the problems have been grouped in five identifiable categories. The weights for each item in a group may then be added together to form a "package value". The relative seriousness of the packages can then be assessed. (For packaged problem statements, see Table VII.)

Although not necessarily an accurate observation, it may be argued that the package with the greatest number of component problems would become the most heavily weighted. To accomodate this condition, the concept of "average seriousness" is introduced. Average seriousness is merely the total seriousness divided by the number of components within the group.

The concept of average seriousness changes the significance of problem assessment. Note in Figure 9 that while the Propulsion group has the lowest total seriousness weighting, the relative average serious is the highest.

Generic packaging, therefore, should become part of the planner's assessment process.

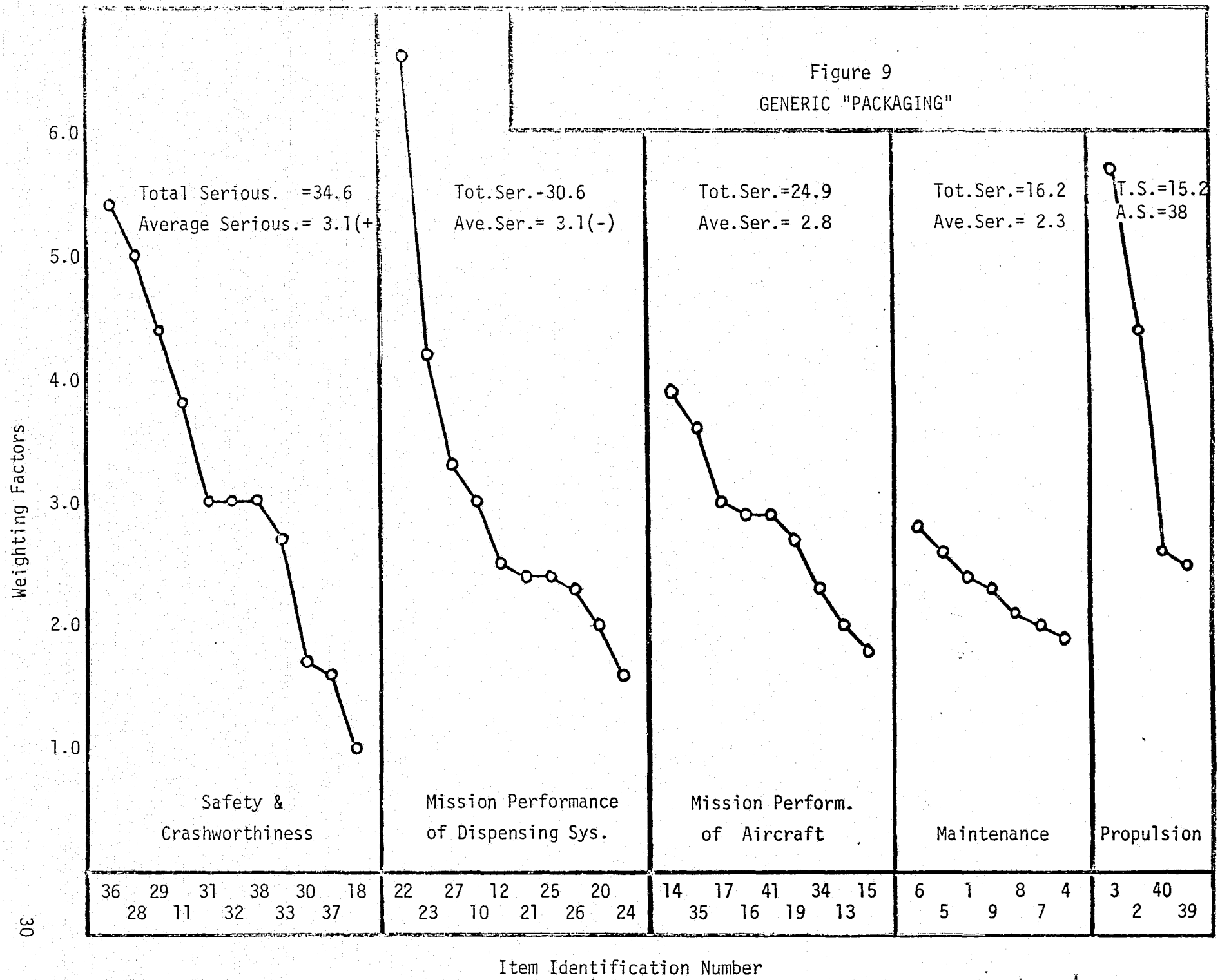


Figure 9
GENERIC "PACKAGING"
Weighting Factors
6.0
5.0
4.0
3.0
2.0
1.0
Total Serious. =34.6
Average Serious.= 3.1(+)
Tot.Ser.-30.6
Ave.Ser.= 3.1(-)
Tot.Ser.=24.9
Ave.Ser.= 2.8
Tot.Ser.=16.2
Ave.Ser.= 2.3
T.S.=15.2
A.S.=38
Safety & Crashworthiness
Mission Performance of Dispensing Sys.
Mission Perform. of Aircraft
Maintenance
Propulsion
36 29 31 38 30 18
28 11 32 33 37
22 27 12 25 20
23 10 21 26 24
14 17 41 34 15
35 16 19 13
6 1 8 4
5 9 7
3 40
2 39
Item Identification Number

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Table VII

Generic "Packaging" of Problem Areas

Generic Group	Weight	No.	Item
I. Safety and Crashworthiness	5.4	36.	Protecting pilot from toxic substances
	5.0	28.	Capability of cockpit area to survive a crash
	4.4	29.	Fire prevention and protection
	3.8	11.	Protecting ground crew from toxic materials
	3.0	31.	The accumulation of dust and chemicals on windscreen
Av. Ser. = 3.1	3.0	32.	Cockpit visibility (unobstructed view)
	3.0	38.	Ground obstacle detection and avoidance
	2.7	33.	Location and design of cockpit flight and emergency controls
	1.7	30.	Maintaining A/C control during dump
	1.6	37.	Mid-air collisions
	1.0	18.	Stall warning
II. Mission Performance of Dispensing System	6.6	22.	Drift
	4.2	23.	Uniform dispersal pattern--providing even lateral (side to side) distribution in a swath
	3.3	27.	Determining uniformity of coverage and dosage of application <u>during flight</u>
	3.0	10.	Ground handling of payload--proportioning, mixing, transfer, weighing, speed of operation
	2.5	12.	Adjusting dispersal systems to meet new application requirements
Av. Ser. = 3.0	2.4	21.	Monitoring flow rate
	2.4	25.	Effects of varying ground speed on dispersal
	2.3	26.	Confirming uniformity and concentration of application <u>post flight</u>
	2.0	20.	Monitoring of individual nozzles/gates in flight
	1.6	24.	Selecting dispenser turn-on/off points
III. Mission Performance of A/C	3.9	14.	Short take-off and landing capability of the A/C
	3.6	35.	Cockpit comfort
	3.0	17.	Steep, short-radius turn capability of the A/C
	2.9	16.	Climb-out/dive-in capability of the A/C
Av. Ser. = 2.8	2.9	41.	Flexibility of A/C to meet different AG requirements
	2.7	19.	Swath guidance
	2.3	34.	Stick force effort during maneuvers
	2.0	13.	Rough-terrain TO and landing capability of the A/C
	1.8	15.	Cruise speed
IV. Maintenance	2.8	6.	Availability of replacement A/C engine
	2.6	5.	Corrosion inspection and control
Av. Ser. = 2.3	2.4	1.	"In-the-field" repair and service of A/C
	2.3	9.	"Change-over" detoxification
	2.1	8.	"Flush-out" of dispersal system
	2.0	7.	"In-the-field" repair and service of dispersal systems
	1.9	4.	"Wash-down" of A/C, inside and out
V. Propulsion	5.7	3.	Engine reliability
Av. Ser. = 3.8	4.4	2.	Length of engine and accessory time-between-overhaul (TBO)
	2.6	40.	External A/C noise
	2.5	39.	Fuel consumption

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

On the basis of a nationwide poll of 625 members of the agricultural aviation community, it is concluded that:

1. Drift is the single most serious problem encountered,

2. "Propulsion" problems are the most serious as a generic group,

3. The differences among problems associated with specific, crop servicing operations may be more individually significant than can be determined from a generalized poll.

4. Although helicopter operations were not the focus of this study, the results obtained from a limited number of helicopter respondents suggests a significantly different array of problem areas than those of fixed-wing operators.

B. Recommendations

It is recommended that:

1. A research task analysis and cost assessment as outlined in paragraph B, Section IV, be conducted for every problem area listed before final program decisions are made.

2. Separate polls of Ag Avn members engaging in helicopter and night operations be undertaken.

3. A feasibility study be undertaken for the purpose of examining in more precise detail, the influence of specific, crop servicing operations on the statement of problem priorities.

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6. T. Wasilewski, A. Gualtierri, R.L. Kaplan and T. Meeland, "Scenario of Advanced Phase I Insurgency in Thailand" (U), Stanford Research Institute, Menlo Park, Ca. 94025, 1968. Secret.

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8. Daryl L. Dell, "Patron Assessment of School Objectives for M — School", Stanford Research Institute, July 13, 1973, 118+pp.

APPENDIX A

The Magnitude Estimation Scaling Procedure

Subjective, qualitative judgments can be summarized in many ways. The typical polling procedure simply requires some form of a yes-no response to an issue. The results are presented in terms of the percent of a group that agrees or disagrees with an issue. When the percentage is high a consensus is indicated and an intensity of feeling is implied, but in reality the actual degree of the intensity is unknown.

It is also common to have items ranked in order of some quality such as attractiveness, goodness, importance, and so on. An average rank of an item can then be shown as well as the rank order correlation among different sets. But the size of the intervals between ranks and the intensity of the feeling expressed are unknown.

A refinement of these polling/rating procedures is to provide the respondent with a spectrum of response categories that represents a range from "never" to "always", or some other set of descriptors. The number of intermediate categories between the extremes (e.g., "never" and "always") varies, commonly runs from five to seven, but may be larger. The intent usually is to provide a series of equally spaced response categories.

There are two major shortcomings to such a procedure. First, the usual treatment of the ensuing data implicitly assumes equal intervals when in fact the categories simply have been assigned numbers from 1 to 5, or 1 to 7. In reality, however, the intervals are almost always unequal, and to an unknown degree, with respect to intensity, amount, or other quality. It is incorrect to conclude that the first category is half the amount of the second category or one-third of the third category, even though numbers have been assigned to each interval. There can be a further compounding

due to the descriptors applied to the categories. Depending on the words chosen to define each category, the distribution of responses can be skewed one way or the other. Strictly speaking, it is improper to compute arithmetic means and similar statistics since the intervals are not equal. In practice, however, such calculations are rarely inhibited.

For several decades there has been an intensive effort to devise judgment scales that have the attribute of additivity. Thurstone and Chave's early study of attitudes toward the church (Ref. A1) and subsequent work on "equal appearing intervals" was an elegant approach to the phenomenon of proportionality that is inherent in human judgments, wherein the variability of judgments is approximately proportional to the magnitude of the stimulus (or reference object, or item).

The method of paired comparisons used to establish these intervals is a tedious procedure for the rater when a large number of items is involved. For example, with forty items, 780 comparisons are required. The work of Stevens (Ref. A2) and others reflected a direct approach to the problem of establishing scale intervals by requiring the subject to estimate ratios of magnitudes with respect to a reference point.

Until quite recently this procedure of magnitude estimation has been applied mainly to psychophysical phenomena. Gradually a body of studies has accumulated in which the relationship between judgments of nonphysical events and objective indices of these events has been examined, e.g., the preference for watches, odors, occupations; the importance of monarchs; the degree of frustration and aggression in a military setting; and the seriousness of delinquents' crimes (Refs. A3, A4, A5, A6, A7, and A8). A decade ago it was noted that the magnitude estimation scaling that

was used in psychophysics showed a remarkable consistency in these other applications and it was suggested that herein was a means to create a metric, i.e., a scale that had the characteristic of additivity (A9). The first major application of magnitude estimation to the scaling of qualitative events occurred in the study of crimes (Ref. A8) noted above. Shortly thereafter applications were made to the assessment of the seriousness of insurgents' activities in Southeast Asia (Refs. A10, A11)and the determination of how much credibility was placed on intelligence reports that had been previously graded according to source reliability and content truthfulness (Ref. A12).

The procedure in Magnitude Estimation is simple in concept. Each item in a list is compared to a single reference item which is initially assigned any non-zero positive number. If the item being appraised is judged to have more or less of a given quality than the reference item, this is noted by assigning a value that shows the magnitude of the judgment in terms of multiples or fractions of the value assigned to the reference number. For example, if the reference item has been given a value of fifteen (15) and the compared item is judged to be three times more worthwhile (or serious, or desirable, or inhibitory, or whatever the characteristic at issue may be) a value of 45 is noted. If it is judged to be only half as worthwhile, a value of $\frac{15}{2}$ or 7.5 is entered. Any multiple or fractional value is permitted except zeros (since geometric means are calculated using logorithms and zeros cannot be handled) or negative numbers (since degrees of "absence of a quality" makes little sense).

In theory, the reference item can be assigned any value or each respondent can assign his own value prior to making the judgments (Ref. A8).

Based on past applications of the procedure, the instructions are more easily followed when a value of ten (10) is provided for each reference number. Unless there is a specific reason to use a single reference item (such as a known or conventional standard) each item is randomly used as a reference among the judges. To compensate for position, or order effects on the compared items, each respondent is given a different, randomly ordered list of items.

It has been traditional to prepare test booklets that present only one item on a page and to instruct each subject not to refer back to scores assigned to prior items. The cost of preparing such booklets is quite high and various alternative procedures have been tried to reduce the costs of printing and assembling the booklets. Computer-generated and printed booklets with random orders and multiple items per page have been used with little loss of fidelity. Some subjects have reported difficulty in handling fractional values where the reference item was considered to have the highest value. A practical compromise is to provide a minimum of 3 or 4 item orders and a designation of 4-8 reference items which can be expected to fall within the extreme weights. This designation requires preliminary information from a pre-test of similar or, better, identical items.

The use of booklets with one item per page to decrease the likelihood of referring back to earlier judgments is practical only when the test group is small enough so that the test administrator can adequately monitor the procedures. In the case of mailed responses, the experimenter will not know if any backreferencing has taken place and it is thus more expedient to display the items in a continuous list.

The subjects should be instructed about the context (the setting, the conditions, or the scenario) in which the judgments are to be made. In effect, this establishes a frame of reference for the respondent.

The Magnitude Estimation Scaling Procedure (MAG-ES) has several distinct advantages. The technique allows each respondent to make judgments without a restriction on the range of values applied to each item. The scores are expressions of the magnitude of the relative quality or intensity at issue. In addition the resulting weights (geometric means) are additive, a characteristic that provides the opportunity to relate highly dissimilar items (the classic "apple" and "orange" dilemma) quantitatively in terms of magnitude so that they can be compared on a common scale.

Appendix A References

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APPENDIX B

Technical Approach

1. Development of the Polling Format

a. Formulation of Problem Statements

The formulation of the problem statements was an iterative and interactive process that systematically considered a range of issues being faced by the agricultural aviation (Ag Avn) industry. The problem areas were identified in various written sources (reports, workshop summaries and memoranda), by interactions with industry members at the national meeting of the National Agricultural Aircraft Association (NAAA), and through interviews with operators and informed National Aeronautics and Space Administration (NASA) personnel. These resources provided critical inputs to the effort described below. In addition, the very recent workshop (Ref. B1) and work contracted by NASA (Ref. B2) provided syntheses of the deliberations by a broad spectrum of experts in Ag Avn. The detailed account of Russian use of aircraft in agriculture and forestry (translated by NASA) was an additional resource (Ref. B3).

The problems concerned with such issues as insurance and related costs, relationships with federal agencies and pressure groups, environmental regulations, public relations, etc., were excluded from consideration, since the primary objective of the study was to provide information that was specific to NASA's technological capabilities. These issues are nonetheless important from an industry-wide perspective.

For the needs of the problem identification task, it seemed most useful to formulate a functional model that delineated areas of activities that represented the major, somewhat independent, operational aspect of aerial application work. After several iterations, the following categories were established:

(1) Ground Support
(2) Ferry/shuttle
(3) Working turns
(4) Dispensing/dispersal
(5) Pilot environment
(6) Operations

Each of these areas was further expanded in terms of the activities that occur during the period of application. These events (or problems) are shown in Figure B1. The identified problems are not mutually exclusive nor do all the subsidiary activities necessarily have to be restricted to any one area, although the representation in the figure was most conducive to the item development.

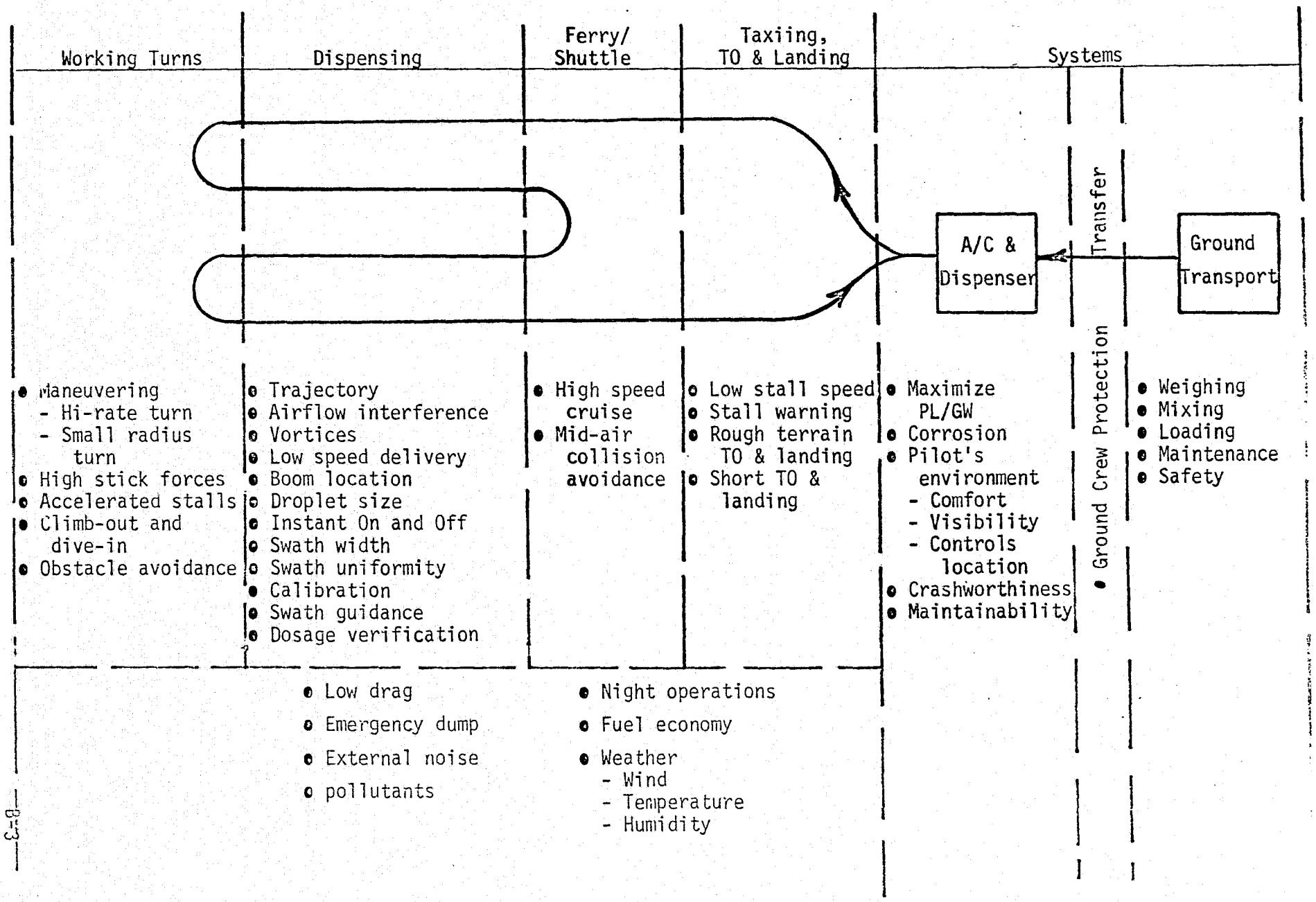
This form of breakout of salient activities provided a useful and efficient means to review, assess and integrate the problem-oriented material that emerged from the various sources examined. A major consideration in the development of the item statements was to maintain a focus on problems and not solutions. For example, an item referring to a "sealed cockpit" is oriented to a solution, whereas "protecting pilots from toxic substance" refers to a problem which can be resolved by a sealed cockpit or some other engineering design effort.

Based on other experiences (Refs. B4, B5, B6) a total of 30-45 items was established as a practical maximum for presentation to the respondents in view of the time constraints. It was planned that no more than 30 minutes of time would be available for the complete administration of the polling format including distribution of forms and the reading of instructions. Since the statements were quite short, the final complement of 41 items was judged to be a workable number to present.

The creation of the set of Ag Avn problem statements was viewed as critical to a successful derivation of priorities. The primary goal of

Figure B-1

FUNCTIONAL CATEGORIZATION



the work in this area was to present to the respondents a set of mutually exclusive problem statements phrased in such a manner as to guarantee that the members of the industry would immediately recognize and understand the issues. The latter condition necessitated the use of "trade" language, although a careful screening to eliminate local jargon or regional variations was essential.

Definitions of the 41 problem areas are found in Annex 1 to this Appendix.

The statement of instructions and a typical listing of the problems (as shown in Booklet A only) are shown in Annex 2.

b. Background Information

It was important to establish the homogeneity and the qualifications of the respondents with respect to Ag Avn. A biographical questionnaire was designed and included for this purpose. The questionnaire is strictly anonymous. The rationale for the biographical items selected is as follows:

(1) Location of operation: Although there was no substantive basis from which to assume that perceptions would vary along state or regional lines, the information was requested to allow the aggregation of respondents by regional or other convenient geographic grouping as desired.

(2) Occupational categories: It was not known if the judgments made by owner/operators (who do not engage in Ag flying) would differ from those who perform as Ag pilots only. Since members of allied industries (chemicals, fuel, aircraft, etc.) would also be in attendance at the NAAA meetings, it was necessary to provide a means of identifying them for later

exclusion, as needed. At the same time, the likelihood existed that some respondents would be participating members of all three categories.

(3) Level of experience: This item concerned the level of experience of the pilots in terms of the Ag flight hours accumulated and the years of Ag aviation experience. Since a log of flight hours is an FAA requirement of all pilots, the reported figures were expected to be accurate within a reasonable degree of recall. In the case of Ag flight hours, less accuracy was expected since there is no requirement for pilots to keep logs and there is some likelihood that a slight exaggeration would occur. The anonymity of the responses, however, probably lessened any need for purposeful inflation of the reported hours or years of experience.

(4) Type of A/C operated: The respondents were asked to identify their aircraft type (by weight). In view of the fixed-wing orientation of the project, it was essential to identify helicopter pilots and operators for possible separation from the other respondents. The weight categories selected were: (a) under 4,500 lbs to include Cessna and Piper aircraft, and (b) 4,500-12,000 lbs. GW to include Thrush Commander and Ag Cat aircraft. A category for aircraft over 12,000 lbs. GW was included to identify those operating large size, surplus military or commercial aircraft.

(5) Crops serviced: The list of crops presented was derived from an open-ended question included in a field trial questionnaire. The operators were asked to identify their primary and secondary crops. The list was further augmented on the basis of a literature search and operators and industry members suggestions. The end result was a list of 17

crops, and one open-end response. Each respondent was asked to identify each crop that he services, and to indicate which of them is his primary crop, and which is his secondary crop.

(6) Primary crop effort: The respondents were asked to indicate the percentage of their operation that was devoted to primary and secondary crops. From this, groups of crop "specialists" could be identified.

(7) Type of dispensing: The intent of this item was to identify a subset of operators that did either wet or dry dispensing primarily. It was considered that perceptions might vary between these groups.

(8) Other operations engaged in: This item was included to learn the frequency with which the operators engaged in activities apart from daytime treatment of crops.

Annex 3 to this appendix provides a copy of the biographical questionnaire.

2. Data Collection Procedures

Five primary activities were performed in the data collection. These activities are described in detail below.

a. Field Trial

The field trial that was conducted had two objectives:

(1) To establish that the instructions could be understood by the intended audience and could be followed with little or no difficulty, and

(2) to obtain preliminary information on the seriousness level of fourteen items adapted from the problem list contained in the 1976 NASA report on Agricultural Aviation. (Ref. B7)

The forms prepared by the Actuarial Research Corporation (ARC) were administered by NAAA staff at four state/regional meetings of the Association. One hundred and forty-one (141) completed forms were obtained from this effort.

b. Preparation of Booklets

To minimize item order effects, four booklets were prepared, each with different random orders of the forty-one items or problem statements. Next, five reference items were selected based on the information derived from the field trial. The intent was to avoid reference items that were at either extreme of the probable range of seriousness weights.

A value of "10" was stamped in each booklet for one of the five reference items. The respondent was asked to compare each of the other 40 items in turn with this reference item and enter a number that expressed how much more or less serious each item was relative to the value of the reference item.

c. Distribution of the Booklets

The NAAA distributed polling format booklets during scheduled sessions at a series of state or regional meetings between 3 January and 15 March 1977. The completed forms were collected and then returned to ARC for processing. In addition, polling formats were mailed by NAAA on 10 February 1977 to all members or operators (a total of 771 in fifteen states) on its mailing list in those states where conventions were not held during the survey period. The NAAA cover letter accompanying the mail-out reiterated the introduction and guidance previously given by NAAA representatives at the state/regional conventions.

To obtain an even distribution of booklets and reference items, sets of twenty booklets were assembled that contained one each of every booklet and reference item combination. All sets were identical. The distribution at the conventions and for the mail-out was done sequentially from a set.

d. Screening of Booklets

At ARC, each booklet was examined for completeness, correctness in scoring procedure and eligibility of the respondent.

e. Processing of Data

Information about the respondents' background was coded by ARC prior to keypunching. There was 100% verification of the keypunching The weights were computed using a Fortran program previously developed by ARC. A detailed check was made on the operating accuracy of the computer program by comparing a preliminary output with a manual calculation of 25 responses.

3. Data Analysis Procedures

This section describes briefly the series of steps or procedures followed in analyzing the data.

It should be noted that some of the investigations were directed toward exploring problems of unknown significance. Of these some proved to be of marginal value with respect to the purpose of the overall study. A few of the major efforts in this regard are included for completeness.

The major data analysis procedures include the following:

a. Distribution of Booklet Type and Reference Items

Upon receipt of the completed polling formats a check was made of the distributions of booklet type (i.e., A, B, C, D) and of the items selected for the reference items. The purpose was to determine if there were uneven distributions that might introduce inadvertent distortions or position induced errors.

The results of the effort to obtain an even spread of booklets and reference items across the range of subjects used are shown in Table B-I.

Table B-I

Summary of Booklets and Reference Item Distribution

Booklet	Reference Item 1	5	15	32	39	Total	Percent
A	39	35	29	25	31	159	25.4%
B	38	27	32	34	26	157	25.1%
C	24	32	34	30	31	151	24.2%
D	26	34	35	31	32	158	25.3%
Total	127	128	130	120	120	625	
Percent	20.3	20.5	20.8	19.2	19.2		100%

Considering that the administrations occurred in fifteen different locations in addition to the mail-out the returns were not sharply distorted with respect to the distribution of booklets (order of presentation) or reference item (frame of reference used for the ratings). The booklet return distribution varied no more than 3.2% from the expected 25% and the largest variation from the expected return of 20% for each reference item was 4%. For the booklet/item combinations, the average variation from the expected return of 5% was 10.3%.

b. Respondent Qualifications

During the analysis of group comparisons, the issue of respondent qualifications was raised relative to the experience levels of the pilots and owner/operator-pilots. The question was basically one which asked, "Did pilots with relatively few flight hours have sufficient experience to be respondents?".

The data contained in the biographical questionnaire was tabulated to assess experience levels. In addition to the distributions noted in

the main body of the study (Figures 1 and 2) a similar histogram (Figure B-2) was prepared for the total flight hours of the respondents. Also, plots were made of Ag flight hours with respect to years of experience for all aviators (including owner/operators) and for "pilots only" as shown in Figures B-3 and B-4.

In lieu of any conventional standard or empirical evidence that could serve as criteria, three arbitrary levels of flight time and experience were selected for examination:

(1) Under 2 years'experience and under 400 hours of Ag flight time

(2) Under 1000 Ag flight hours

(3) 2,000-2,999 Ag flight hours and 3-10 years experience

Although minor disparities appeared in the group comparisons, there was insufficient evidence to suggest that experience levels created marked differences in the perceptions of seriousness for the 41 problem areas.

c. Group Comparisons

Separate groups or subgroups of subjects were examined to determine if there were major differences in perception that could be associated with particular activities, operations, and/or levels of experience. The background information obtained from the biographical questionnaire provided the basis for a computer sort of respondents into the following identifiable groups:

- Location of operation
- Occupational categories
- Level of experience
- Type of A/C operated
- Type of crop serviced

Figure B-2
TOTAL FLIGHT HOURS

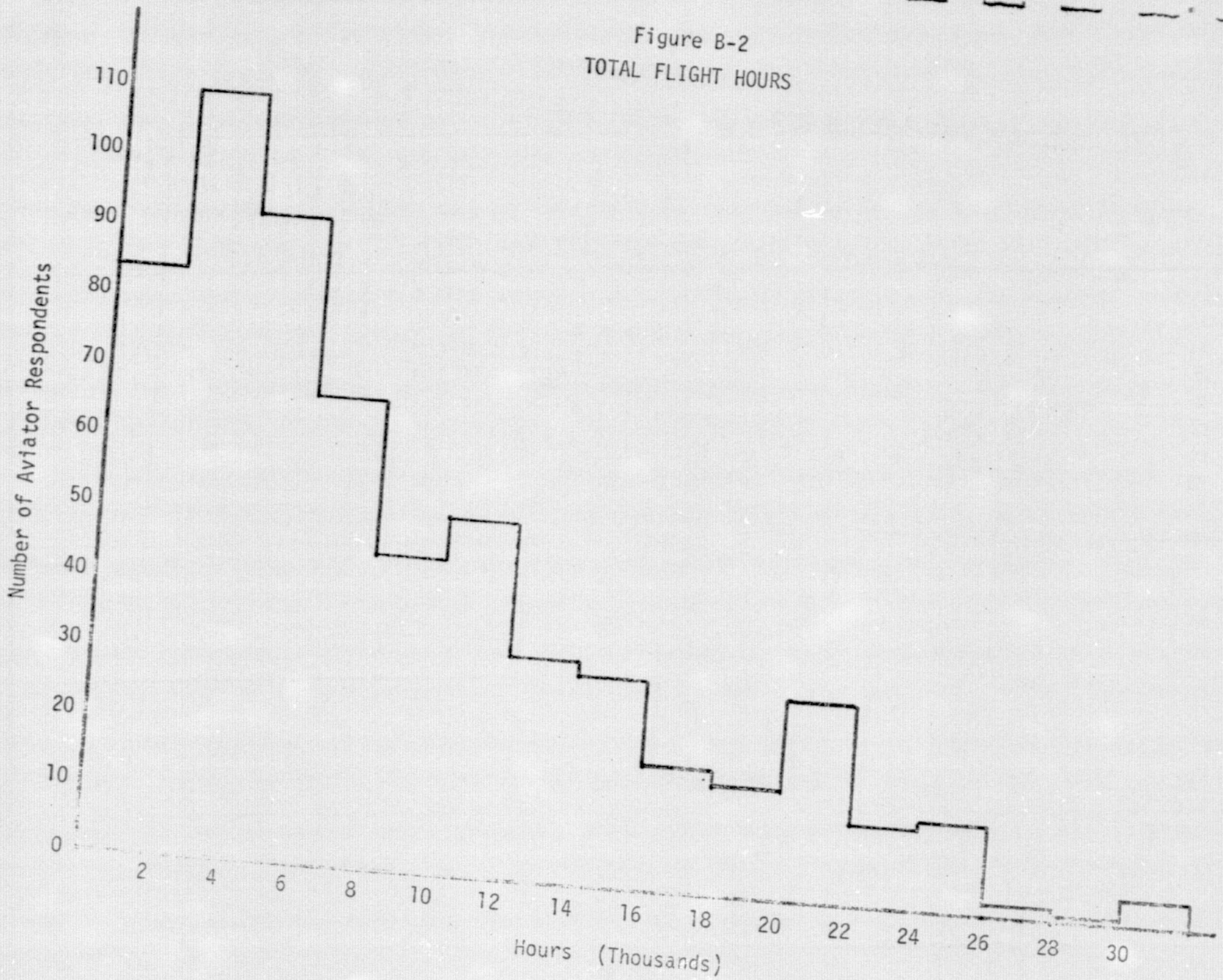


Figure B-3

DISPLAY OF AG FLIGHT HOURS vs YEARS OF EXPERIENCE

N=525

Ag Flight Hours	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	XX	Total
26																															1								1
24																																1							1
23																																							0
22																										1	1												2
21																																							0
20																					1					1				2	3	1							8
19																												1											1
18																								1						1									2
17																										1			1	2									4
16																					1	1		1							3								6
15																					1	2	.		1	2			2	1	5	2	1	2	1		2		22
14																1									2		1	1	1		1								7
13																										1			1									1	3
12																			1		2			1		2	3	2		2		1	1				1		13
11													1				1	1	1		2					1	1		1				1						10
10											1	1			1	1	2	1	1		2	1	1	1		1	1	2	3		6	2		1					20
9										1	1		1		1	1				2	1	1			2				1	1									13
8													1	1	1	1	3	1			4			3	2	3		2	2	3	2								29
7											4	2				4	1	2	3	1	4								3	2	1							1	23
6								1	1	1	1	2		1	2	2	1	2	1		2		3	3						1	3		1						23
5								2	1	4	4	5	7	3	1	5	5		3		1					2		1			2		1						47
4					1	1		4	8	3	3	1	2	2	2	2	4	2	2	1	2			2				1		1	1								45
3					1	6	1	5	5	4	12	1	4	1	3	3	1		1		4			1	1						1							1	55
2				1	3	16	11	6	5	4	12	2	2	1		4			1		4				1														73
1		1	2	14	12	13	6	6	5	3	8		1	1	1	1		1			3																	1	70
.8			1	4	4		1	2								1																							13
.6		2	6	8	2	2	1	1																															22
.4		2	5	4			1														1																		13
.2		9	7	1	2				2		1																												22
.000		6	2	1						1																													10
0	3																																						3
X			1			1			1				1								2						1	1			1							28	37
Total																																							

Years of Experience

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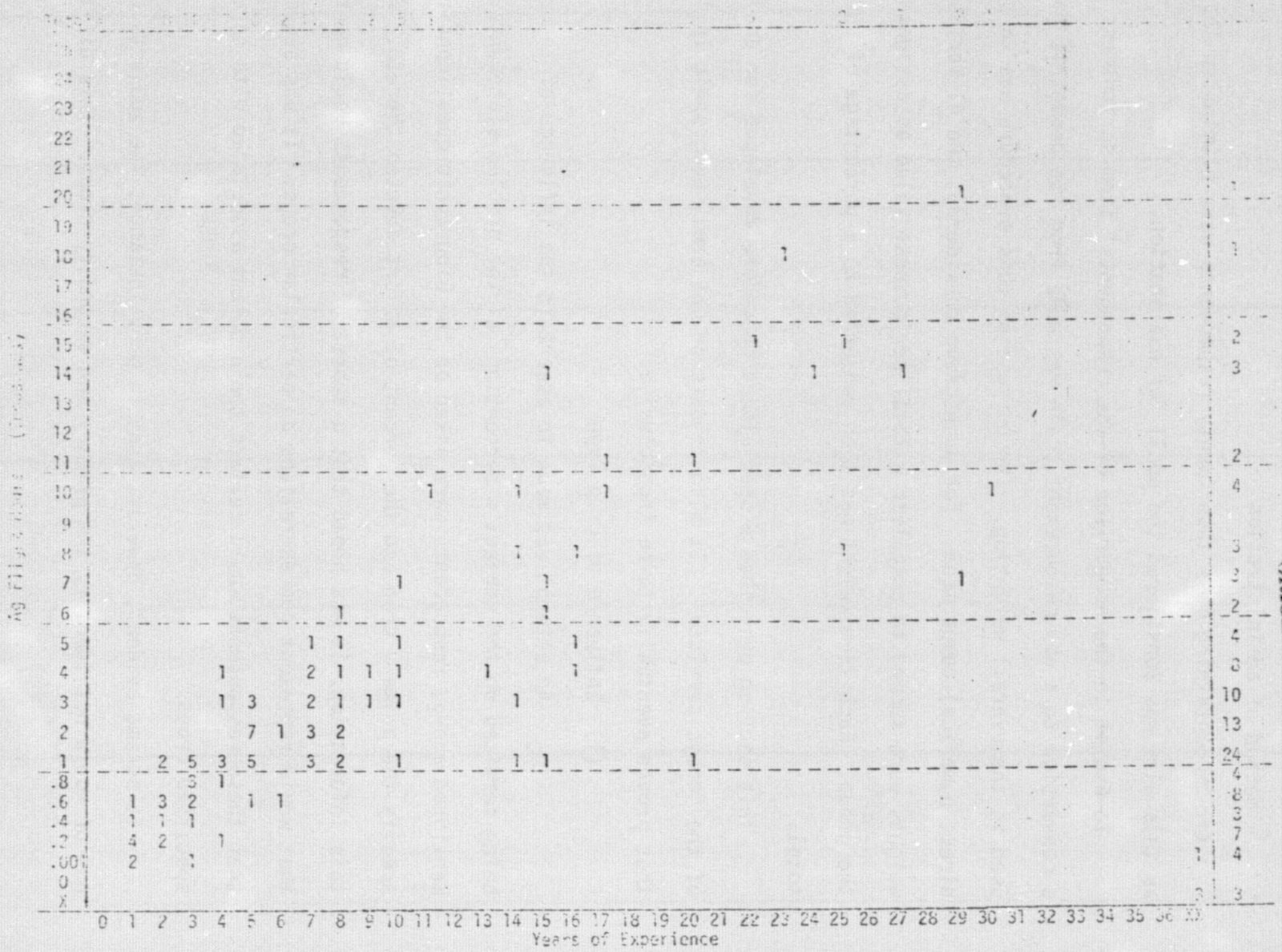
Figure B-4

DISPLAY OF AG FLIGHT HOURS vs YEARS OF EXPERIENCE

Pilots Only, N=109



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- Booklet type
- Reference item
- Method of administration

Groups containing less than twenty respondents were eliminated inasmuch as this size was considered too small for examination.

To assist in the comparison of the respondents' item-seriousness weights, a conversion to a new measurement scale was made from the geometric means used in the overall weighting. The purpose of this procedure was to permit direct numerical comparison. For each group considered, the 41 seriousness weights were summed to establish a total seriousness value as assigned by the group. Each item weight was then converted to a percentage of this total.

This section describes a specialized procedure developed for analysis of the "crops serviced". It also reports on one area, Geographic Influences, that proved eventually to be inconclusive.

(1) Influence of Crop Type

An attempt was made to ascertain the influence of the crop being serviced on the subject's perceptions of the problem statements. As mentioned above, respondents were asked on the biographic questionnaire to specify the primary crop and the percent of effort devoted thereto. From this information, it was hoped that a subset of respondents would emerge that would represent concentrations on particular crops. It was assumed that these respondents would reflect the problems associated with servicing specified crops.

It became evident, however, that in many instances the subjects could not or would not identify the primary and secondary crops. This difficulty

may have arisen from the fact that many could not designate a single crop as primary or that the determination was complicated according to whether "primary" referred to the resources committed to the crop, the financial returns, or time and effort involved. Also, frequently it was noted that more than one crop would be identified as "primary" or "secondary", or in many instances, the designation would be omitted entirely.

Consequently, any entry (a check-mark or a rank number) was considered to be merely an indication that the crop was serviced. The entry, "other", was considered to be a single, undesignated crop since the item was not always completed to show specifically the type of crop.

A three-step approach was devised, therefore, to define groups that could be considered to reflect this kind of specialization.

In the first step, states which are heavy producers (acreage and crop value) of a specified crop (i.e., wheat, cotton, or rice) were identified from the U.S.D.A. Statistical Reporting Services Reports (Ref. B8). In the second step, respondents were selected within these states who identified the crop under consideration as the primary crop (by inserting a "1" in the blank next to the crop), and who indicated that the specified crop was the only primary crop. From this group, those who indicated that they devoted more than 50% of their operation to the specified crop were selected as operators servicing the specified crop.

In this manner, only three groups of respondents could be identified:

a. Wheat - 56 respondents
b. Rice - 47 respondents
c. Cotton - 46 respondents

The results of this comparison are discussed in the main body.

(2) Geographical Influences

An investigation of the influence of location (state of operation) on perceptions was initiated during pre-test activities. Some variations were observed but no rationale relative to political boundaries could be established for these differences. It was concluded that other factors were influencing the results.

Respondents were asked in the final questionnaire to specify the location of operation. An attempt was made to combine states into agricultural regions as specified by the U.S. Department of Agriculture (USDA), but investigation of both USDA and Census regions yielded little refinement. The reason may lie in the fact that few related agricultural similarities exist within and among these regions.* Categorization of information by political boundaries and regions was nevertheless useful for bookkeeping purposes.

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* It was found that within regions, there were large variations by state in length of growing season. In addition, the climates of these states varied greatly with respect to average temperature, average humidity, and average windspeed.

ANNEX 1 to APPENDIX B

Definitions of the Problem Statements

Definitions of the Problem Statements

1. "In-the-field" repair and service of A/C: An aircraft maintenance and/or repair function that is performed by an operator's staff in a location other than at the operator's base of operation.

2. Length of engine and accessory time-between-overhaul (TBO): The time interval (number of hours) between major maintenance overhaul of the aircraft engine and its major accessories.

3. Engine reliability: The probability that the aircraft engine will perform predictably and consistently for a specified time under given conditions.

4. "Wash-down" of A/C, inside and out: A maintenance function that removes accumulated chemicals, dust, and debris from the interior and exterior of the airframe.

5. Corrosion inspection and control: The capability for inspecting all parts of the airframe for the presence of and/or the damage that may result from exposure to agricultural chemicals and moisture. Also included are the systematic attempts by operational procedures or mechanical means (i.e., paint, sealers, etc.) to limit future exposure and vulnerability within the airframe.

6. Availability of replacement A/C engine: The supply of, and access to replacement power plants within the aviation industry and market place.

7. "In-the-field" repair and service of dispersal systems: An aircraft dispersal system maintenance and/or repair function that is performed by an operator's staff in a location other than at the operator's base of operation.

8. "Flush-out" of dispersal system: A maintenance function, performed on the aircraft dispensing hardware, that is intended to remove any trace of agricultural chemical substances post-flight.

9. "Change-over" detoxification: A maintenance function, performed on the aircraft dispersal system to decontaminate the system during a change of mission when a possible threat of damage to vegetation exists from the incompatibility of the agricultural chemicals or other materials to be used.

10. Ground handling of payload -- proportioning, mixing, transfer, weighing, speed of operation: All pre-flight functions that are performed in the transfer of the agricultural chemical compounds from the ground storage area to the aircraft dispensing system storage cell.

11. Protecting ground crew from toxic materials: The safety measures taken to reduce exposure of persons participating in the operation (other than pilot) to noxious substances.

12. Adjusting dispersal systems to meet new application requirements: The flexibility and adaptability of the aircraft dispensing equipment to meet a variety of application technique requirements.

13. Rough-terrain TO and landing capability of the A/C: The performance characteristics of the structural components (landing gear, etc.) of the aircraft to permit take-off and landing under off-airport or off-runway conditions.

14. Short take-off and landing capability of the A/C: The performance ability of the aircraft to take-off and land safely under short field conditions or in the vicinity of perimeter obstacles.

15. Cruise speed: The in-flight speed of the aircraft to and from the field being treated.

16. Climb-out/dive-in capability of the A/C: The performance characteristics of the aircraft during the dispensing maneuvers of dropping into the field being treated (dive-in) and pulling out of the field being treated (climb-out).

17. Steep, short-radius turn capability of the A/C: The performance characteristics of the aircraft during the dispensing maneuver (high, narrow radius turn) that is required to complete one swath and begin another parallel, adjacent swath.

18. Stall Warning: An audio/optical/mechanical devise installed in an aircraft as a means of alerting the pilot to the onset of stall.

19. Swath guidance: Signals or instructions that enable the pilot to dispense on a pre-selected target in a line of a specified width (swath) with prescribed overlap.

20. Monitoring of individual nozzles/gates in flight: A pilot activity that provides information as to the functioning of the individual primary dispensing units of dispersal system while in-flight.

21. Monitoring flow rate: A pilot activity that involves the monitoring of the rate at which the application chemical is being dispensed.

22. Drift: The deviation of a chemical droplet or particle from its target area as a result of variations in the droplet size and weight, the altitude at release, and existing meteorological conditions.

23. Uniform dispersal pattern -- providing even lateral (side-to-side) distribution in a swath: The distribution pattern of the chemical droplets or particles over the width of the swath irrespective of distance traveled.

24. Selecting dispenser turn-on/off points: A decision as to the optimal point, within one swath, at which to begin and end dispensing operations.

25. Effects of varying ground speeds on dispersal: The stability and uniformity of the dispersal pattern under changing aircraft speeds.

26. Confirming uniformity and concentration of application post-flight: A post application procedure that involves close scrutiny of the treated field to verify the quality and accuracy of the application.

27. Determining uniformity of coverage and dosage of application during flight: An in-flight procedure that involves inspection of the field by the pilot to determine the quality and accuracy of the application.

28. Capability of the cockpit area to survive a crash: The structural integrity of the cockpit upon impact that prevents undue injury to the operator.

29. Fire prevention and protection: Aircraft subsystems, installed equipment, materials, and procedures employed to reduce or eliminate damage and/or crew injury resulting from inflight or crash-induced fires.

30. Maintaining A/C control during dump: The ability of the pilot to maintain safe flight altitude of the aircraft upon initiation of and during the emergency procedure that expells the payload from the dispensing system storage cell.

31. The accumulation of dust and chemicals on windscreen: A visual hazard caused by the adherence of foreign, opaque matter to the aircraft windscreen during flight.

32. Cockpit visibility (unobstructed view): The ability of the pilot to have a view of the operation in all attitudes unobstructed by the airframe or components.

33. Location and design of cockpit flight and emergency controls: The ability of the pilot to reach and engage flight and emergency controls with ease. Note: this also implies protection from inadvertent actuation of certain controls.

34. Stick force effort during maneuvers: The amount of control effort required by the pilot during aircraft maneuvering.

35. Cockpit comfort: The degree to which the cockpit provides a comfortable, fatigue-reducing environment.

36. Protecting pilot from toxic substances: The safety procedures that reduce or eliminate the pilot's contact with agricultural chemicals being dispensed.

37. Mid-air collisions: The collision of two or more aircraft in flight.

38. Ground obstacle detection and avoidance: The ability of the pilot to visually identify and anticipate ground hazards (power lines, trees, etc.) and adjust his flight path accordingly.

39. Fuel consumption: The amount of fuel consumed by the aircraft during an aerial application operation.

40. External A/C noise: The amount of external noise generated by the aircraft during normal operations.

41. Flexibility of A/C to meet different Ag requirements: The ability of the aircraft to adapt to a variety of application techniques.

ANNEX 2 to APPENDIX B

Polling Format Instructions

and a

Typical Listing of Problem Statements

ANNEX 2
Explanation

A series of four variations (Booklets A, B, C, D) of the polling format were used. Each booklet represents a different random ordering of the 41 problem statements. The sample included in this annex is a copy of Booklet A only. The instructions are the same for all booklets.

All presentations in the main body of the report are in terms of a master code number. A table relating the individual item numbers of each booklet to the master code is attached for convenience (Table B-II).

Here is a list of problems affecting Ag Aviation operators and pilots. You are asked to judge how SERIOUS each problem is to you (with respect to daytime operations).

INSTRUCTIONS

- The items are in no particular order
- One item has already been given an arbitrary value of 10 and is to be used as the basis of comparison as you judge the SERIOUSNESS of the other problems
- Procedure

  1. Compare the first "problem" with the designated "comparison" item. Judge how much more or less SERIOUS the first item is than the "comparison" item. It if is 3 times as SERIOUS, enter '30'. Or, you may feel it is 16 times as SERIOUS, in which case enter '160'. If you should consider it to be only half as SERIOUS, enter '5' .... and so on.
  2. You may enter any number, even fractions or decimals, but do not use 0 (zero) or negatives.
  3. Compare the next item in the list with the "comparison" item and enter the number that shows how much more or less SERIOUS it is than the "comparison" item.
  4. Continue through the list.

Booklet A_____

P R O B L E M S

_____ 1. "Wash-down" of A/C, inside and out

_____ 2. Monitoring of individual nozzles/gates in flight

_____ 3. Determining uniformity of coverage and dosage of application during flight

_____ 4. Cockpit visibility (unobstructed view)

_____ 5. Capability of cockpit area to survive a crash

_____ 6. "In-the-field" repair and service of dispersal systems

_____ 7. "Flush-out" of dispersal system

_____ 8. Uniform dispersal pattern - providing even lateral (side-to-side) distribution in a swath

_____ 9. Corrosion inspection and control

_____10. Steep, short-radius turn capability of the A/C

_____11. Adjusting dispersal systems to meet new application requirements

_____12. Confirming uniformity and concentration of application post flight

_____ 13. Ground obstacle detection and avoidance

_____ 14. Mid-air collisions

_____ 15. Maintaining A/C control during dump

_____ 16. Drift

_____ 17. Monitoring flow rate

_____ 18. Rough-terrain TO and landing capability of the A/C

_____ 19. Availability of replacement A/C engine

_____ 20. "In-the-field" repair and service of A/C

_____ 21. Protecting pilot from toxic substances

_____ 22. Swath guidance

_____ 23. Cockpit comfort

_____ 24. Flexibility of A/C to meet different Ag requirements

_____ 25. Ground handling of payload - proportioning, mixing, transfer, weighing, speed of operation

_____ 26. Engine reliability

_____ 27. Fuel consumption

_____ 28. External A/C noise

_____ 29. Stall warning

_____ 30. Stick force effort during maneuvers

_____ 31. Effects of varying ground speed on dispersal

_____ 32. Fire prevention and protection

_____ 33. Short take-off and landing capability of the A/C

_____ 34. Protecting ground crew from toxic materials

_____ 35. The accumulation of dust and chemicals on windscreen

_____ 36. Cruise speed

_____ 37. "Change-over" detoxification

_____ 38. Climb-out/dive-in capability of the A/C

_____ 39. Length of engine and accessory time-between-overhaul (TBO)

_____ 40. Selecting dispenser turn-on/off points

_____ 41. Location and design of cockpit flight and emergency controls

IMPORTANT: PLEASE COMPLETE THE BACK PAGE

Table B-II

Item Order of the Problem Statements in the Test Booklets

Master Item No.	Item Order			
	Booklet A	Booklet B	Booklet C	Booklet D
1	20	20	38	31
2	39	29	29	21
3	26	31	40	35
4	1	19	13	16
5	9	41	4	28
6	19	14	26	8
7	6	9	9	26
8	7	2	25	9
9	37	1	35	15
10	25	10	6	34
11	34	32	12	39
12	11	15	3	17
13	18	23	1	1
14	33	38	36	23
15	36	35	27	40
16	38	17	24	6
17	10	37	21	14
18	29	18	30	36
19	22	4	22	22
20	2	33	20	12
21	17	5	8	19
22	16	39	16	20
23	8	26	32	27
24	40	16	23	41
25	31	40	41	38
26	12	25	18	29
27	3	13	15	3
28	5	3	5	4
29	32	28	17	7
30	15	12	31	18
31	35	34	14	2
32	4	30	37	25
33	41	6	39	30
34	30	27	7	37
35	23	21	11	33
36	21	36	10	32
37	14	8	33	11
38	13	7	34	13
39	27	11	28	24
40	28	24	2	10
41	24	22	19	5

ANNEX 3 to APPENDIX B

Polling Format

Biographical Questionnaire

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PLEASE COMPLETE THE FOLLOWING:

1. In what state(s) do you operate? _____

2. Are you an: Ag Pilot? Yes____ No____

   Ag aviation service owner and/or manager? Yes____ No____

   Allied industry member? Yes____ No____

3. If a pilot, you have: _____hours total flight time

   _____Ag flight hours

   _____years of Ag aviation experience

4. You principally operate: (check)

   a. Helicopter____

   b. Fixed wing____
      - Over 12,000 lbs GW ____
      - 4,000-12,000 lbs GW____
      - Under 4,500 lbs GW ____

5. In the following list:

   a. Check each crop you service
   b. Place a '1' next to the primary crop
   c. Place a '2' next to the secondary crop

__(1) Alfalfa, clover
__(2) Berries
__(3) Citrus orchards
__(4) Corn, field
__(5) Corn, sweet
__(6) Cotton
__(7) Forests (wood products
__(8) Fruit orchards
__(9) Grain (wheat, rye, oats, barley,etc.
__(10) Grapes
__(11) Milo, sorghum
__(12) Range land
__(13) Rice
__(14) Soybeans
__(15) Sugar cane
__(16) Tobacco
__(17) Vegetables
__(18) Other_____ (Specify)

6. What part of your total operation is devoted to your

   a. Primary crop? _____%
   b. Secondary crop? _____%

7. What percentage of your operations are:

   a. Wet dispensing? _____%
   b. Dry dispensing? _____%

8. Which of the following do you perform? (check all that apply)

   a. Pest control non crop only_____
   b. Fire fighting: Water _____
      Chemicals _____
   c. Aerial seeding _____
   d. Night operations _____
   e. Rights-of-way (herbicides)_____
   f. None of these _____

Appendix B References

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