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Cockpit Communication and Aircraft Safety: An Empirical Study

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Abstract

Several investigators have recently put forward the possibility that members of the flight crew may have been aware of problems before accidents, but that difficulties in communication may have prevented them from taking appropriate corrective actions. This has led to an'increased interest in the process of cockpit communication and the group dynamics of flight crews.

Although early studies have been useful; nonetheless, the study of cockpit communication is still relatively undeveloped. Accordingly, the present study was designed as a preliminary effort to identify the principle concepts which control cockpit communication.

The study consisted of two phases. In the first phase twenty-four in depth interviews were conducted with flight crews of general aviation aircraft. The major concepts identified in these unstructured interviews were then incorporated into a very precise Galileo(tm) type questionnaire which was administered to additional flight crews.

Although this study should be considered preliminary, several strategies for improving cockpit communication were identified. Should further research confirm the usefulness of these types of strategies, they might be appropriately included in flight crew training programs to increase the likelihood that flight crew members would report unusual or hazardous circumstances early enough for corrective actions to be taken.

The Problem

A complete discussion of the problem of cockpit communication is not possible here given space constraints. However, a review is available from the authors. Given those limitations, at this point we must simply state that the thrust of the available literature, shows clearly a need for increased attention to communication processes in the cockpit, and an analysis of the flight crew as a system, rather than as isolated individuals. Moreover, trends in aviation also warrant an extension of these studies beyond the large carriers and into the area of general aviation.

The main goals of the present research, therefore, are to provide some preliminary data and analysis concerning the process of communication within the cockpit for general aviation crews.

The Theory

A complete hypothesis synthesizing physological, sociological, and methodological considerations into a coherent theory of pilot performance and behavior predictability has yet to be formulated. We are, however, at an initial state where experimental work is needed to detect how communications difficulties are related so that some corrective measure can be introduced into the human cockpit system before an in-flight situation becomes an accident.

Currently, aviation research is simultaneously suggesting theories to explain behavior that include two distinct approaches to the study of science, namely, Reduction Theory and Systems Theory. While both approaches are valid and useful, both contain theorectical constructs that are mutually exclusive. For example, reductionism, or trying to explain a whole phenomena by investigating the smallest pieces that compose the whole, is the thought orientation that underlies the psychological orientation to explain the behavior. On the other hand, characterizing United Airlines' directive to "have a more efficient, proficient and safe operation," as a goal, verbalized as "striving for synergism in the cockpit," (Carroll,1981,p.8) indicates a systems approach is being applied to solve the problem.

Using systems theory as a fundamental approach, communications scholars are suggesting a new model to more fully explain all human communication. Called the Convergence Model, the new model describes communication as "a process in which the participants create and share information with one another to reach mutual understanding" (Rogers,Kincaid,1981,p.63).

This exchange between individuals who are processing information from the environment simultaneously creates new information that must also be processed. This new information is called feedback.

According to advocates for this theory of viewing communication processes, "No human system can function properly, that is, to be coordinated to accomplish a set of goals, without feedback" (Rogers,Kincaid,1981,p.61).

Not surprisingly, one of the positive solutions offered by Capt. R.F. Gabriel, Douglas Aircraft Corp., to improve pilot performance in the cockpit was exactly what Rogers, Kincaid, and others considered a prerequsite for proper functioning of the human communication system, none other than, "Feedback."

Flight Crew Magazine, Fall, 1981, quotes Gabriel as saying:

> Feedback offers great benefits for improving performance. No other variable has been shown to have the same immediate effects. The

cessation of feedback can cause an almost immediate reduction in performance...

Intellectually and operationally, the aviation community has embraced the constructs without utilizing the measurement technique that goes with it.

The Convergence Model is a very general model which applies to human, non-human and even non-living thermodynamic systems. In order to apply Convergence Theory to a specific human communication system, a more specific (and measureable) model is needed. Most convergency theorists apply what has been called the "Galileo" theory to model human communication systems (Woelfel, Fink, 1980).

Galileo Theory considers any communication situation as a system of "objects" arrayed in a "space." Each object represents an essential concept, idea, or aspect of the communication situation as it is defined by its participants. The <u>distances</u> among these objects in the space represents the relationships among the objects as the participants in the situation see them. Objects that pilots think are similar or "go together" will be located close to each other in a Galileo space. Objects which are very different (such as "Safety" and "Flying into the Ground"), for example, will be located far apart.

The Galileo Theory bridges the gap between older reductionist theory and modern systems theory because it includes older concepts such as beliefs and attitudes within an overall system. The distance between any object and any other object represents a "belief". The distance between any object and "Yourself" represents an "attitude". The system of all these distances and relationships, taken together, consitiutes a Galileo "space".

A great deal of research shows that the structure of Galileo spaces is importantly related to the behavior of both individuals and systems of people (like the flight crew).

The Method

The first step in implementing any Galileo type research is to determine what objects make up the situation as its participants see it. In this case, that required determining what objects pilots and co-pilots believe make up the situation in which cockpit communication takes place. Usually, this information is gained from focused in-depth interviews. In the first stage, twenty-four general aviation pilots were interviewed at length. The interviewer was a female and introduced herself, or was introduced by an associate of the pilot to be interviewed, as a private pilot, with an academic interest in the study of communications. The pilots were asked to speak as long as they wished about anything dealing with aviation, anything at all. The interview was completely unstructured and leading questions were deliberately avoided. Instead, the interviewer added only probes to comments made, such as, "This is interesting, can you tell me more...can you be more specific...do you have an example." Only when the pilot being interviewed indicated that he has said all that he wanted to say was the interview terminated.

The interviews were conducted on ten (10) different days between September and December, 1984. The interviews took place at four different physical locations, in three states and represented fourteen (14) different companies or organizations. All the interviewees were male. Aviation experience, as measured by the total flying hours and job description of the interviewee, ranged from a new hire co-pilot on a King Air with 875 hours, to a Director of Flight Operations for a Fortune Five Hundred company with 24,000 hours. The median time was 6,550 hours; the average, or mean, was 7,561.46.

All pilots operated in a two person environment most of the time. The most notable exception was flights to maintenance facilities in aircraft that were rated single pilot, In such cases, which usually meant flights without corporate passengers, some pilots flew the mission single-pilot. The age of the pilots interviewed ranged from 25 to 72; the median age was 37; the average, or mean age, was 37.38.

Since it is policy in some operations for one person to have the rank and responsibility of captain, but to also fly as a co-pilot depending upon senority or type of equipment, it was impossible to categorize respondents as either "captains," or, "co-pilots"; however, some additional demographic information illustrates the pains taken to have the sample representative of the professional pilot segment of the general aviation population.

Of the 24 pilots taking part in the interview portion of the study, two were exclusively helicopter rated, and a third flew both rotary and fixed wing aircraft, We spoke to one Director of Flight Operations for an aviation department having 16 pilots, two chief pilots for Fortune Five Hundred corporations, and two owner/operators of relatively small charter operations, with piston, turbine, and jet aircraft in their respective fleets.

Of the remaining 16 pilots, six (6) described themselves as flying in the position of captain exclusively, or most of the time; five (5) described their flying time as a 50/50 split between captain and co-pilot, depending on equipment assignment or senority of the other pilot; and, five (5) described themselves as always, or usually always, flying as a first officer.

The interviews were transcribed verbatim into Galileo* CATPAC(tm), a computer program that counts words and searches for words that occur together, called word clusters. The actual words, plus the clusters of frequently co-occurring words are indicators of concepts that exist in the minds of the pilots being interviewed. Thus, we had a count of the most commonly used words, and a mathematical account for the concepts most frequently envoked by general aviation pilots to describe aviation.

Drawing from the information provided from the cluster analysis, and from the content of the interviews as well, seventeen (17) major concepts or "objects" were identified. These concepts seem to be the most important underlying ideas or themes which represent pilots' and co-pilots' understanding of the cockpit situation as they think of it.

The second step in a Galileo-type experiment is to measure the structure of the pilots' and co-pilots' beliefs and attitudes about these 17 concepts. Since these 17 concepts constitute a system of ideas, however, rather than a set of isolated beliefs and attitudes, it is necessary to measure all possible inter-relationships among the objects. This requires each pilot and/or co-pilot to specify the differences between each concept and all 16 of the remaining concepts for the complete 136 [(17 X 16) / 2] possible pair comparisons. This is done on a precise mumerical scale which is unbounded in principle, but in practice usually yields numbers between 0 and about 5000 (Woelfel, Fink, 1980).

In addition to the quantitative Galileo-type questions, pilots were also asked to offer their opinions about communication and safety in response to several open-ended questions.

Thus far, the questionnaire has been distributed to 117 general aviation pilots in nine different operation in four Northeastern states. The director of flight operations and/or chief pilot was informed of the nature of the project and asked to distribute the questionnaires to members in their flight depart-ments. If he/she was willing to allow the pilots in the operation to voluntarily complete the questionnaire, the contact person was sent one questionnaire for each pilot. To insure confidentiality, the questionnaire came with a pre-addressed envelope so the respondent could return the questionnaire directly to the researchers.

Results

Results at this juncture are extremely preliminary. They cannot be construed to be definitive, except to say that the overwhelming interest and support exhibited by the members of general aviation community for more study. Of the 24 people responding to date, 23 indicated in open ended questions that communication is a prime consideration in safe crew operations.

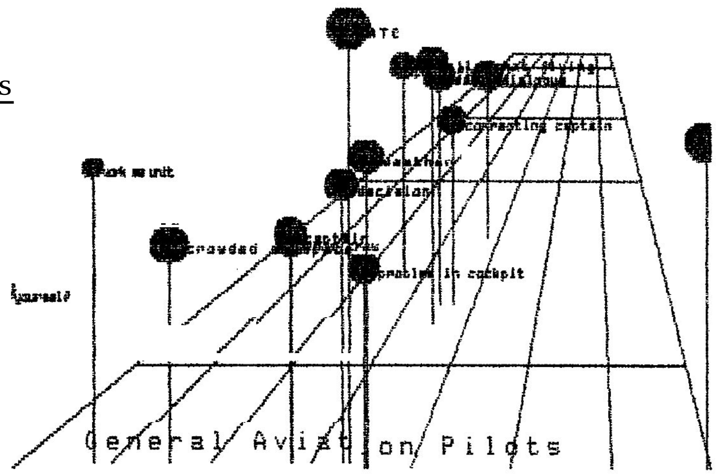
The Structure of the Communication Situations

The overall structure of the pilots' attitudes and belief system is shown in Figure #l. Our most precise understanding of the structure of the communications situation can ultimately come from the Galileo type data, but these preliminary 24 cases should only be taken as an indication of what may be possible when further data are available.

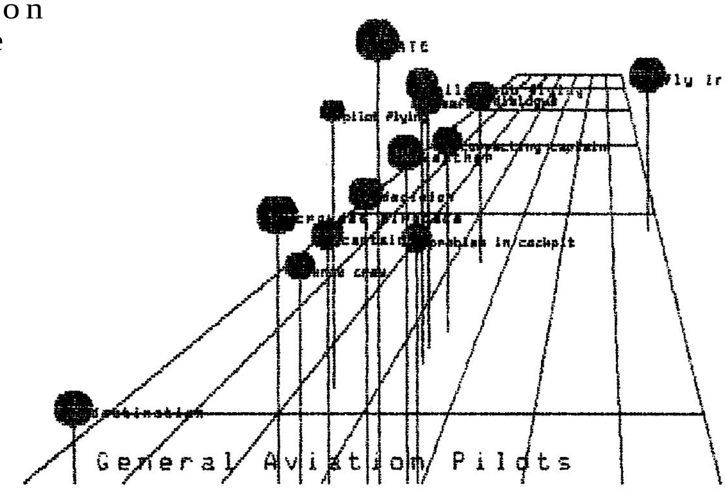
Figure 1: Galileo Structure of Pilots' Attitude and Belief System

The Structure of the Communication Situations

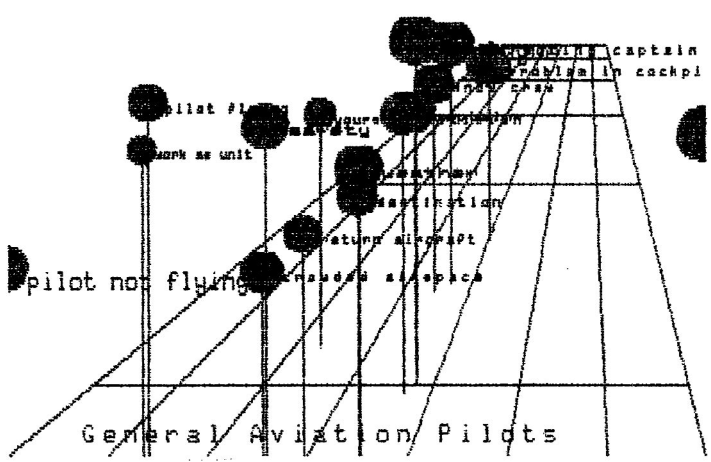
The overall structure of the pilots' attitudes and belief system is shown here. (Figure #1) Our most precise understanding of the structure of the communications situation can ultimately come from the Galileo type data; but, these preliminary 24 cases should only be taken as an indication of what may be possible when further data are available.



Front View



Side View



Top View

Table #1

Attitudes and Beliefs of 24 General Aviation Pilots Toward Safety

(Smaller numbers indicate close association; large numbers indicate less association.)

	1. Safety	17 Yourself
1. Safety	--	5.57
2. Pilot Flying	2.21	12.87
3, Pilot Not Flying	3.89	16.62
4. Dialogue	5.55	15.64
5. ATC	5.16	20.00
6. Flying into the Ground	40.63	64.56
7, Problem in the Cockpit	13.72	10.21
8. Correcting the Captain	7.38	10.00
9. Weather	9.22	5.66
10. Getting to Your Assigned Destination	20.38	7.13
11. Bringing the Aircraft Back	16.22	8.07
12. Knowing the Other Crew Members Personally	17.73	14.28
13. Working Together As a Unit	1.05	3.60
14. Crowded Airspace	11.15	9.07
15. Decision	3.00	1.53
16. Captain	6.00	.73
17. Yourself	5.57	--

Table #1 points out some of the main features of this structure. The first column shows the distances from "Safety", (Concept #1) to each of the remaining objects. Objects which pilots associate with "Safety" are "close" to "Safety" in the Galileo Space. Thus, "Working Together as a Unit" is only 1.05 units from "Safety", while "Flying into the Ground" (obviously an unsafe process) is 40.63 units from "Safety".

The second column of Table #1 shows the distances between the pilot's own position or sense of identity, or "Yourself", (concept #17) and all other concepts. Notice the concept, "Captain", is less than one unit (.73) from "Yourself", where "Flying into the Ground" again, is over 64 units from the self.

While these data warrant no more than preliminary confidence, they reveal a structure which is remarkably like what we would hope to see. The pilots are quite close to "Safety", "Decision", "Working Together as a Unit", "Getting to the Assigned Destination", and "Bringing the Aircraft Back". They see, "Working as a Unit", "Decision", both "Pilot Flying" and "Pilot Not Flying", and "Correcting the Captain", as close to "Safety".

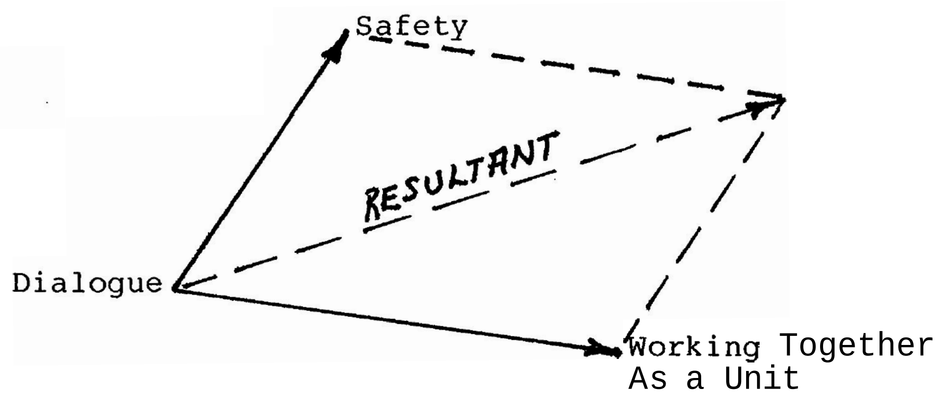
Since the picture of the attitude and belief system of these pilots is quite sensible and exhibits no obvious flaws in structure, and, since aircraft are, in general, so safe, it would be very imprudent to recommend changes in these belief systems hastily. What we will do here is to illustrate how this might be done should further research indicate the merit of such a campaign.

If we were to assume that increased dialogue would result in greater safety, the Galileo Model could evaluate all possible strategies for moving "Dialogue" closer to the pilot's self concept in the Galileo map. This is done in a manner quite analogous to ordinary navigation, since research indicates that messages take the form of vectors in the Galileo space. If one says, for example, that "Dialogue" is related to "Safety", this message may be represented as a vector in the Galileo space from "Dialogue's" coordinates to "Safety's" coordinates.

Equally important, message vectors in Galileo space actually behave mathematically like vectors. Thus, if one says that "Dialogue" is associated with "Safety"(V1), and "Working Together as a Unit"(V2), then the actual course travelled by "Dialogue" will be along the resultant of these two vectors. The following figure explains.

Figure #2

Messages as Vectors in a Galileo Space



Once again, it is important to make clear the fact that sufficient evidence does not now exist to warrant changing pilot's attitudes toward "Dialogue". If it should at some future time, however, the following examples show how Galileo methods could be useful in such an effort.

Figures #3 through #8 are computer drawn maps of the "Galileo Space" of the professional pilots from the business sector of general aviation who returned our questionnaires.

Figures #3 through #8 show examples of different message strategies in pilots' conception of the word "Dialogue". The pictures differ only in angle of view, including top view, side view, et cetera.

In these examples, the "Target" is a point in Galileo space you wish to approach, It is always the self point, or "Yourself". The "Start* concept is the one you wish to move. For example, in Figure #3, the "Start" concept is "Dialogue". It is located 15.64 units from the "Start" concept, "Yourself''.

Figure #4 shows a message that uses two concepts from the pilots' mind, *Working Together as a Unit*, and "Pilot Flying'. The question is, if one wanted to bring "Dialogue" and "Yourself" closer, is "Working together as a Unit* and "Pilot Flying" a good message? The answer is yes. If these two concepts were used, only 8.6 units would remain between them, down 55.1% from the initial distance of 15.64 units. In other words, you are about half way to where you wan't to go.

Figure #5 showing the message "Pilot Flying", "Working Together as a Unit", and "Safety", is slightly better than the message without the addition of the concept "Safety". This message will leave you just 7.9 units from the target, "Yourself" when you start out with the concept of "Dialogue".

Figure #6 shows that a message using the words, "Safety", "Problem in the Cockpit", "Crowded Airspace", and "Captain",is an exceptionally good message if aligning the concepts of "Dialogue", and "Yourself" was considered desirable. Joining the the concepts "Safety" , "Problem in.the Cockpit", "Crowded Airspace," and "Captain" into one message will result in the two sets of concepts being drawn very close, to within 1.1 units of each other in Galileo space.

Figure #7 is similarly effective. A message using the concepts, "Know the Crew Members Personally", Crowded airspace," and "Captain" will also leave just 1.1 units between the "Start" and "Target" concepts mentioned above.

Figure #8 is illustrative of concepts that would be only marginally useful, and definitely less effective than the messages already mentioned in Figures #4,#5,#6,and #7. If one wanted to close a gap between the concepts "Dialogue" and "Yourself" with the concepts "Safety" and "ATC" the distance would be reduced somewhat, from 15.64 units to 14.5 units, or about 92% of the current 15.6. In other words, the concepts in the group mind would be changed some by this message, but the concepts mentioned in Figures #7 and #8 are considerably more effective in shortening the space between the start concept, "Dialogue" and the target, "Yourself".

Repeating what we have already said, it is important at this early juncture to make it clear that sufficient evidence does NOT exist to warrant changing pilots' attitudes toward "Dialogue".

Conclusion

The amount of cooperation we encountered in the general aviation community was beyond our expectations. Our research idea was warmly received where ever we went. Even in flight operations that were overloaded, we were encouraged to come back when specific intervening factors, such as moving, or training on new equipment subsided. When management was involved, they cooperated unconditionally, never asking to see individual responses.

Likewise, the line pilots who have participated have indiciated an extraordinary amount of interest and patience in completing the questionnaires, again in the expressed hope that we could synthesize this material into some coherent theory or program. Thus far, the response rate is approximately six times higher than the national average for unsolicited multidimensional questionnaires, and about seven times higher than for unsolicited questionnaires of any type.

Although the results are extremely preliminary, the first cognitive map of the attitudes arrayed in a "Galileo" space show that the concepts of "Safety", "Yourself", and "Working Together as a Unit" are closely associated with each other in the minds of the general aviation, professional pilot population. For example if one were to choose to move the concept "Working Together as a Unit", and try to place it closer in the pilots' minds to the concept of "Safety", it would be a short trip, since the concepts are already just 1.05 units apart.

Overall, Galileo results shows a cognitive structure quite close to what one might ideally hope to find in pilots. This is not to say that no change in pilots' attitudes is called for, but rather that one should be very careful not to distort what is already quite clearly a very successful system by acting too hastily.

The article also illustrates the usefulness of Galileo as a method of implementing changes in the pilot communicative system, should additional study prove this to be desirable.

Much further research is needed. Clearly, much larger samples are required. Comparisons among airline pilots and general aivation's professional pilots are needed. Moreover, laboratory experiments on the effects of increased dialogue on in-flight performance are clearly called for.

Footnotes

1. Another portion of the questionnaire asked the general aviation pilots five of the ten questions asked airline pilots in the behavior/attitude study conducted by Helmrich. The mesaurement scale to report the findings was a 5 item Likert Scale, with 1 indicating Strong Agreement and 5 meaning Strong Disagreement. These data are not discussed in the present paper.

Fig. #3

Please enter target(s)
-1 when done.
yourself
-1
Please enter start concept.
dialogue
-1
The distance from start
to target is 15.64 units.
Please enter words to be
tested, -1 when through.

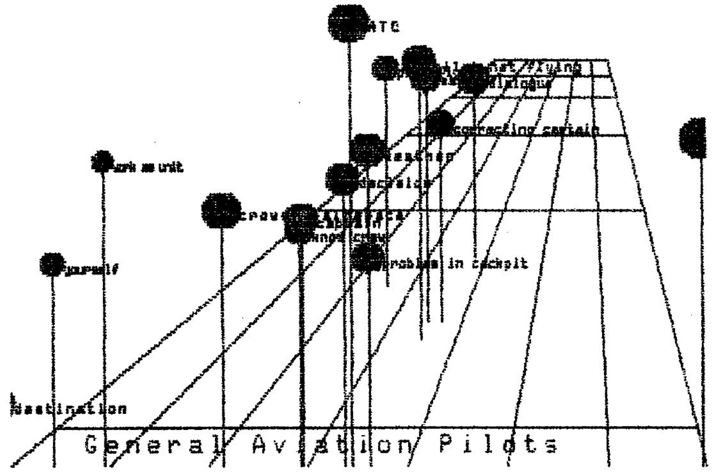


Fig. #4

The message
work as unit
pilaf; Flying
will leave you 8.5 units
from your target.
This is 55.1%
of the present distance.

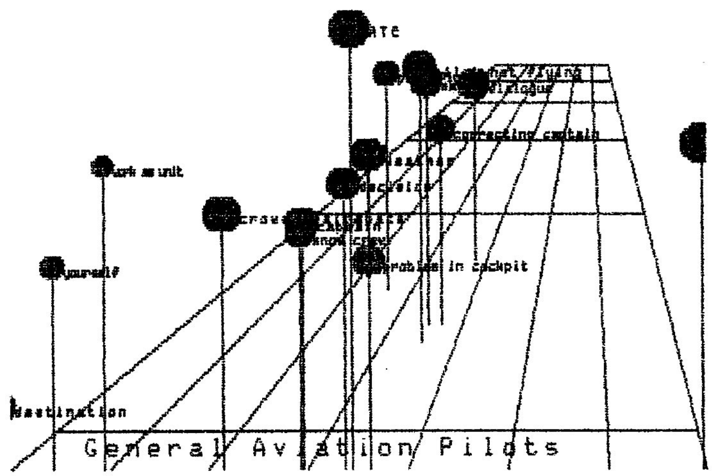
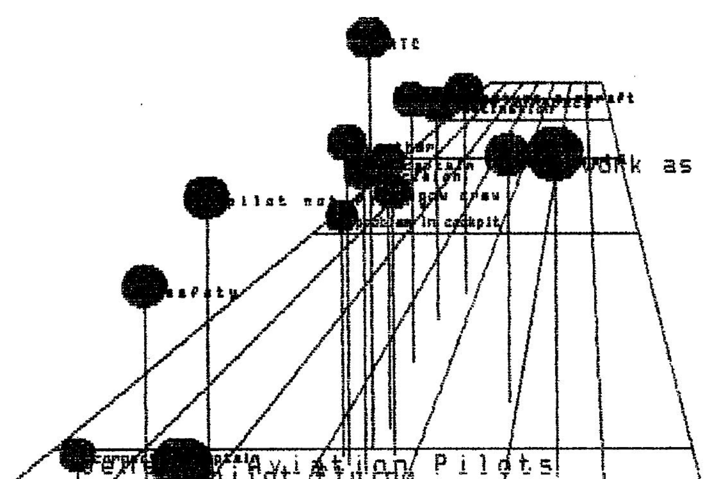


Fig. #5

The message
pilot flying
work as unit
safety
will leave you 7.3 units
from yaw target,
This is 50.6%
of the present distance.



The message

Fig. #6

The message
safety
problem in cockpit
crowded airspace
captain
will leave you 1.1 units
from your target.
This is 6.7%
of the present distance.

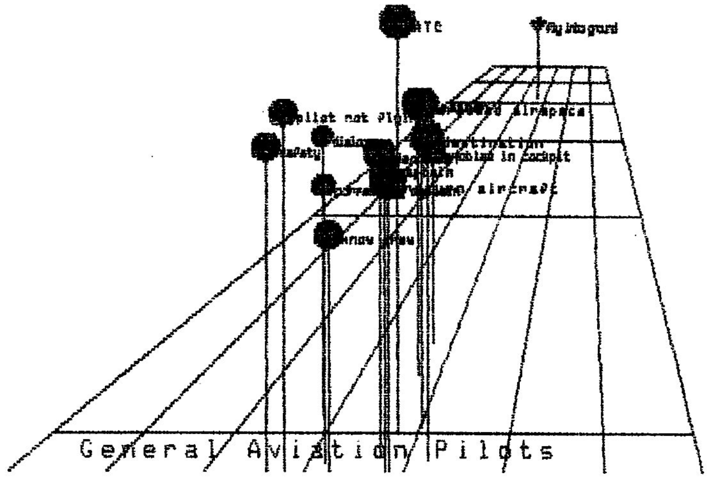


Fig. #7

The message
know *crew*
crowded airspace
captain
will leave you 1.1 units
from your target.
This is 6.9%
of the present distance.

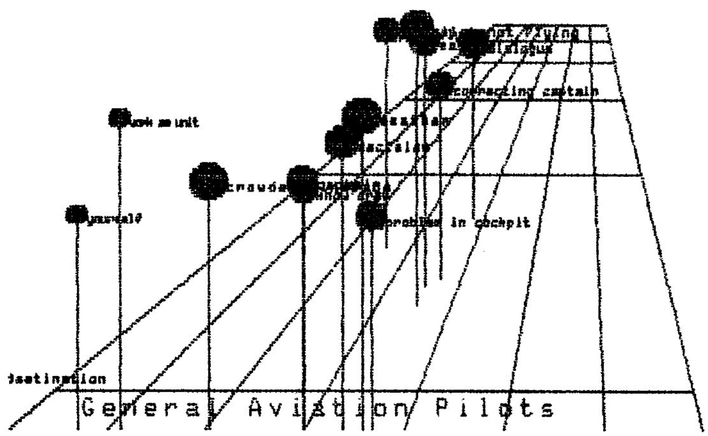
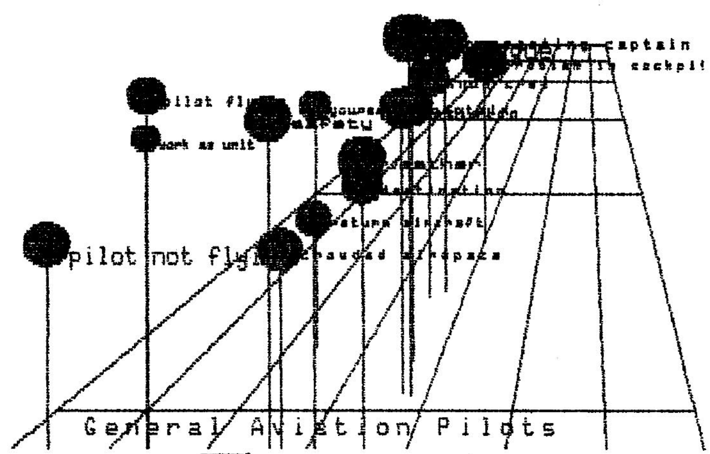


Fig. #8

The message
safety
ATC
will leave you 14.5 units
from your target.
This is 92.4%
of the present distance.



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