Pilot Attitudes toward Automation

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Abstract: Pilots flying the Boeing 757/767 for a large US-based airline responded to a survey containing 16 attitude probes concerning autoflight automation. Their responses indicate that pilots feel more comfortable with automation as their experience of automation increases. Comparing their responses to those obtained by Earl Wiener a decade ago at another carrier reveals remarkable stability in the community of airline pilots flying this airplane. A cross-correlational analysis of the attitude probes shows that pilots group the probes in terms of facilitation of and interference with the job of flying. This analysis also suggests that pilots are concerned about challenges to pilot authority. A cross-correlational analysis of the pilots reveals variability among the pilots in the dimensions of ``discomfort with automation" and ``automation as magic".

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Introduction

This report is part of a continuing study of pilot conceptions about cockpit automation. The goal of the project is to better understand what pilots of modern airliners know and believe about the automation, especially the autoflight functions, of the airplanes they fly. The project seeks to document the knowledge and attitudes and to discover how these are distributed among the pilots in the airline fleets. This report focuses on attitudes toward automation. A later report will discuss the content of the knowledge pilots have about autoflight functions.

The study described here examined attitudes toward automation among pilots flying the Boeing 757/767 for a large airline. The Boeing 757 and 767 are different airplanes of quite different sizes. However, the cockpits of the two airplanes are nearly identical, only a few switches differ, so they are considered to be a single fleet, and pilots earn a single type rating that qualifies them to fly either airplane. See figure 1.

The 757/767 has a moderate level of flight automation. It has a complete Flight Management Computer System (FMCS) which can be programmed to guide the airplane through a complete flight from shortly after takeoff until the after-landing rollout. It also has a partial Electronic Flight Instrument System (EFIS). The attitude indicator and the lateral navigation display (ND) are computer generated displays. The airspeed indicator, altimeter, and vertical speed indicator are traditional electro-mechanical devices.

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Understanding autoflight automation

Autoflight mode management is the process involved in understanding the character and consequences of autoflight modes, planning and selecting engagement, disengagement and transitions between modes, and anticipating automatic mode transitions made by the autoflight system itself. The full detail of autoflight logic is probably too complex to be easily understood, even by the engineers who created it. The logic diagrams that describe the behavior of the system in all anticipated conditions are typically composed of diagrams that span dozens of pages. Much of this complexity arises from rarely encountered conditions. Still, the actual behavior of the autoflight system in operational circumstances can be baffling [9] Funk and his colleagues [3] conducted a major review of perceived human factors problems of flightdeck automation. This study showed that the complexity of automation and failures of pilot understanding of automation were thought by industry professionals to be major problems. Sarter and Woods [5,6] have documented failures of pilot understanding of autoflight modes via both observational and experimental methods. In the face of this complexity and the problems it seems to cause, pilots should and do apparently develop and use simplified models of what the autoflight system is doing. Ultimately, we are most interested in what pilots do with respect to autoflight functions. Presumably, what pilots do is related to how they think about autoflight, which is in turn related to what they know about autoflight. To date, there has been no systematic study of what pilots actually do know about autoflight. Such a study is one component of this project. That component will be descriptive rather than proscriptive in nature. It will use primarily ethnographic methods to determine how pilots conceive of autoflight mode management (especially vertical mode management).

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Previous work

The attitude survey portion of this project is a partial replication of Earl Wiener's classic 1989 study [9]. There have been a number of other similar studies since by Wiener and others [11,10,8]. In general our findings are consistent with the other studies. As will be discussed below, this indicates an impressive stability of attitudes through time and across different airlines in the United States.

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Methods

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Subject population

The subjects for this study were pilots flying the Boeing 757/767 for a major US-based international airline in the fall of 1998. The study was approved by the flight operations office of the airline. The union representing the pilots flying for that airline was also consulted and approved the study.

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Distribution procedure

2909 surveys were shipped to the airline. Airline personnel then placed the surveys in the company mailboxes of the pilots. To ensure confidentiality, the survey package contained a postage paid envelope with which the pilots could return the survey directly to the researchers at University of California San Diego. The first step in processing the returned surveys was to remove the signed consent form from the package. There is no way to identify the individual respondents.

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The Survey

The survey package consisted of three main parts (See appendix 1):

- an experience questionnaire
- a set of probes concerning attitudes toward automation
- a set of similarity judgments concerning the names of autoflight modes that appear on the flight mode annunciator

Participants were instructed to sign and return the consent form that was stapled to the data collection portions of the survey. They could keep the cover letter and the consent form that was printed on the back of the cover letter for future reference.

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Design of the survey

We are interested in the distribution of attitudes toward automation among the pilots. As is common in such studies, we characterize the pilot population in terms of culturally recognized features such as experience level in hours of flight, operational base, and role in the cockpit.

The 757/767 has two pilot seats. In airline operations, the captain sits in the left seat and the first officer in the right seat. ``Seat'' thus becomes a metonym for role in the cockpit. Captains have a wider scope of authority and responsibility than first officers. They also normally have more flight experience than first officers. We are interested in how these factors may affect attitudes toward automation. Airlines operate from bases where crew trips (possibly consisting of many flight segments over several days) begin and end. We speculated that differing kinds of flight operations flown from different bases, for example principally international or domestic operations, might affect crew attitudes toward automation.

In recent years, the backgrounds of pilots coming to the airlines has changed. The proportion of pilots with military training has decreased. Some in the industry have expressed concern about this trend. We wondered if there are any differences in attitudes toward automation among pilots who received flight training from the various branches of the military and those who had no military flight training.

Finally, we are interested in the effect of experience on attitudes toward automation. In the world of flying, hours of experience is the primary measure of expertise. We measured three types of experience: total flying hours, hours in type (that is, in the 757/767), and hours in other automated airplanes (airplanes equipped with a Flight Management Computer System). Two additional measures of experience were created in later analysis procedures. First, time in other FMS equipped aircraft was added to time in type to produce a measure of total experience in FMS equipped aircraft. Second, the ratio of FMS equipped time to total time was computed for each subject. Imagine two pilots who each has 3000 hours of experience in automated airplanes. One has 23,000 hours of total time and the other has 5,000 hours of total time. We expect that some attitudes toward automation might depend as much on the proportion of one's career spent in automated airplanes as on the total number of hours in automated airplanes.

We felt that automated hours would be the most important of these measures of experience in determining attitudes toward automation. The cultural convention in the pilot community is to specify flight experience in hours, and all responding subjects did so. One problem with the survey was that it did not include the Airbus A300 as an explicit prompt on the questionnaire. Twenty nine of the responding pilots used the 'other' entry to indicate that they had experience in this FMS equipped airplane.

The amount of calendar time it takes to acquire a given number of hours may be different for different pilots. Pilots with enough seniority to bid and hold a steady schedule may be able to fly about 80 hours per month. Pilots with less seniority may not alway be able to fly as many hours as they desire. In case attitudes toward automation are formed by time spent thinking about the system as well as time spent actually operating it, we also measured calendar time since completion of training in the airplane. We chose to partially replicate Wiener's 1989 study [9]. We retained the format of Wiener's instrument, presenting each probe as an assertion over scaled responses (a modified Likert scale): ``strongly agree", ``agree", ``neutral", ``disagree", ``strongly disagree". We chose the 15 probes that were most closely related to autoflight from the original 36 probes in Wiener's study.

Appendix 2 provides a list of the probes and the abbreviations for them that will be used throughout this report.

In some cases, we made slight changes to the wording of the questions to accommodate our plans to use the attitude survey with pilots flying airplanes other than the 757/767. For example, Wiener's probe, ``The B-757 automation works great in today's ATC environment." was reworded to read ``The automation in my current aircraft works great in today's ATC environment."

We added one new probe to the survey. This item is ``I always consult the flight mode annunciator to determine which mode the autopilot/flight director is in." Over the past decade, the automation in airplanes has become more complex. The issue of ``mode awareness" that is, the crew's understanding of what the automation is doing, has been cited as a causal factor in a number of accidents [2,4]. Because of this, airlines and airframe manufacturers have stressed the importance of consulting the flight mode annunciator. However, observations of pilots and conversations with them indicate that pilots may not use the flight mode annunciators in the way intended. We hoped that this probe would help us understand the relationship of consulting the flight mode annunciators to other attitudes toward automation. We also recognized from the outset that pilots might be tempted to respond to this probe by reporting what they know they are supposed to do rather than what they actually do. We have no way of knowing how many pilots dissembled on this probe. We do know that several of them indicated that they did not always consult the FMA, but wrote in the margins of the survey that they knew they should.

The survey also included a set of prompts for judgments of the similarities among the names of autoflight modes that appear on the flight mode annunciator in the airplane. The results of that part of the study will be presented in a later report.

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Next: Demographics of the respondents **Up:** The Survey **Previous:** The Survey *Ed Hutchins 1999-08-02*

Demographics of the respondents

Of 2909 surveys distributed, 575 (19.8%) were returned. Of the surveys returned, thirteen did not include signed consent forms and could not be used.

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Seat

Of the remaining 562 usable surveys returned, 254 were from Captains, 267 were from First Officers, and 41 did not indicate which seat they occupied.

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Next: Experience **Up:** Demographics of the respondents **Previous:** Seat

Base

Surveys were returned from pilots flying out of eight operational bases. The frequency of responses from the various bases seemed consistent with the sizes of the bases.

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Experience

On average, the respondents had 11,833 hours of total flight time. Of that, 3,013 hours were in automated airplanes, and 2,657 of the automated hours were in the 757/767. The average amount of time since initial training in the 757/767 was 5 years 0 months, so pilots were flying, on average, about 530 hours per year in this airplane. Figures 2 thru 5 show histograms of the distributions of the various measures of experience.

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Next: Results **Up:** Demographics of the respondents **Previous:** Experience

Military/Civilian flight training

Flight training was coded in four categories: navy, marines, airforce, and none. We inferred civilian training when no branch of the military was specified. This may leave us with a few cases mis-classified if a pilot with military training either forgot to indicate which branch or did not like the categories we offered. Sixteen pilots wrote in other designations for military training. These included Army, Air National Guard, Airforce Reserve. We excluded these write-in cases from the analyses of military training. The other cases gave us 111 with navy training, 42 with marine corps training, 234 with airforce training, and 159 with no military training (See figure 6).

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Next: Correlations among the demographic **Up:** automation-attitudes **Previous:** Military/Civilian flight training

Results

First we will examine the correlations among the demographic variables. This will help us understand the structure of the subject community. Second, we will examine the responses to the attitude probes and compare them to Wiener's 1989 study. This will show how the pilots feel about automation. Third, we will examine the cross-correlations among the attitude probes. This will allow us to describe the structure of the set of attitude probes. Fourth, we will consider the correlations between the demographic variables and the individual attitude probes. This will show how the attitudes are distributed among the pilots. Finally, we return to the structure of the pilot population, this time on the basis of their responses to the attitude probes. We will compare the structure that is derived from the patterns of responses to the structure implied in the demographic variables. This will allow us to explore the possibility that there are groups of pilots who share certain attitude profiles.

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Correlations among the demographic variables

It comes as no surprise that captains have more total flight hours (14,718) and more automated hours (3,251) than first officers (9080 and 2814) (p<0.01 by t-test and Wilcoxon nonparametric tests). They also have more, but not significantly more, time in the 757/767 than the first officers have (2811 to 2533). See table 1.

Pilots with no military training have significantly more total hours, more time since training, and more automated hours than pilots with airforce training have (All p< 0.05 by the Scheffe's test). See table X. Similarly, pilots with Navy training report more time since training, more automated hours, and more hours on the 757/767 than pilots with airforce training (All p< 0.05 by the Scheffe's test). It may be important to keep this in mind while interpreting the findings that follow. Contrary to the general perception in the industry, the ranks of less senior and less experienced pilots at this airline are not loaded with pilots who lack military training. This airline seems to have been drawing on pilots without military training for some time.

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Next: Cross correlations of the **Up:** Results **Previous:** Correlations among the demographic

Responses to the attitude probes

In general, the attitudes toward automation in the subject community of this study match closely the attitudes observed by Wiener a decade ago [9]. This was somewhat surprising, since the participants in Wiener's study worked for a different airline, were flying what was for most their first automated airplane, and had on average less than half the automated flight experience of the participants in the present study (The median hours in type at phase two of Wiener's study was 1,100. Median hours in type for the present population is 2570.) This indicates a fairly stable structure of attitudes in the pilot population at large. Our subjects seemed slightly more positive about automation than Wiener's subjects. This is consistent with the general trend to view automation more positively with increasing experience of it as discussed below.

See appendix 3 for the response histograms discussed in this section.

The scaled responses of the pilots were coded with values from 1 for strongly disagree to 5 for strongly agree. The scores reported below are simple averages of these numeric values. A score of 3.0 indicates a neutral response. Scores above 3.0 are positive on the probe, and scores below 3.0 indicate negative responses to the probe. For each probe, the mean and standard deviation are reported in the following format (mean/std dev).

Probe 1, FlyingSkills: In general, our respondents agree with this probe (3.43/1.15). The distribution of responses across agreement levels looks very much like that in Wiener's 1989 study except that more of our subjects agree strongly and fewer are neutral. The distribution is slightly bi-modal.

Probe2, WorksGreat: Our respondents agree with this probe (3.62/0.90). They are more in agreement with this probe than Wiener's subjects were.

Probe 3, KnowMode: Our pilots agree strongly with this probe (3.72/0.98). Their responses are virtually identical to those observed by Wiener. The distribution is very slightly bi-modal.

Probe 4, CompanyPressure: Our pilots did not agree with this probe (2.38/0.88). Their responses are virtually identical to those observed by Wiener.

Probe 5, FreeToManage: Our pilots agree strongly with this probe (3.79/0.91). The distribution of responses across agreement levels shows more pilots agreeing with this probe than did so in Wiener's study.

Probe 6, Surprises: Our pilots agree with this probe (3.37/1.04). They tend to agree slightly less than did the subjects in Wiener's study. The distribution is slightly bi-modal.

Probe 7, FewerErrors: Our pilots are neutral on this probe. The distribution approximates a normal distribution centered on 3.0. (3.02/0.97).

Probe 8, AheadOfAirplane: The pilots agree with this probe (3.51/0.96). The distribution is uni-modal and more skewed toward agreement than was observed by Wiener.

Probe 9, SetupAndManage: The pilots are on average neutral on this probe (3.17/1.13), but the distribution is strongly bi-modal. The bi-modality in our case is skewed toward agreement, while in Wiener's study a similar structure of bi-modality was skewed toward disagreement.

Probe10, NotReduceWorkload: The pilots disagree with this probe (2.69/1.11). The distribution is moderately bi-modal and skewed toward disagreement. Wiener observed a very strong, nearly symmetrical, bi-modality on this probe.

Probe 11, ConsultAnnunciator: Pilots agree with this probe (3.61/0.99). The distribution has a very slight bi-modality. There was no corresponding probe in Wiener's study.

Probe 12, AdequateTraining: The pilots agree with this probe (3.46/1.13). The distribution shows a slight bi-modality. Wiener's results showed a similar, but more pronounced bi-modality.

Probe 13, HelpDoJob: This probe received the strongest agreement levels (3.84/0.76). Our distribution is more strongly skewed toward agreement and has lower variance than Wiener's.

Probe 14, AltitudeBust: This is the probe with which the pilots agree least (2.27/2.67). Our distribution is unimodal, Wiener's was very slightly bi-modal.

Probe 15, ButtonPusher: The pilots do not agree with this probe (2.67/1.11). The distribution shows a moderate bi-modality. Wiener observed a uni-modal distribution skewed toward disagreement. [Some group of our guys feel more like button pushers than Wiener's pilots] Probe 16, MisunderstoodModes: The pilots disagree with this probe (2.48/1.15). We observe a strongly bi-modal distribution, as did Wiener. More of our pilots strongly disagree with the probe than did in Wiener's study.

Summary: In terms of grand means, HelpDoJob received the strongest agreement (and had the smallest variance), with FreeToManage, KnowMode, ConsultAnnunciator, and WorksGreat close behind. AltitudeBust was most strongly disagreed with, along with CompanyPressure and MisunderstoodModes. MisunderstoodModes and FlyingSkills showed the highest variance. Every possible response (from strongly agree to strongly disagree occurred at least once for every attitude probe.

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Next: Cross correlations of the **Up:** Results **Previous:** Correlations among the demographic *Ed Hutchins 1999-08-02*

Cross correlations of the attitude probes

A 16X16 cross-correlation matrix was computed, showing the correlation between every pair of probes based on how the pilots responded to the probes. This matrix shows that the probes fall neatly into two major groups. One group includes all of the probes that reflect positive attitudes toward automation while the other includes the probes that reflect negative attitudes toward automation.

One advantage of the raw cross correlation matrix that is lost in the attitude probe clustering described below is that the matrix indicates the negative correlations among specific pairs of probes. For example, it shows that the largest negative correlation is between the probes ``I always know what mode the AP/FD system is in.'' and ``There are still things about the airplane that surprise me.''

For the next set of analyses, the 16 attitude probes were mapped as points in a 547-dimensional space (547 pilots responded to all of the probes). Euclidean distances in this space were computed for every pair of probes. This yields a 16X16 matrix of distances. A complete-linkage cluster analysis was performed on this matrix. The cluster tree is shown in figure 7.

This cluster analysis clearly shows the two major clusters that were identified in the cross correlation matrix. A principal components analysis was then performed on this distance matrix. The first three eigenvalues account for .34, .12, and .09 of the variance for a cumulative total of 56% of the variance. Figure 8 shows the probes in spaces defined by the first/second and first/third principal components. As can be seen in figure 8, the first principal component maps fairly nicely onto the distinction between the probes that reflect positive attitudes toward automation and those that reflect negative attitudes. This comes as no surprise since we, and all of the other researchers using this technique [10], have tried to be sure that a range of positive and negative attitudes were represented in the probes.

The second principal component is more interesting. It appears to encode some aspect of the authority of the pilot. At the high end are probes that concern the direct relationship of the pilot to the behavior of the airplane. On the positive side automation helps the pilot do his job, on the negative side, it may cause him to lose his flying skills and it may surprise him. In the middle are probes that concern what is called ``supervisory control'' [7,1]. These probes concern the mediating role of automation between the pilot and the airplane. On the positive side automation frees the pilot to manage the flight, and keeps him ahead of the airplane. On the negative side, it does not reduce workload because there is more to monitor, and a pilot may spend more time setting up the system than he would hand-flying the same situation. At the low end of this principal component are probes that concern the context for the use of automation. On the positive side, pilots make fewer errors with automation. On the negative side, automation makes it easier to bust an altitude and some pilots use it because of company pressure.

Sherman [8] discusses the underlying domains that the probes in the University of Texas Aviation Automation Survey were designed to tap. The probes in the survey used in the present study were intended to tap pilots' understanding of the automation and of their own practices with automation. We did not choose the probes in order to tap issues concerning the pilot's authority, but the principal components analysis tells us that this is an important dimension for the pilots participating in our study.

It is not clear what the third principal component encodes.

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Next: Correlations of attitude probes **Up:** Results **Previous:** Responses to the attitude *Ed Hutchins 1999-08-02*

Correlations of attitude probes with demographic variables

Analyses were performed to test the relationships between the attitude probes and the demographic variables. Overall, the operational base of the pilot, where his or her trips begin and end, and whether the pilot had military or civilian flight training were weak predictors of the responses to the attitude probes. The variable called ``seat'' (Values: Captain and First Officer) describes the pilot's social status and operational responsibility in the cockpit, and was significantly correlated with some attitude probes.

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Operational Base

Surveys were returned by pilots flying out of 8 operational bases. A general linear models procedure (ANOVA) analysis showed a significant relationship between operational base and the structure of the responses to attitude probes 11 ($p < .01$) and 12 ($p < .03$). To test more carefully for the relationship between particular bases and these probes, Scheffe's test of pairwise relations was performed on the bases and attitude probes 11 and 12. In this pairwise comparison of bases, there were no significant differences in the responses to these attitude probes.

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Seat

To examine the relationship between the 'seat' variable and the attitude items, we performed T-tests on all of the attitude items looking to see if the means for captains and first-officers were significantly different. The tests showed significant effects with respect to three of the attitude items.

On the ``company pressure'' probe, both captains and first officers tended to disagree with the statement. Captains gave it an average response of 2.32 and first officers had an average response of 2.49. The difference is significant ($p < .05$).

On average, our pilots disagreed with the item ``not reduce workload''; grand mean 2.7. First officers disagreed significantly more than captains did. (2.56 to 2.85, $p < .002$.)

Overall, our pilots agree with the ``adequate training'' item (mean response is 3.5). First officers agree with this item significantly more than captains do (3.6 to 3.3, $p < .003$). It is difficult to be sure what this means, however, because the probe is in the form of a comparison and we have no knowledge of the other training experiences to which the subjects are comparing their 757/767 training. (But see the correlation analysis of the ratio total/auto hours to this item below).

The simple T-test analysis also indicated a significant relationship between seat and the probe, ``It is easier to bust an altitude in an automated airplane than in other airplanes'' ($p < .04$). However, because this relationship is not strong and because T-tests can be problematic when the distributions being compared are not nearly normal, we also conducted a non-parametric test of all of these relationships. The Wilcoxon (rank sums) test indicated a significant relationship for the ``company pressure'', ``not reduce workload'', and ``adequate training'' probes, but not for the ``altitude bust'' probe or any of the other probes.

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Flight training

Looking at the relation of flight training with the attitude probes, an ANOVA revealed two significant relationships. One is with the attitude probe 6, ``surprises,'' (Pr > *F* .05) and the other with probe 8 ``ahead of the airplane'' (Pr > *F* .05). On average pilots of all training backgrounds agreed with both of these probes. A Scheffe test was performed to determine which pairs of flight training backgrounds were significantly different. The Scheffe test showed no pairwise significant differences on the probe ``There are still modes that surprise me''. Airforce pilots had a significantly higher level of agreement than marine pilots on attitude probe 8, ``Automation helps me stay ahead of the airplane''.

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Flight hours

All of the measures of experience with automated aircraft (Calendar time since training, time in type, and automated hours) have significant negative correlations ($p<0.01$) with the MisunderstoodModes, Surprises, SetupAndManage, and ButtonPusher probes. (Note: these are the negative side of supervisory control). These measures also have significant positive correlations with the KnowMode probe. In addition, time in type and automated hours share significant negative correlations on NotReduceWorkload and AltitudeBust, and a positive correlation with FewerErrors. Automated hours has a negative correlation with the CompanyPressure probe and with the NotReduceWorkload probe. Time in type has a positive correlation with HelpDoJob. In summary, experience with automated aircraft is positively correlated with the probes that represent positive attitudes toward automation and negatively correlated with the probes that represent negative attitudes toward automation.

The relationship between the attitude probes and the measure of total flight time has a very different structure. TotalHours is strongly positively correlated with the AltitudeBust and the NotReduceWorkload probes. Recall that these probes were negatively correlated with the automated experience measures. TotalHours also shows a strong negative correlation with AdequateTraining, which was not correlated with any other experience measure.

These results indicate that more experience with automation leads to greater comfort with automation.

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Next: Principal Components Analysis of **Up:** Results **Previous:** Flight hours

Analysis of the structure of the pilot population

The demographic variables define a structure of the pilot community in terms of features that have meaning to the pilots themselves, role in the cockpit, level of experience, and so on. Another sort of structure of the community can be derived from the patterns of responses to the probes. To do this we created a pilotXpilot correlation matrix, where each correlation is a function of the pilots' responses to the 16 attitude probes. In effect, this maps the 547 pilots into a 16 dimensional space.

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Principal Components Analysis of Pilot Correlation Matrix

We then performed a principal components analysis on this matrix, rotating the space to find the axes of greatest variability. The PCA produced four eigenvalues greater than 1.0, with a significant gap between the fourth and fifth eigenvalues. The first four components account for 28, 11, 9, and 6 percent of the variability, respectively for a cumulative total of 54%. (See table 2.) To determine the meaning of the dimensions of the PCA, we examine the loadings of the attitude probes on each of the first four eigenvectors. (See table 3.)

The first principal component seems to encode something like ``discomfort with automation'' The probes with the strongest positive loadings on this component are NotReduceWorkload, SetupAndManage, and ButtonPusher. Other probes with positive loadings are FlyingSkills, CompanyPressure, Surprises, AltitudeBust, and MisunderstoodModes. The probes with negative loadings are WorksGreat, KnowMode, Freetomanage, FewerErrors, AheadOfAirplane, ConsultAnnunciator, AdequateTraining, and HelpDoJob. That is, this component has positive loadings on every one of the probes that express discomfort with automation and negative loadings on every probe that expresses comfort with automation. By their responses the pilots array themselves from comfortable to uncomfortable with automation on this dimension.

We have interpreted the second principal component as encoding an idea that is widespread in the culture of pilots, but which has received little formal recognition. The probes with the strongest positive loadings on this component are Surprises, MisunderstoodModes, and AheadOfAirplane. The strongest negative loading is for the probe KnowMode. The probes representing feeling like a button pusher and feeling that automation helps one do the job both have positive loadings on this component. At first glance this seems inconsistent. How could misunderstanding modes and keeping ahead of the airplane be aspects of the same thing? In interviews with pilots and observations of them flying as part of another study, pilots sometimes referred to the automation as ``magic''. An interpretation in which automation is believed to work well, but the pilot does not know why fits the loadings on this component.

The probes with the strongest positive loadings on the third principal component are ConsultAnnunciator and KnowMode and ButtonPusher. It also has positive loadings on CompanyPressure and AdequateTraining. The strongest, and only substantial negative loadings are for the probes Surprises and MisunderstoodModes. There is a mix of positive and negative attitudes with positive loadings on attitudes that represent conformance to procedure and negative loadings on attitudes that reflect confusion or misunderstanding. We interpret this dimension as encoding something like ``by the book'' or ``following orders''.

We were unable to find a coherent interpretation for principal component 4.

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Clustering of Pilots

We performed a complete-linkage clustering on the matrix of inter-subject correlations. We considered solutions with from 2 to five clusters. The four cluster solution yielded clusters of reasonable sizes (305, 105, 84 and 53 subjects each). The clusters are plotted in the space defined by the principal components analysis in figures 10 thru 12.

Cluster 1, the largest cluster is low on PC1 (discomfort). These pilots are comfortable with the automation. Cluster 2 is higher on PC1 and very high on PC2(Magic). These pilots also tend to have less time than the pilots in cluster 1.

None of the observed clusters maps cleanly onto PC3 (by the book).

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Correlations of Demographic variables and Principal Components of the Pilot Correlation Matrix

All of the measures of experience with automated airplanes are negatively correlated with both PC1 (discomfort) and PC2 (magic). This is additional evidence that more experience with automation leads to greater comfort with automation.

Total hours is not significantly correlated with any of the principal components.

The ratio of automated to total hours is negatively correlated with PC1, which is expected, and also with PC4, but not PC2. This last result is not expected. It may mean that only the absolute magnitude of experience with automation affects the ``magical'' view of automation.

The relationship of seat to the principal components of the attitude questions was also tested. Captains were significantly higher on PC4 ($p.<.004$) than First Officers. Since we have no interpretation for PC4, we don't know what this means.

PC1(discomfort), PC3(by the book) and PC4 showed no significant effects for the military training variable. PC2(magic) shows a significant difference in that pilots with airforce training are higher on this component than pilots without military training are.

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Discussion

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1999-08-02

Responses to the attitude probes

On the whole the pilots are positive about automation. The pilots in our sample are even more positive on it than the pilots observed by Wiener 10 years ago were. On two probes, though, our pilots were more negative. They agreed more strongly with the SetupAndManage and ButtonPusher probes. Both of these probes deal with representations of programming the FMCS as distractions from the activity of flying. This change could be a result of a difference in company policy between the two airlines involved. Another possibility is that with increasing density of air traffic over the last decade, the use of this automation now requires more inflight programming or reprogramming of the FMCS.

Ed Hutchins
1999-08-02

Attitude cross-correlations

We added the ConsultAnnunciator probe in order to see if it predicted any of the other attitudes toward automation. Not surprisingly, its strongest correlation is a positive one with the KnowMode probe. It is also positively correlated with FreeToManage and negatively correlated with MisunderstoodModes.

While it was expected that some of the probes would convey positive attitudes and some negative attitudes toward automation, it was not known that this positive/negative split would be so pronounced or that it would map so cleanly onto the first principal component of the attitude cross-correlation matrix.

The second principal component of the attitude cross-correlation matrix was a surprise. It appears that in their responses to the probes, the pilots treat probes that tap representations of their authority similarly. The distinction between hand-flying the airplane and managing automation is a salient one in the industry, but we did not expect to see it emerge from the analysis of the structure of the attitude probes. The interpretation of this dimension is complicated because it involves issues of authority, direct versus mediated control, and the context of automation usage.

Ed Hutchins
1999-08-02

Correlations of demographics and attitude probes

We were surprised to find no relationships between operational base variable and the attitude probes. In interviews pilots have commented on the cultural differences between bases and on the differences in the types of flying that are done from different bases. Whatever factors are involved in the formation of attitudes toward automation, they seem not to be tied to the operational base.

Overall, the correlations of the seat variable with the attitude probes was consistent with the differences in duties of captains as compared to first officers.

Since Captains have more confidence and autonomy than first officers, and are in command of the airplane, it is not surprising that they agree less than first officers with the CompanyPressure probe. Captains have usually been with the company longer, have more seniority, and may find the company less intimidating than first officers do. All of these things may lead them to be less influenced than first officers are by the perceived wants of the company. This appears to be an effect of differences in the experience and roles of the occupants of the two seats as mediated by organizational culture.

First officers disagreed significantly more than captains did with the NotReduceWorkload probe. We believe this difference is a result of the nature of the mandated division of labor in the cockpit. This is a complex issue, since pilots generally alternate legs, both captains and first officers assume the duties of pilot flying (aviate and navigate) and pilot not flying (communicate and operate). In many crews, captain and first officer discuss and share decision making. Still, the fact that the authority and responsibility for the flight as a whole and everything associated with it rest with the captain, captains have a wider scope of tasks and their workload includes more areas that are unaffected by automation than is the case for first officers. When a first officer is the pilot flying, he flies the airplane. When a captain is the pilot flying, he flies the airplane and also does all the other things captains do. This may result in the captain perceiving a smaller workload reduction due to automation than that perceived by first officers. Since automation applies to a larger fraction of a first officers' job the effect of workload reduction may be more pronounced for him, leading him to disagree more strongly than a captain would with the proposition that ``Automation does not reduce total workload because there is more to monitor now."

We must proceed with caution with all of these interpretations however, because the seat variable is confounded with experience and the probes with which the seat variable has significant correlations also have significant correlations with experience level. It is unclear at this point whether the observed effects are driven by the properties of the seat variable or if they are driven by experience.

We found no significant relationships between the military training variable and the attitude probes. This seemed surprising because the differences between military and civilian culture are so many and so strong. It is possible that airline training and airline experience wash out the effects of earlier training experience. In any case, the data from this study do not support a model in which military background or its lack affect the ways pilots view automation.

From a theoretical point of view, we expect that with increasing experience, pilots will come to understand the behavior of the automation better and that they will develop efficient strategies for using the automation. We have observed pilots in the cockpit teaching each other strategies or ``tricks'' for more effective automation use. The correlations of experience measures with attitude probes indicate that as pilots acquire experience with automation, they have better mode awareness, they have more confidence in their ability to manage automation, and they report making fewer errors. The facts that they also report sensing a reduction in workload and spending less time setting up an managing the automation suggest that they may be developing better strategies for using the automation.

Total flight experience does not have the correlations with positive probes that are seen for the measures of automated hours. In fact, pilots with many total hours may worry about busting an altitude in an automated airplane, and seem to think that the training they got for the 757/767 is not as good as some previous training they had. The concern about busting an altitude may appear because the strategies used to avoid busting an altitude in a traditional airplane may not work in a glass cockpit. The attitude among more senior pilots that training was better in the past may be linked to a general perception in the industry of a change in the nature of training over the years. In the first generation of jet aircraft, pilots were trained extensively on all of the airplane systems at a 'nuts and bolts' level. As airplanes became more complex it was no longer possible to teach pilots 'everything'. Instead, training focused on what pilots 'need to know' about the airplane. It may be that the more senior pilots are comparing this need to know training for the 757/767 to the earlier form of know everything training.

The fact that significant relationships exist between the measures of automated experience and the attitude probes indicates that pilots attitudes change as a function of experience with automation (but not as a function of total flight experience). This suggests that much of what pilots know and believe about automation is learned after they leave the training center. We have been told by pilots that they learned 70% of what they know about automation while flying on the line.

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next up previous

Next: Principal components analysis of **Up:** Discussion **Previous:** Attitude cross-correlations *Ed Hutchins*
1999-08-02

Principal components analysis of the pilot correlation matrix

The principal components analysis of the pilot correlation matrix and the correlations between the principal components and the experience measures is consistent with the findings of the demographic analysis. That is, the first principal component seems to encode 'discomfort' and it is negatively correlated with experience in automated airplanes. Since we know that the first principal component of the attitude probe correlation matrix splits the probes into positive and negative probes, it is not surprising that most of the variance in the pilot correlations is accounted for by a similar dimension.

The emergence of the ``magic'' dimension as the second principal component of the pilot correlation matrix was a surprise. Of the many aspects of automation that might have been made salient by the response patterns of the pilots, this was not expected. As mentioned above, the idea that automation is magic appears often in pilot explanation of automation. It is interesting, however, that this component also has a negative correlation with the automated experience measures. It may be that the ``magic'' interpretation is a conceptualization that serves pilots early in their experience with automated airplanes but is replaced later by a model that contains more insight into the internal logic of the system.

It came as something of a surprise that the third principal component which we had called 'by the book' did not correlate with the military/civilian training demographic variables. This is probably simply a case where our stereotypes lead us to expect a relationship that does not exist. Pilots with airforce training were higher on PC2(magic) than pilots with no military training were. It is difficult to interpret this, however, because pilots without military training have, on average, more automated experience than pilots with airforce training and PC2 is negatively correlated with automated experience.

It is interesting that the measure of total flight experience is not significantly correlated with any of the principal components of the pilot correlation matrix. This suggests that attitudes toward automation are formed in the use of automation and may not depend much on the flying experience that preceded the experience of automation.

 Ed Hutchins 1999-08-02

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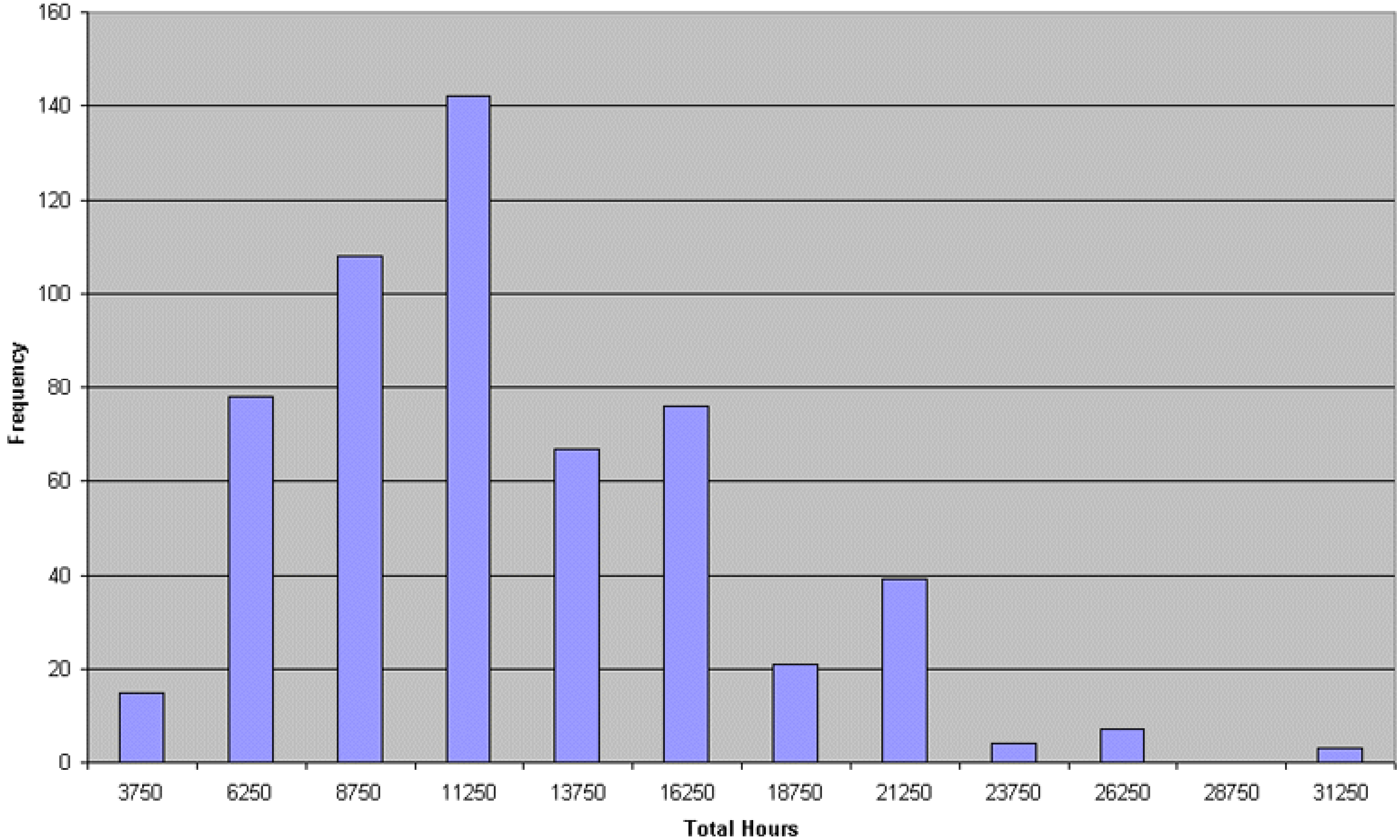
Ed Hutchins
1999-08-02

Figures

Figure 1. Boeing 757 Cockpit

Figure 2. Total Hours



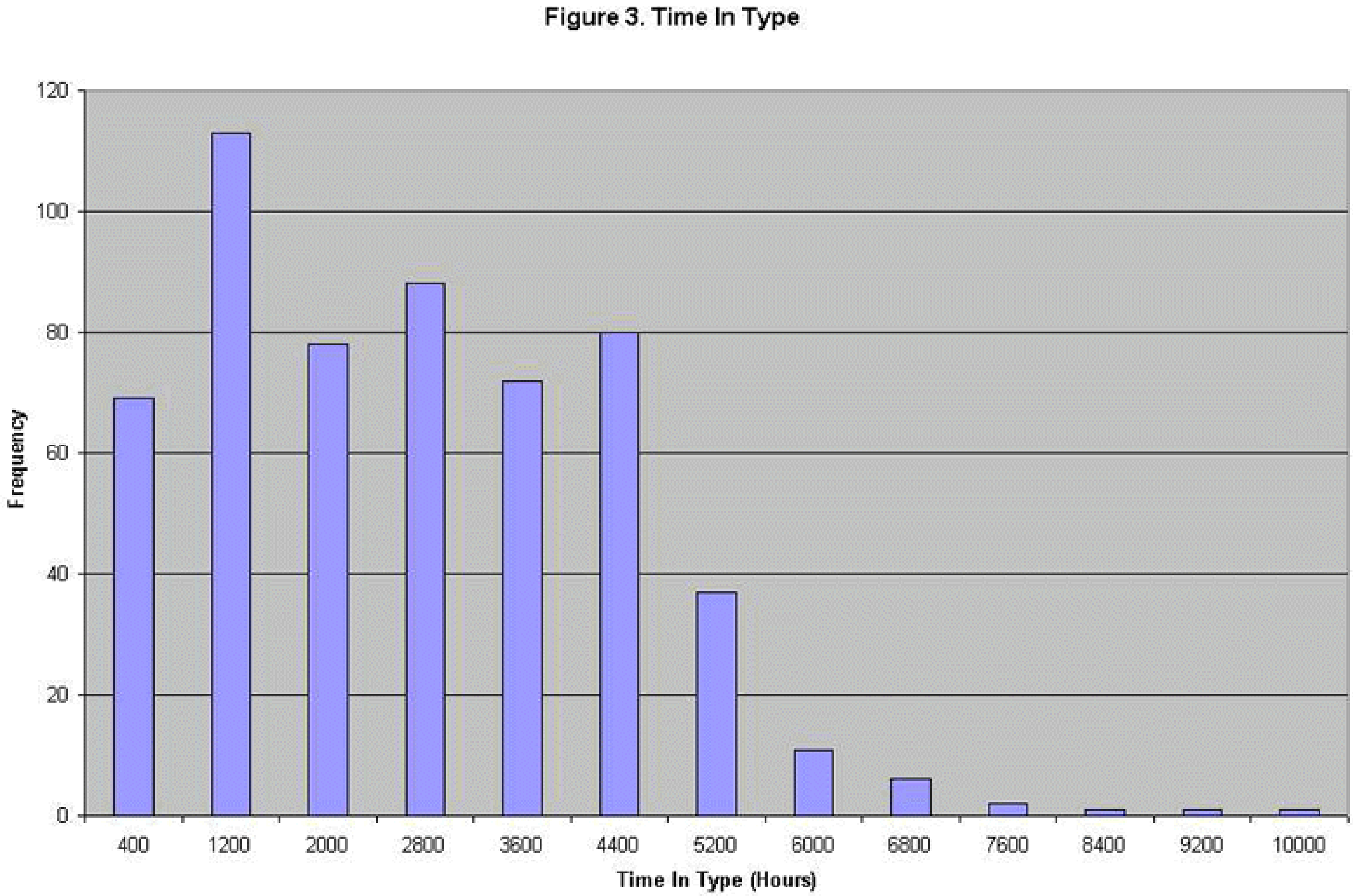


Figure 3. Time In Type
120
100
80
60
40
20
0
Frequency
400
1200
2000
2800
3600
4400
5200
6000
6800
7600
8400
9200
10000
Time In Type (Hours)

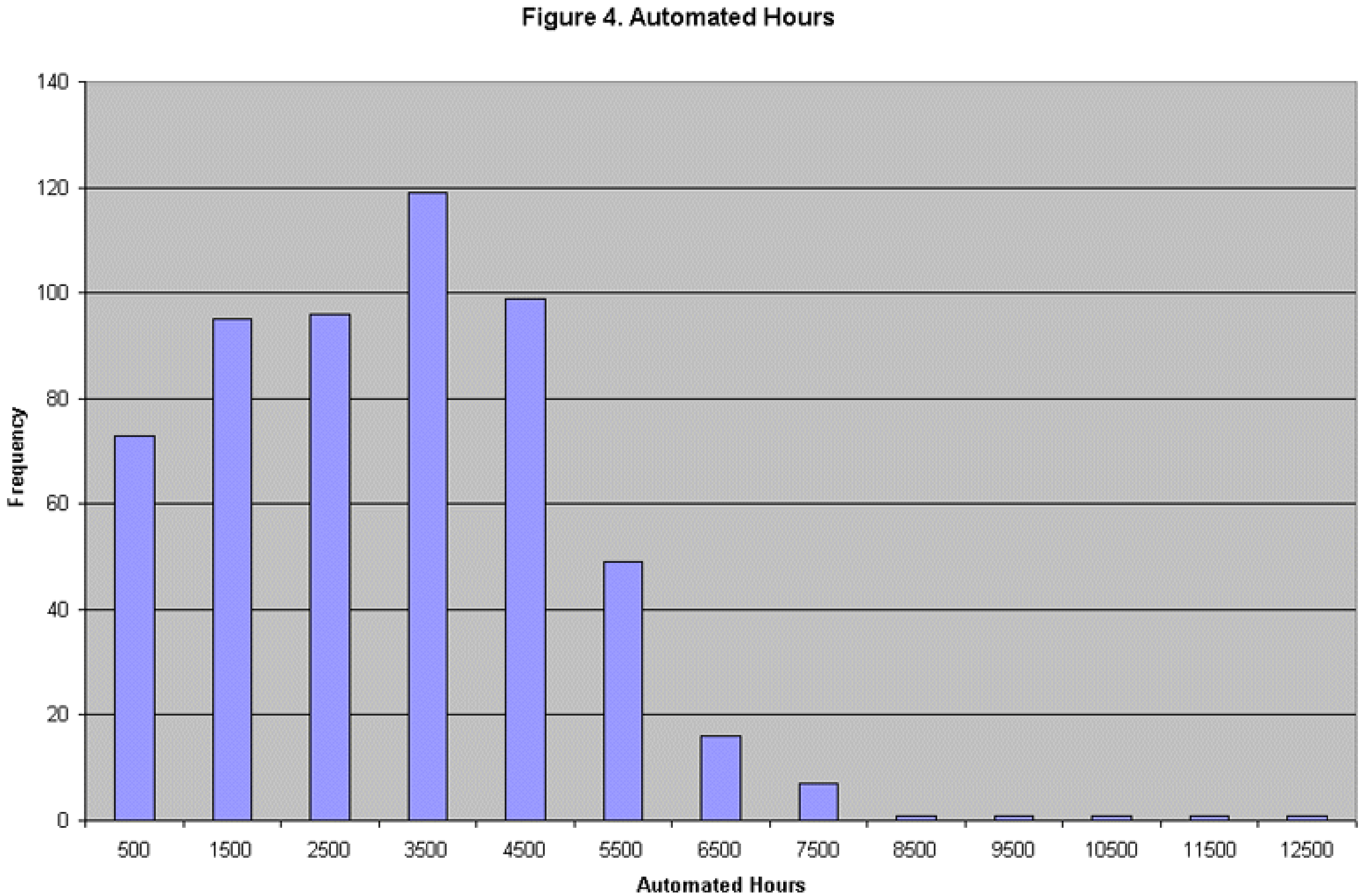


Figure 4. Automated Hours
Frequency
140
120
100
80
60
40
20
0
500
1500
2500
3500
4500
5500
6500
7500
8500
9500
10500
11500
12500
Automated Hours

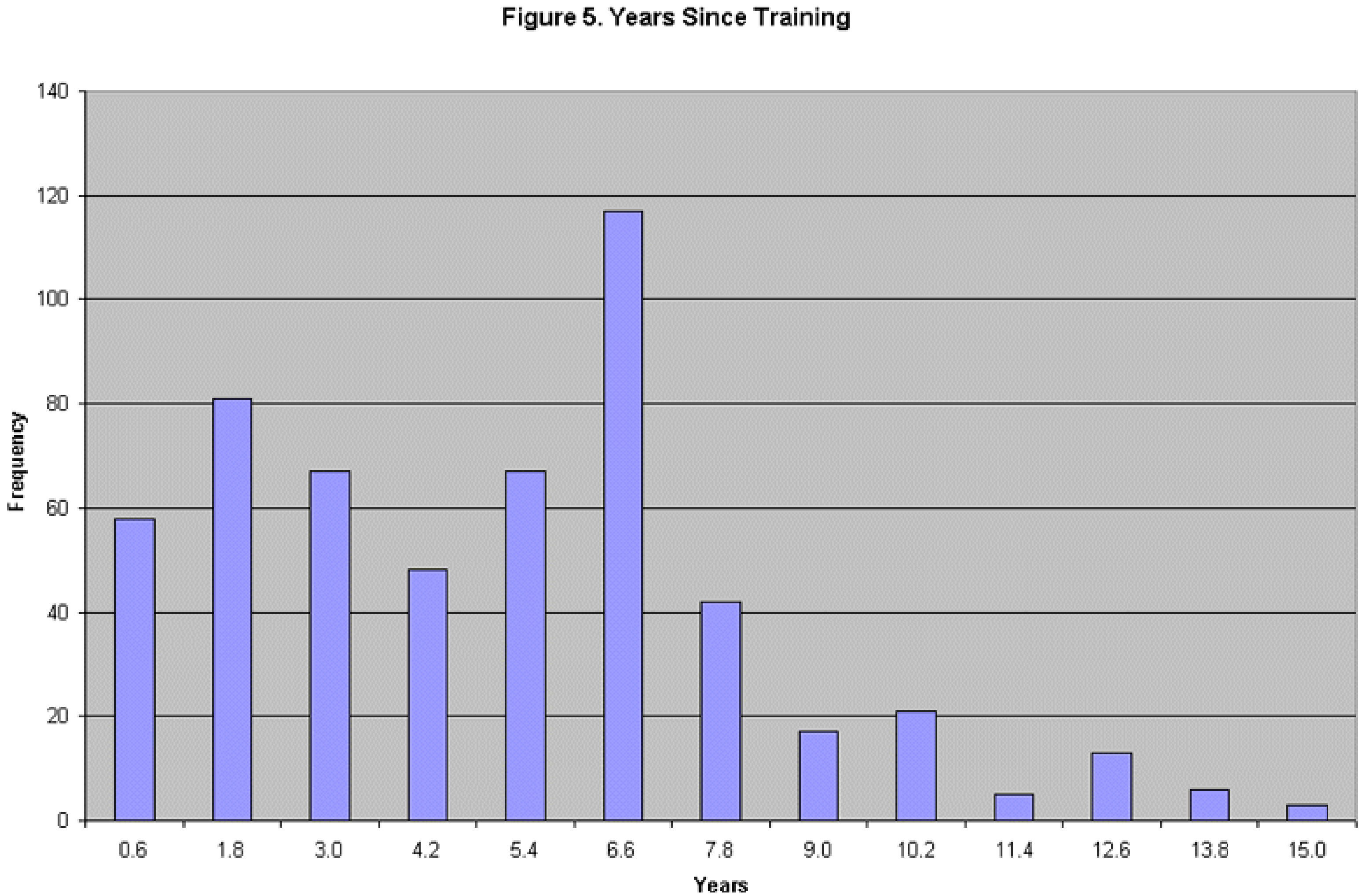


Figure 5. Years Since Training
140
120
100
80
60
40
20
0
Frequency
0.6
1.8
3.0
4.2
5.4
6.6
7.8
9.0
10.2
11.4
12.6
13.8
15.0
Years

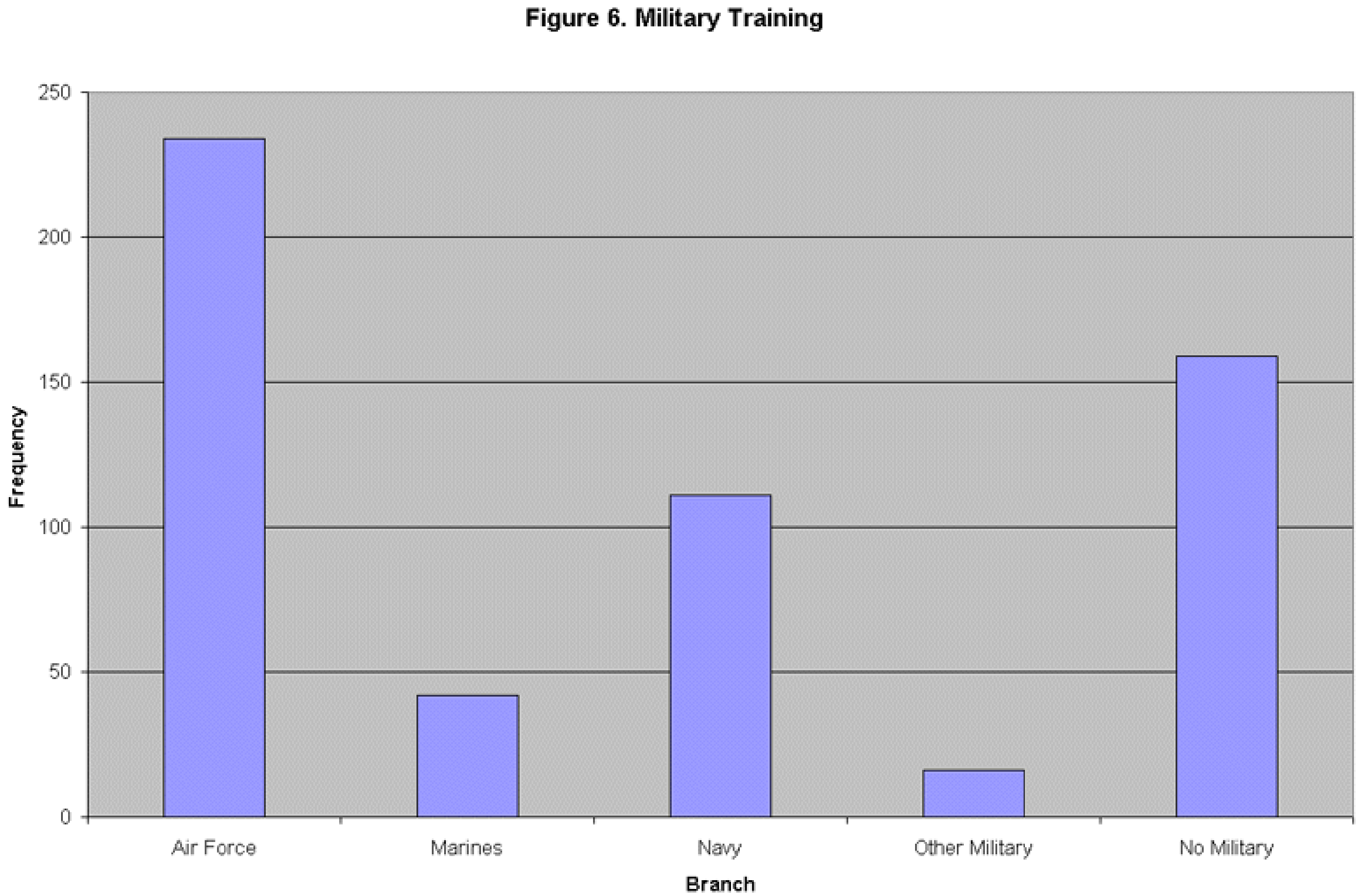
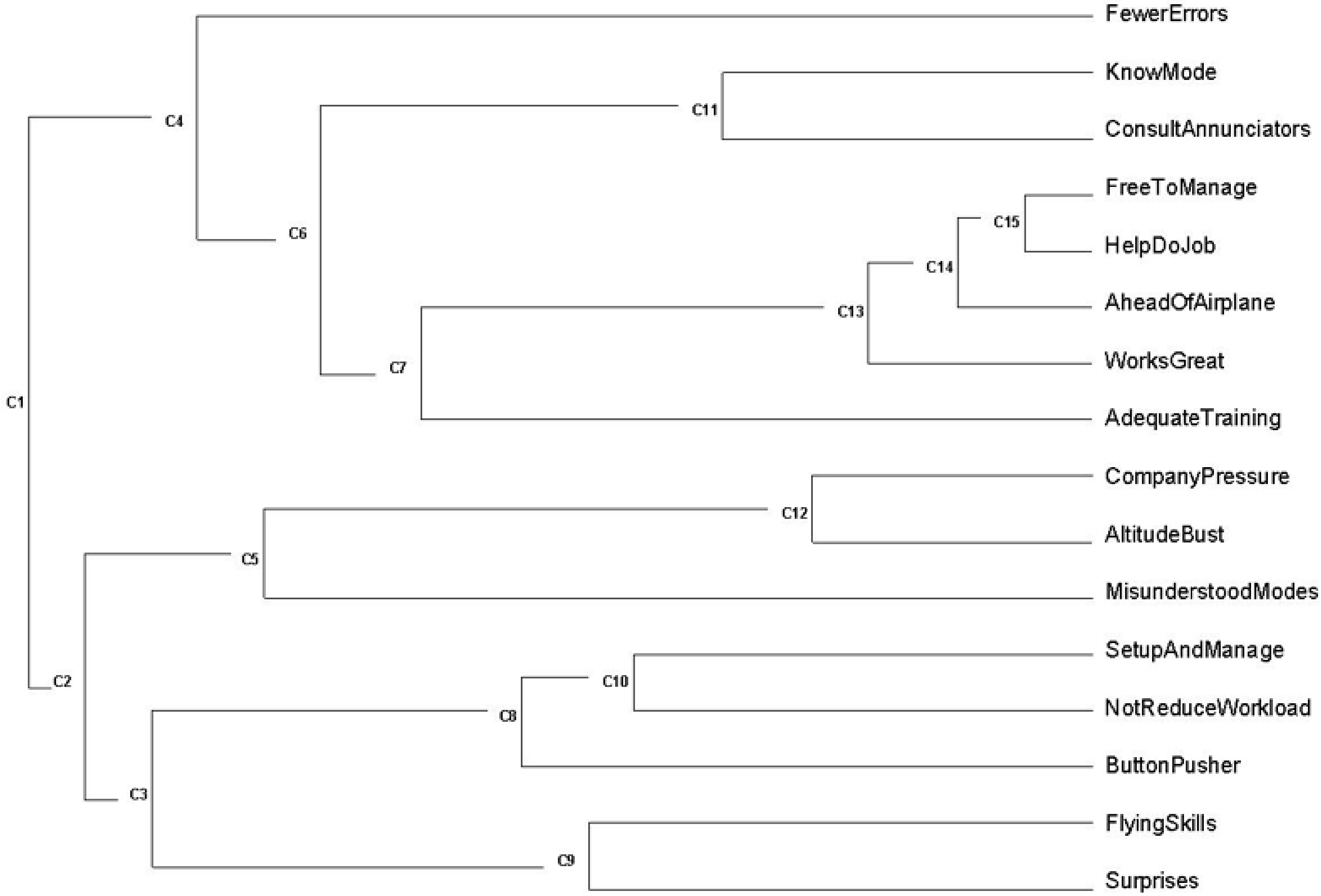


Figure 6. Military Training
250
200
150
100
50
0
Frequency
Air Force
Marines
Navy
Other Military
No Military
Branch

Figure 7. Cluster Tree of Attitude Probes



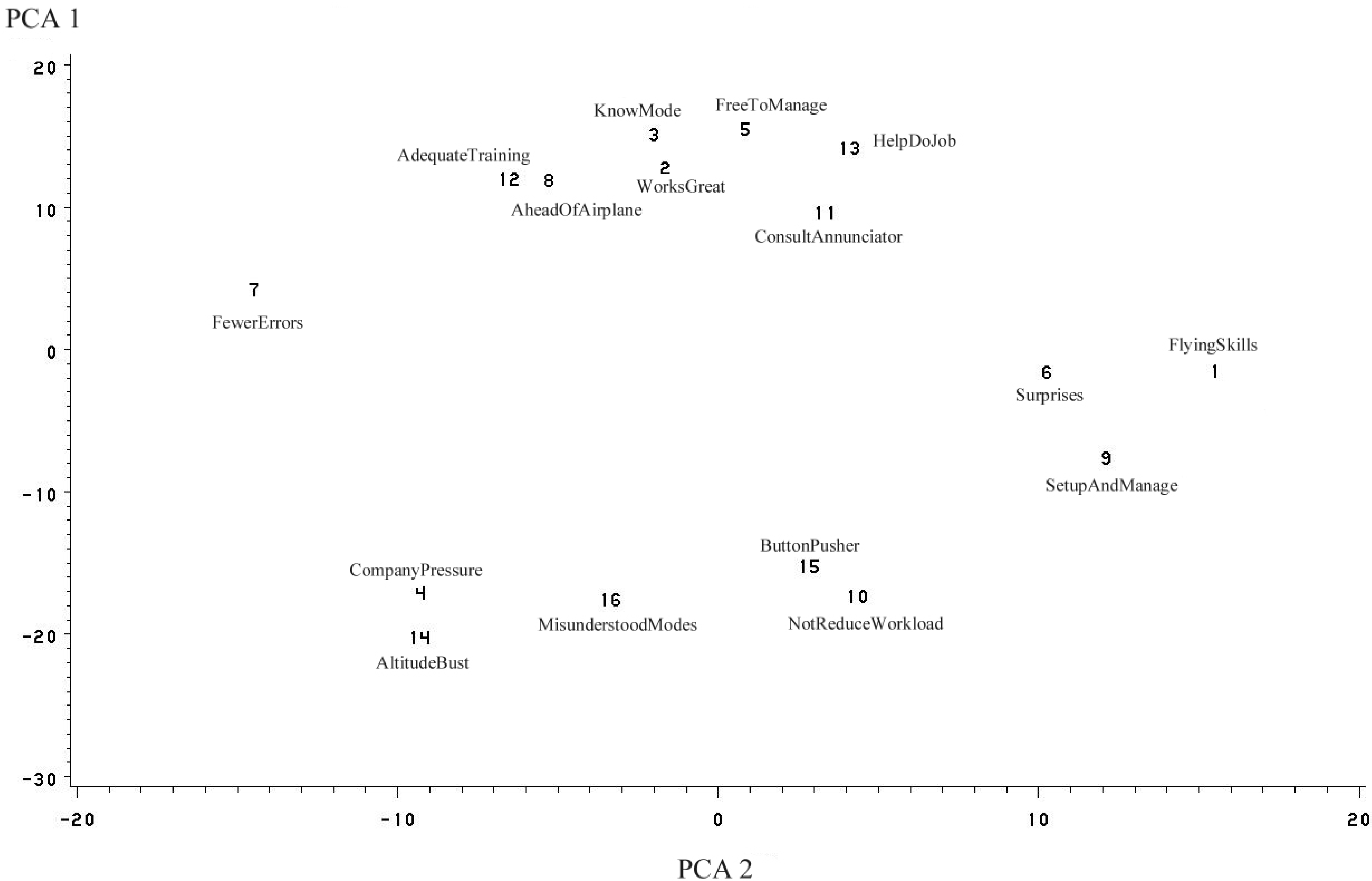


Fig. 8: Attitude Probes, plotted against principal components 1 and 2

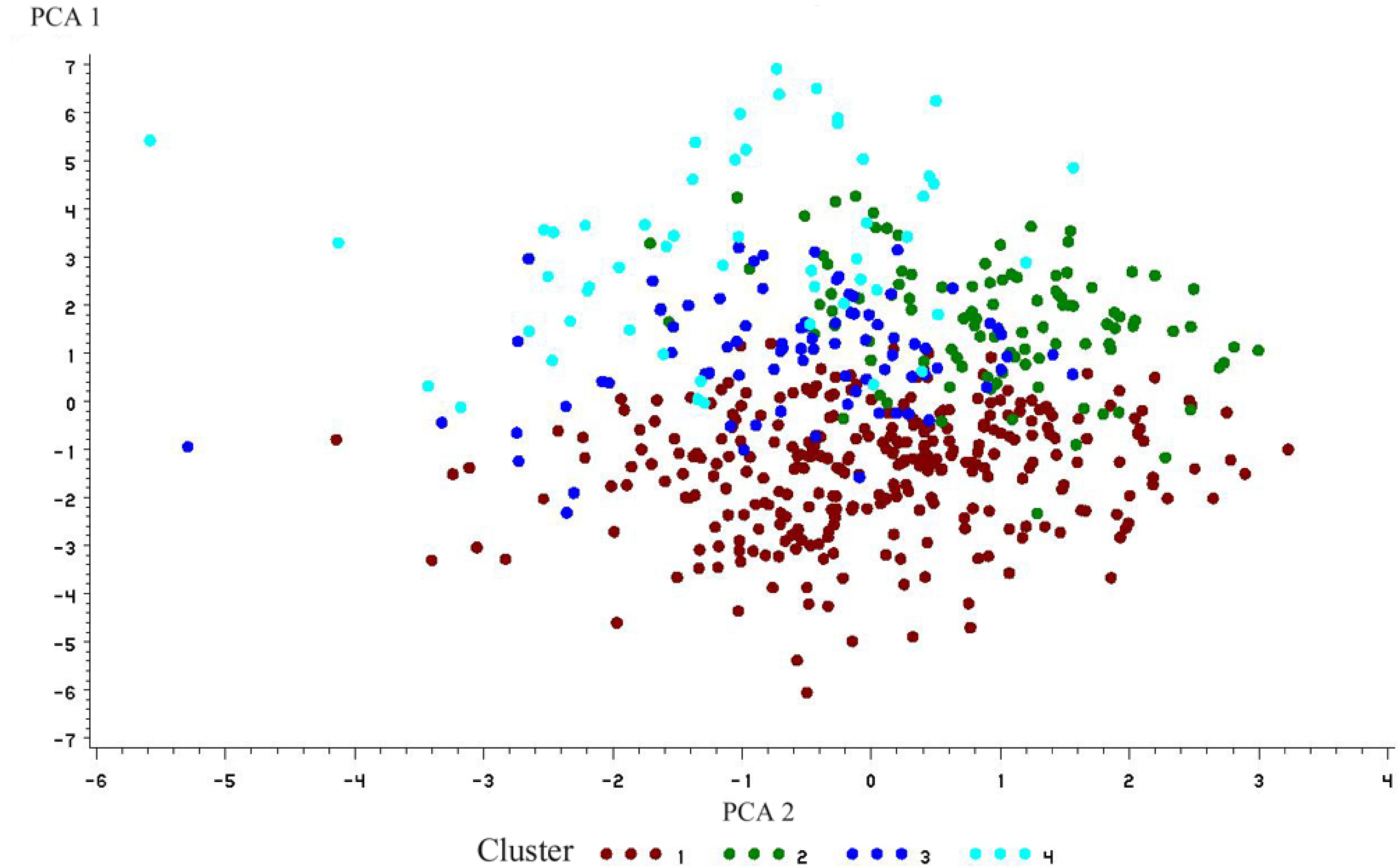


Fig. 10: Pilot clusters by attitude, plotted against principal components 1 and 2

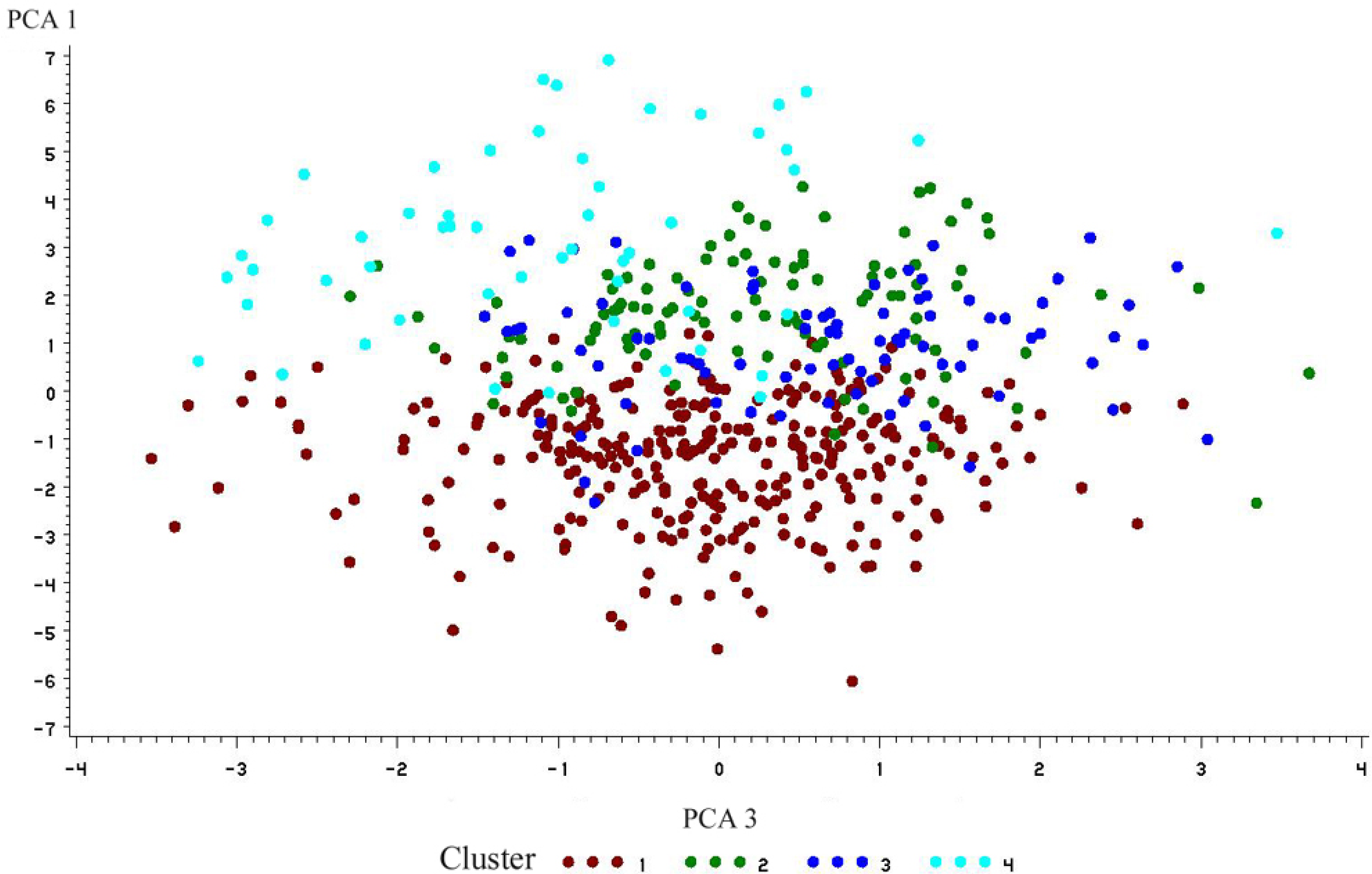


Fig. 11: Pilot clusters by attitude, plotted against principal components 1 and 3

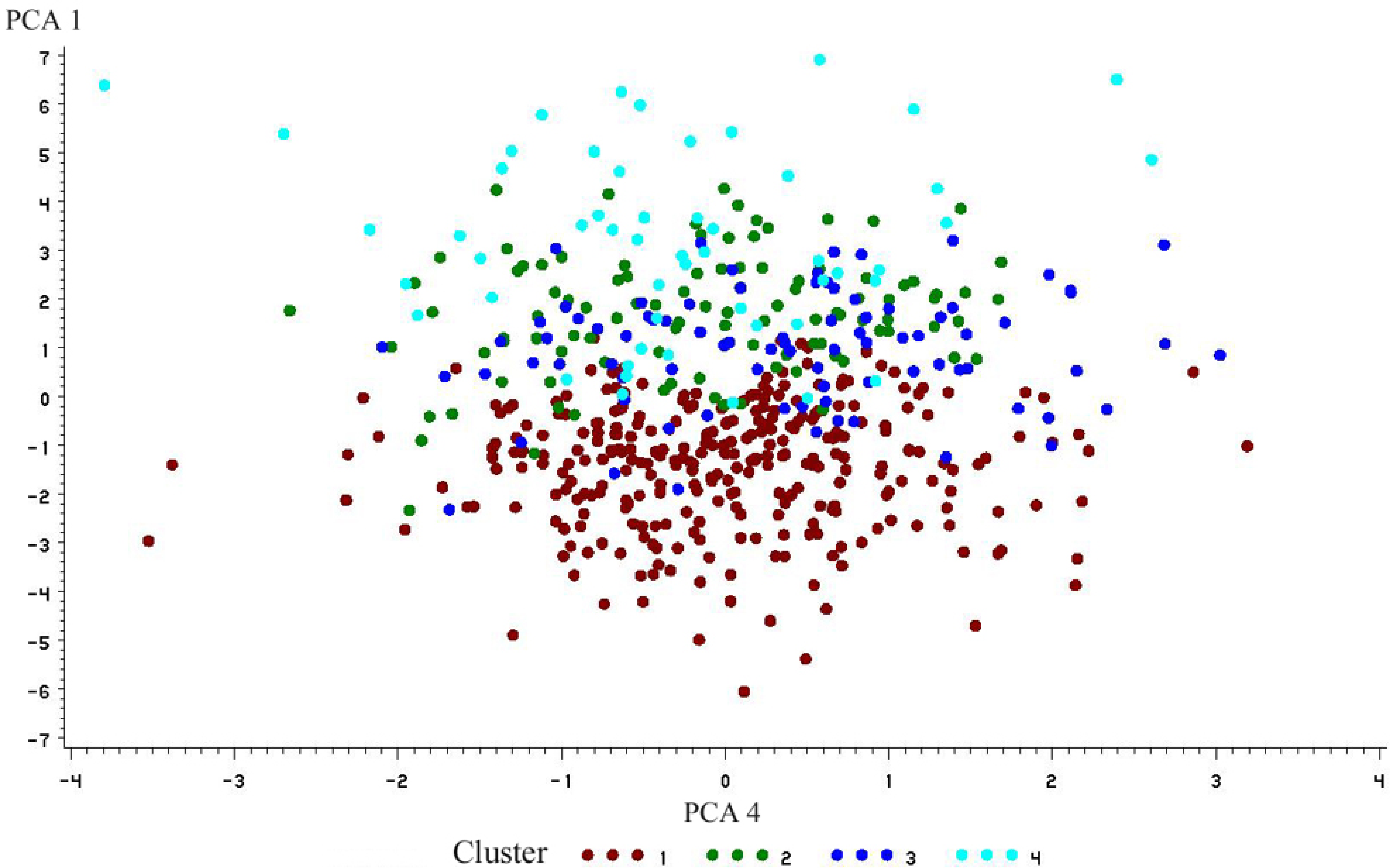

PCA 1
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-4
-3
-2
-1
0
1
2
3
4
PCA 4
Cluster 1 2 3 4

Fig. 12: Pilot clusters by attitude, plotted against principal components 1 and 4

Tables

Table 1. Captain / First Officer Experience

Mean (Standard Deviation)

	Total Hours	Hours in Type	Automated Hours	Years Since Training
Captain	14718.42 (4596.13)	2811.40 (1750.19)	3251.84 (1834.53)	5.52 (3.66)
First Officer	9080.09 (3320.69)	2532.90 (1601.08)	2814.67 (1739.77)	4.56 (2.56)

Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	4.54938	2.85364	0.284336	0.28434
2	1.69574	0.28235	0.105984	0.39032
3	1.41339	0.37653	0.088337	0.47866
4	1.03686	0.14914	0.064804	0.54346
5	0.88772	0.07149	0.055482	0.59894
6	0.81623	0.04242	0.051014	0.64996
7	0.77381	0.07205	0.048363	0.69832
8	0.70176	0.02305	0.043860	0.74218
9	0.67871	0.05029	0.042419	0.78460
10	0.62842	0.05782	0.039276	0.82388
11	0.57060	0.01992	0.035663	0.85954
12	0.55068	0.08673	0.034418	0.89396
13	0.46395	0.02894	0.028997	0.92295
14	0.43501	0.00452	0.027188	0.95014
15	0.43049	0.06325	0.026906	0.97705
16	0.36725	.	0.022953	1.00000

The data have been standardized to mean 0 and variance 1
Root-Mean-Square Total-Sample Standard Deviation = 1
Mean Distance Between Observations = 5.477205

Table 2. Eigenvalues of the PCA for the pilot correlations

	Eigenvectors 1	2	3	4	
ATT1	0.26063	0.21454	0.24229	-0.20350	FlyingSkills
ATT2	-0.24232	0.15249	0.23133	-0.37760	WorksGreat
ATT3	-0.24523	-0.20559	0.39282	-0.20937	KnowMode
ATT4	0.20064	0.14332	0.27056	-0.48147	CompanyPressure
ATT5	-0.26316	0.30713	0.13997	0.18426	FreeToManage
ATT6	0.23331	0.43793	-0.15831	0.19307	Surprises
ATT7	-0.29806	0.24527	-0.05570	-0.01867	FewerErrors
ATT8	-0.28012	0.39444	0.04332	0.09598	AheadOfAirplane
ATT9	0.29820	0.06189	0.22663	0.26396	SetupAndManage
ATT10	0.32784	-0.13852	0.14228	0.26036	NotReduceWorkload
ATT11	-0.06264	-0.16692	0.48792	0.39086	ConsultAnnunciator
ATT12	-0.22256	0.05589	0.30155	0.07933	AdequateTraining
ATT13	-0.19303	0.26624	0.16225	0.35413	HelpDoJob
ATT14	0.24970	-0.08294	0.22733	0.11513	AltitudeBust
ATT15	0.28720	0.25442	0.33192	-0.15319	ButtonPusher
ATT16	0.22363	0.41178	-0.14784	-0.03022	MisunderstoodModes

Table 3. Weightings of the attitudes on the first 4 eigenvectors

next up previous

Next: Appendix 1. Pilot Survey **Up:** automation-attitudes **Previous:** Table 3. Weightings of the attitudes on the first 4 eigenvectors

Appendices

Dear (Airline Name) Pilot,

We are seeking your participation in a research project. The project is part of a cooperative agreement between the Human-Computer Interaction laboratory of the University of California at San Diego and the Human-Automation Integration branch of NASA. This project has also been approved both by (Airline Name) management and (Pilot Union). The goal of the project is to find out more about how pilots think about autoflight modes and to design improved training for autoflight.

The specific goals of this project are to determine the concepts that pilots use in thinking about autoflight vertical navigation mode annunciations, and to determine how those concepts vary with experience. You will be asked to make judgments concerning the meanings of common vertical navigation mode annunciations. You should be able to do the task in about a half-hour of your spare time.

The materials include:

- Two copies of an informed-consent form. The first copy is on the back of this letter. You may keep this copy for your records. The second copy is stapled to the data collection forms. Please read and sign this copy and return it with the completed forms.
- A brief questionnaire concerning your flight experience.
- A questionnaire regarding your attitudes towards automation.
- A list of 20 sets of autoflight mode names. There are three mode names in each set. Please follow the instructions for making similarity judgments on the meanings of the modes.

Place the signed consent form, the completed experience and attitude questionnaires, and the autoflight mode judgment sheets in the enclosed envelope and drop it in the mail. When we receive your data packet, the first thing we do is tear off the signed consent form. This means that **no information that could be used to identify you will be associated with your responses.**

Please return the materials within two weeks if possible.

If you have any questions feel free to contact us.

Sincerely,

Edwin Hutchins
UCSD Principal Investigator
(619)534-1134

Steve Casner
NASA Principal Investigator
(650)604-6908

Professor Edwin Hutchins of UC San Diego and Dr. Steven Casner of the NASA Ames research center are conducting a research study to find out more about how pilots think about autoflight mode annunciations. You have been asked to take part because of your experience flying glass-cockpit aircraft.

If you agree to participate, you will be asked to: 1) complete two brief questionnaires concerning your flight experience with and attitudes towards automation and 2) make a series of judgments concerning the similarity of the meanings of the vertical mode annunciations that appear as flight mode annunciations on the aircraft you currently fly.

Completing these questionnaires and the similarity judgments should take no more than one half hour of your time. Although there will be no direct benefit to you from these procedures, the results of this study may help in the design of training, operational procedures, or instrumentation in the future.

You may call the UCSD Human Subjects Office at (619) 534-4520 to inquire about your rights as a research subject or to report research related problems. If you have other questions or research-related problems, you may contact Professor Hutchins at (619) 534-1134, or send him email at ehutchins@ucsd.edu.

Participation in research is entirely voluntary.

With the exception of your experience profile, no information that could be used to identify you will be associated with your responses.

You have received a copy of this consent document to keep.

You agree to participate.

______________________________ ____________

Signature Date

Experience Questionnaire

Please fill in the blanks in the space provided. If a question does not apply to you, simply leave the space blank.

General Information:

Airline: (Airline Name)

Current aircraft: **757/767**

Seat (circle one): CAPT. F/0

Based at: ____________

Years/Months since completion of initial training in current aircraft: Y____M____

Flight Time:

Total flight time: __________

Total time in the 757/767: __________

Time in FMS equipped aircraft (other than 757/767) by type:

B737	______________
B747-400	______________
B777	______________
MD-80-88	______________
MD-11	______________
A320	______________
Fokker 100	______________
Other	______________

If you had military flight training, was it NAVY, MARINES, AIRFORCE?

Attitudes-Toward-Automation Questionnaire

Please indicate your agreement or disagreement with the following statements by circling the words that best describe your feelings:

1. I am concerned about a possible loss of my flying skills with too much automation.
   Strongly Agree Agree Neutral Disagree Strongly Disagree

2. The automation in my current aircraft works great in today's ATC environment.
   Strongly Agree Agree Neutral Disagree Strongly Disagree

3. I always know what mode the autopilot/flight director is in.
   Strongly Agree Agree Neutral Disagree Strongly Disagree

4. I use the automation mainly because my company wants me to.
Strongly Agree Agree Neutral Disagree Strongly Disagree

5. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.
Strongly Agree Agree Neutral Disagree Strongly Disagree

6. In the automation of my current aircraft, there are still things that happen that surprise me.
Strongly Agree Agree Neutral Disagree Strongly Disagree

7. I make fewer errors in the automated airplanes than I did in the older models.
Strongly Agree Agree Neutral Disagree Strongly Disagree

8. Automation helps me stay "ahead of the airplane".
Strongly Agree Agree Neutral Disagree Strongly Disagree

9. I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.
Strongly Agree Agree Neutral Disagree Strongly Disagree

10. Automation does not reduce total workload, because there is more to monitor now.
Strongly Agree Agree Neutral Disagree Strongly Disagree

11. I always consult the flight mode annunciator to determine which mode the autopilot/ flight director is in.
Strongly Agree Agree Neutral Disagree Strongly Disagree

12. Training for my current aircraft was as adequate as any training I have had.
Strongly Agree Agree Neutral Disagree Strongly Disagree

13. I use automation mainly because it helps me get the job done.
Strongly Agree Agree Neutral Disagree Strongly Disagree

14. It is easier to bust an altitude in an automated airplane than in other planes.
Strongly Agree Agree Neutral Disagree Strongly Disagree

15. Sometimes I feel more like a "button pusher" than a pilot.
Strongly Agree Agree Neutral Disagree Strongly Disagree

16. There are still modes and features of the autoflight system that I don't understand.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Similarity Judgments: Boeing 757/67 Mode Names

Below and on the following pages you will see sets of three autoflight **pitch mode** names arranged in a row. Please proceed one row at a time and do the following: Read the mode names in the set. Choose the one mode name that is most different in meaning from the meanings of the other two mode names in the set. For example, if the items were kinship terms rather than mode names, and you saw the set,

Mother	Nephew	Daughter

you would probably judge Nephew to be the term that is most different. Circle the term you feel is most different from the other two:

Mother	Nephew	Daughter

Next, consider the two uncircled terms. Of those two, which is closest in meaning to the term that you circled in the first step? For the example above, most people would say that Nephew is closer in meaning to Daughter than Nephew is to Mother. Underline the term that is closer in meaning to the circled term. Thus, your completed judgment would look like this:

Mother	Nephew	Daughter

Go through the items in order, one at a time. There are no right or wrong answers. Take your time, but do not agonize over your answers or try to look back to see what you did before. Just relax and if it seems difficult to make up your mind, go with your gut feelings.

1.	V/S	G/S	VNAV PTH
2.	VNAV SPD	VNAV PTH	SPD
3.	VNAV SPD	ALT HOLD	SPD
4.	V/S	SPD	G/S

5.	SPD	V/S	ALT HOLD
6.	VNAV PTH	SPD	ALT HOLD
7.	VNAV SPD	ALT HOLD	G/S
8.	SPD	VNAV PTH	V/S
9.	V/S	VNAV PTH	VNAV SPD
10.	ALT HOLD	V/S	G/S
11.	VNAV SPD	V/S	SPD
12.	VNAV PTH	SPD	G/S
13.	ALT HOLD	G/S	VNAV PTH
14.	G/S	V/S	VNAV SPD
15.	VNAV SPD	VNAV PTH	ALT HOLD

16.	V/S	VNAV PTH	ALT HOLD
17.	SPD	VNAV SPD	G/S
18.	G/S	SPD	ALT HOLD
19.	ALT HOLD	V/S	VNAV SPD
20.	VNAV PTH	G/S	VNAV SPD

Attitude Probe Codes

- **FlyingSkills**
  I am concerned about a possible loss of my flying skills with too much automation.

- **WorksGreat**
  The automation in my current aircraft works great in today's ATC environment.

- **KnowMode**
  I always know what mode the autopilot/flight director is in.

- **CompanyPressure**
  I use the automation mainly because my company wants me to.

- **FreeToManage**
  Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing"the flight.

- **Surprises**
  In the automation of my current aircraft, there are still things that happen that surprise me.

- **FewerErrors**
  I make fewer errors in the automated airplanes than I did in the older models.

- **AheadOfAirplane**
  Automation helps me stay "ahead of the airplane".

- **SetupAndManage**
  I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.

- **NotReduceWorkload**
  Automation does not reduce total workload, because there is more to monitor now.

- **ConsultAnnunciator**
  I always consult the flight mode annunciator to determine which mode the autopilot/flight director is in.

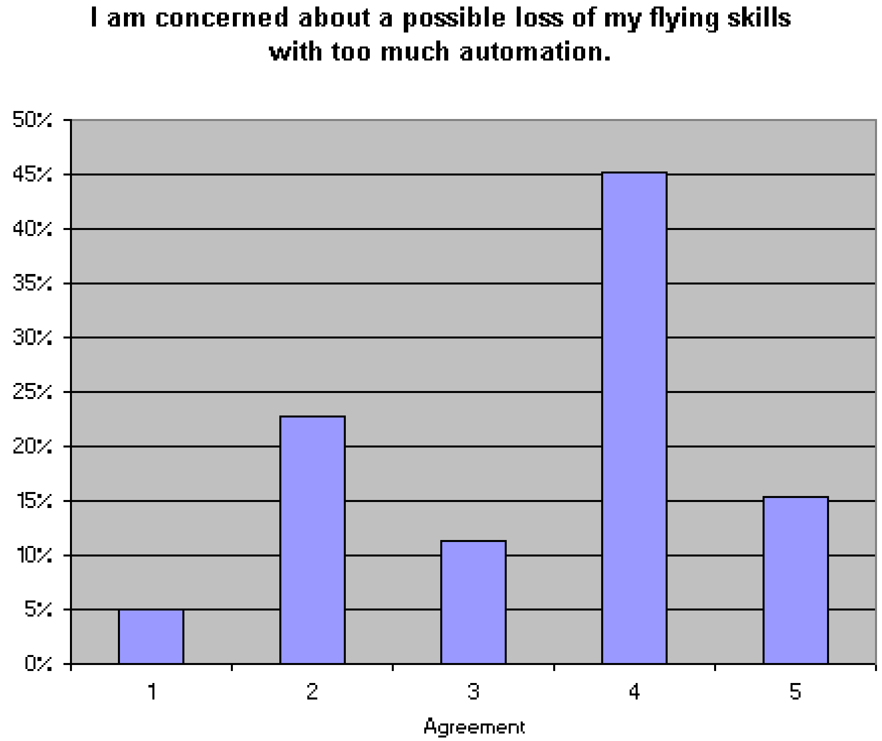
- **AdequateTraining**
  Training for my current aircraft was as adequate as any training I have had.

- **HelpDoJob**
  I use automation mainly because it helps me get the job done.

- **AltitudeBust**
  It is easier to bust an altitude in an automated airplane than in other planes.

- **ButtonPusher**
  Sometimes I feel more like a "button pusher" than a pilot.

- **MisunderstoodModes**
  There are still modes and features of the autoflight system that I don't understand.


I am concerned about a possible loss of my flying skills with too much automation.
50%
45%
40%
35%
30%
25%
20%
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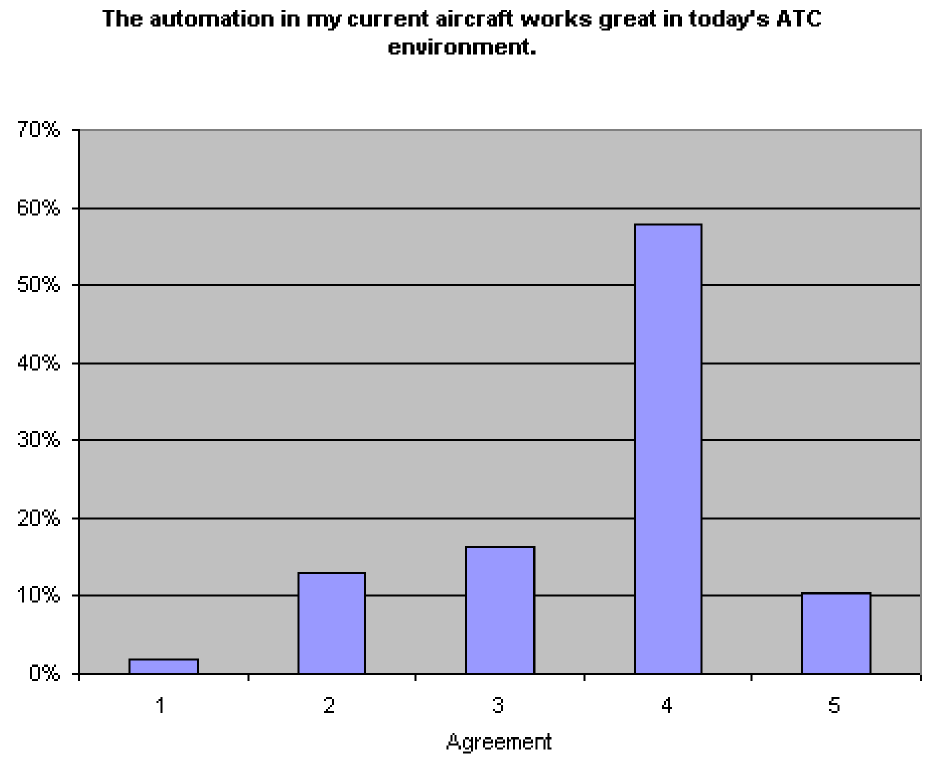
Agreement


The automation in my current aircraft works great in today's ATC environment.
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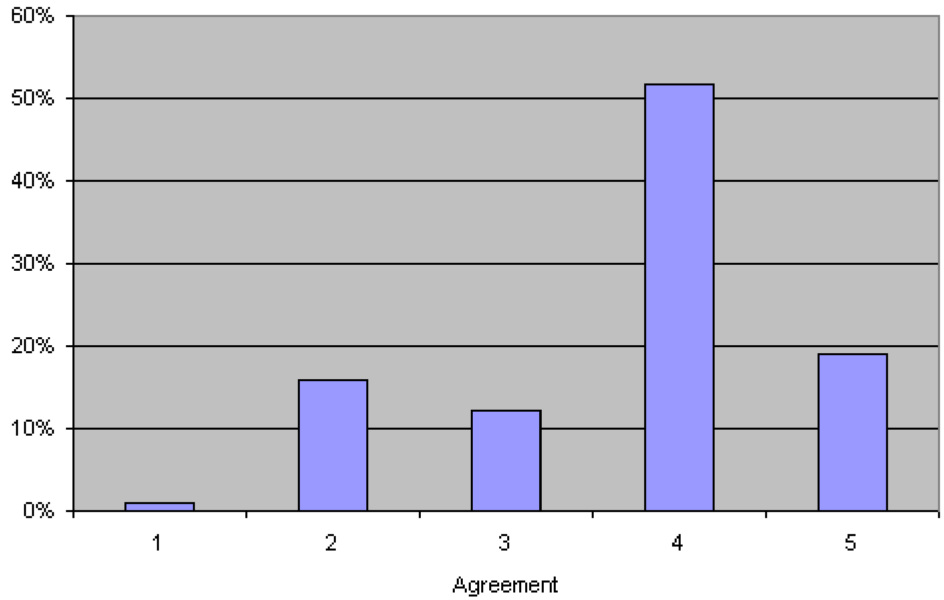
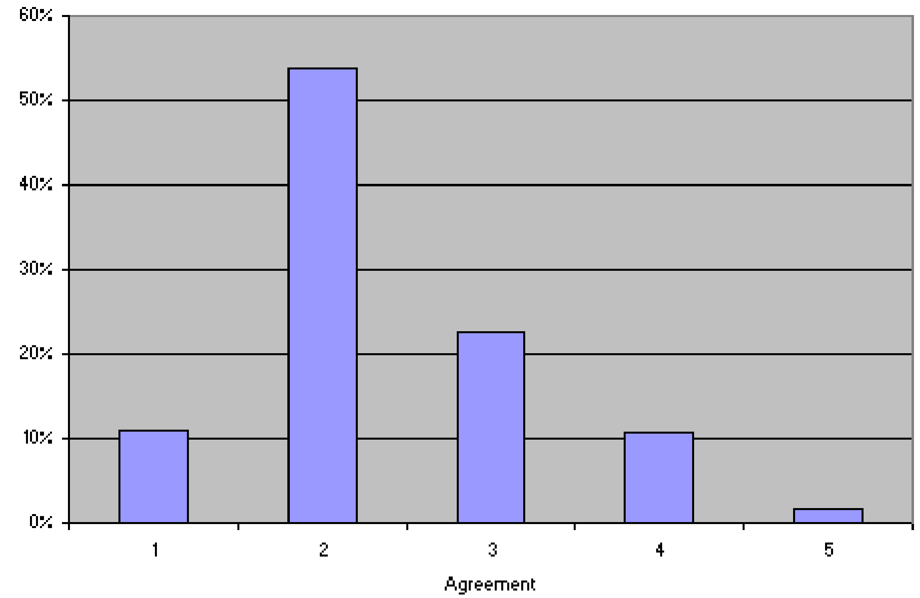
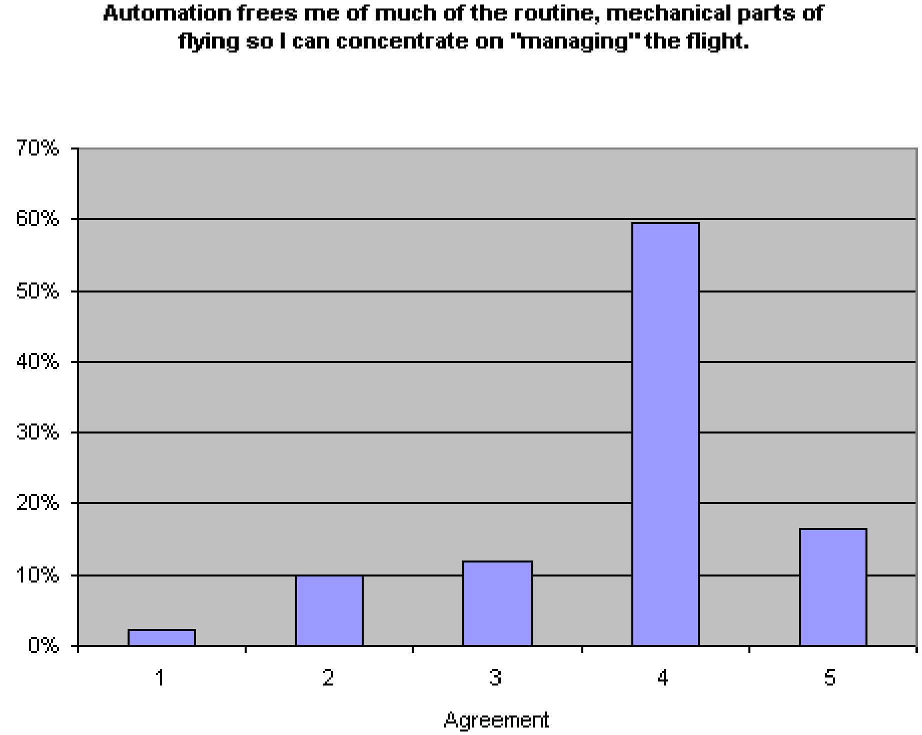
Agreement

I always know what mode the autopilot / flight director is in.



I use the automation mainly because my company wants me to.




Automation frees me of much of the routine, mechanical parts of flying so I can concentrate on "managing" the flight.
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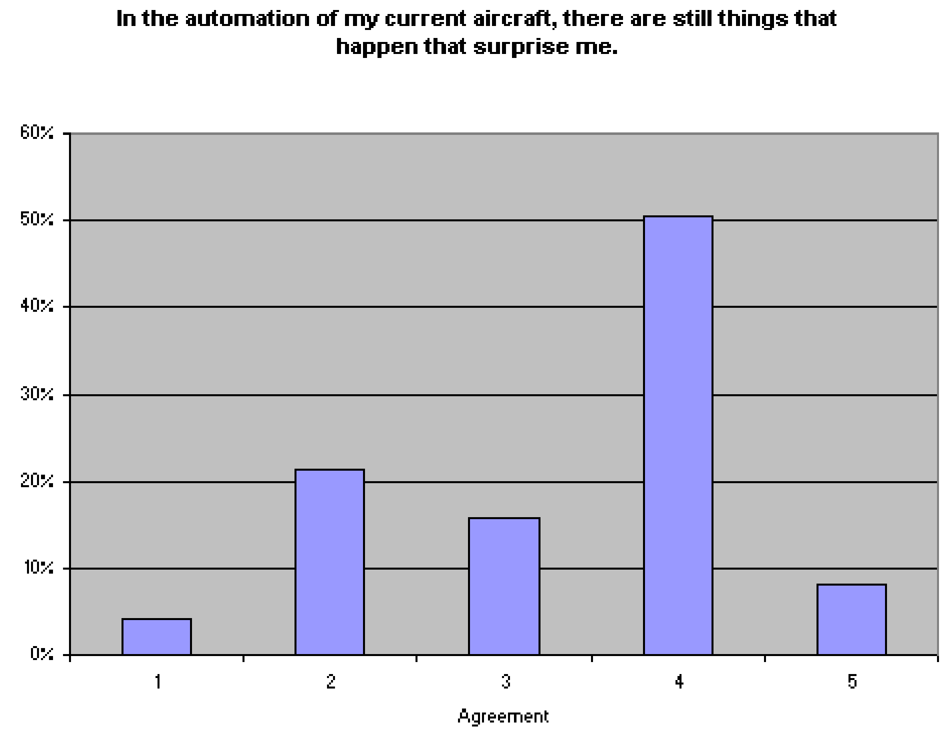
Agreement


In the automation of my current aircraft, there are still things that happen that surprise me.
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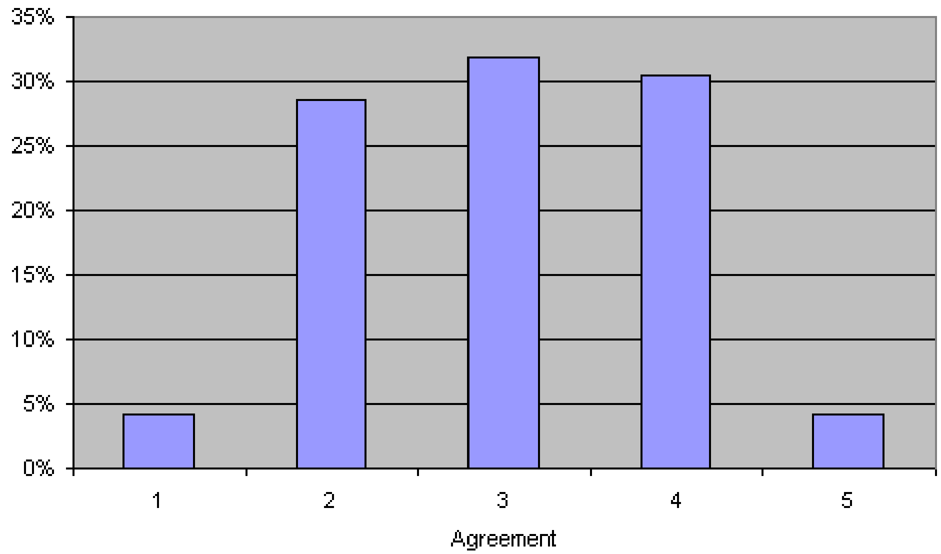
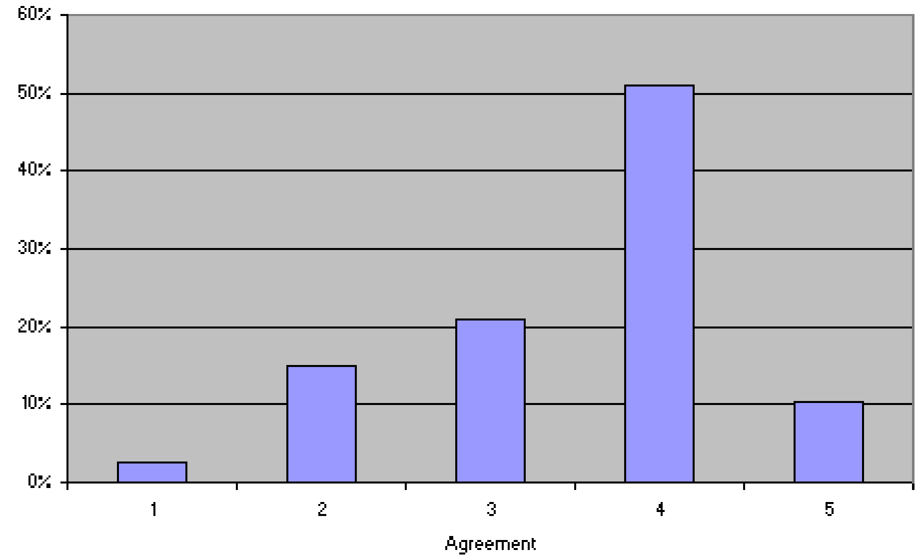
Agreement

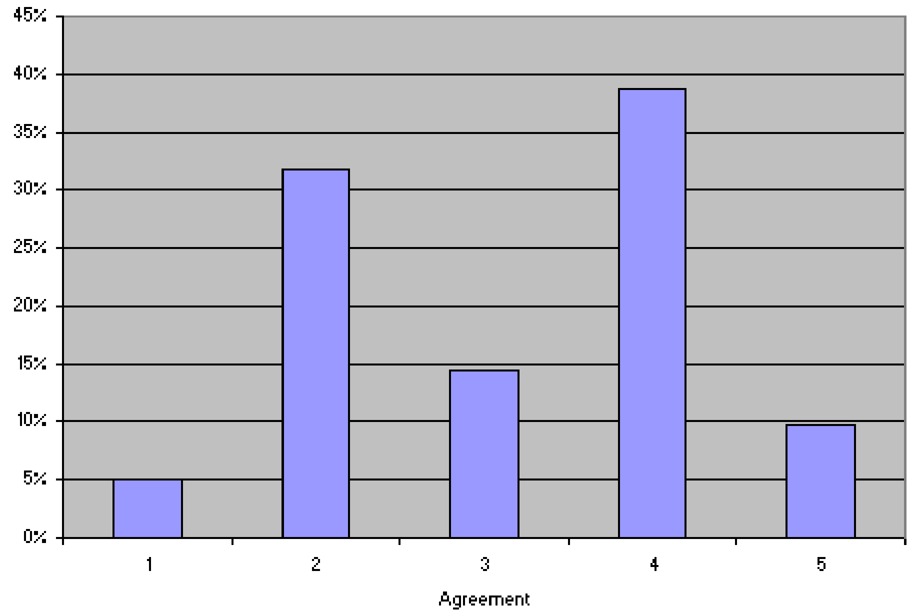
I make fewer errors in the automated airplanes than I did in the older models.



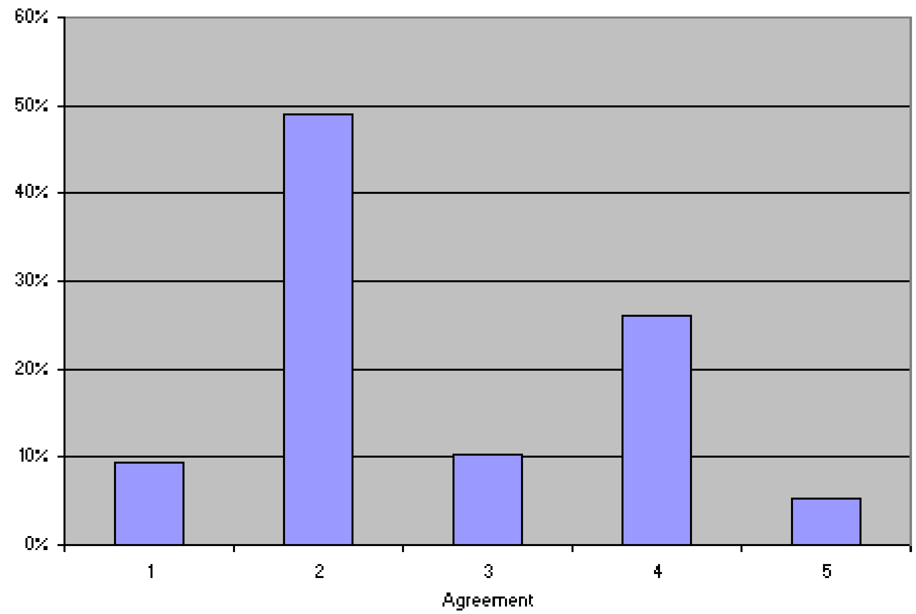
Automation helps me stay "ahead of the airplane".

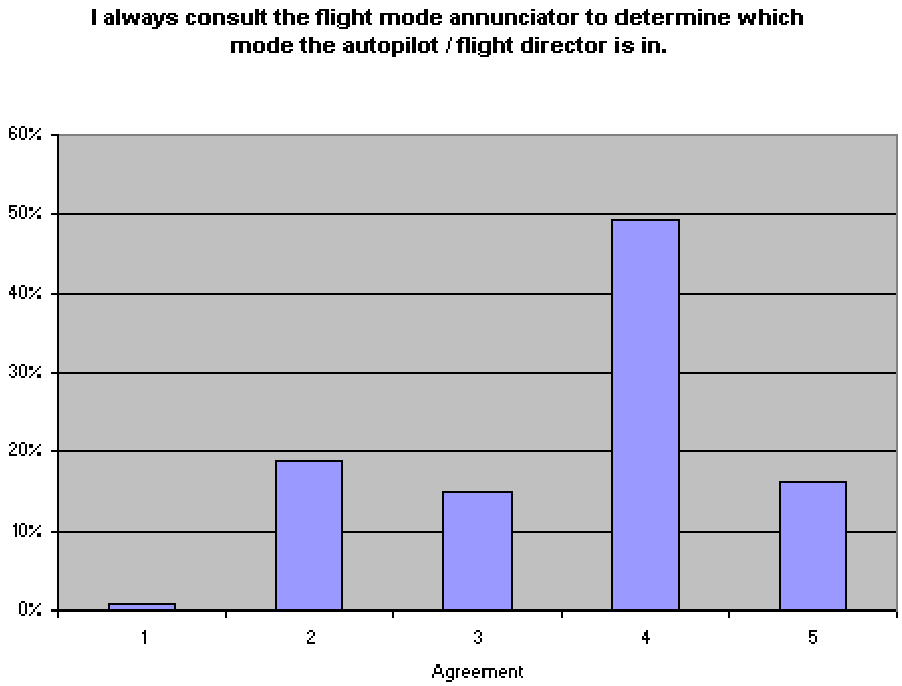


I spend more time setting up and managing the automation (CDU, FMS) than I would hand-flying or using a plain autopilot.



Automation does not reduce total workload, because there is more to monitor now.




I always consult the flight mode annunciator to determine which mode the autopilot / flight director is in.
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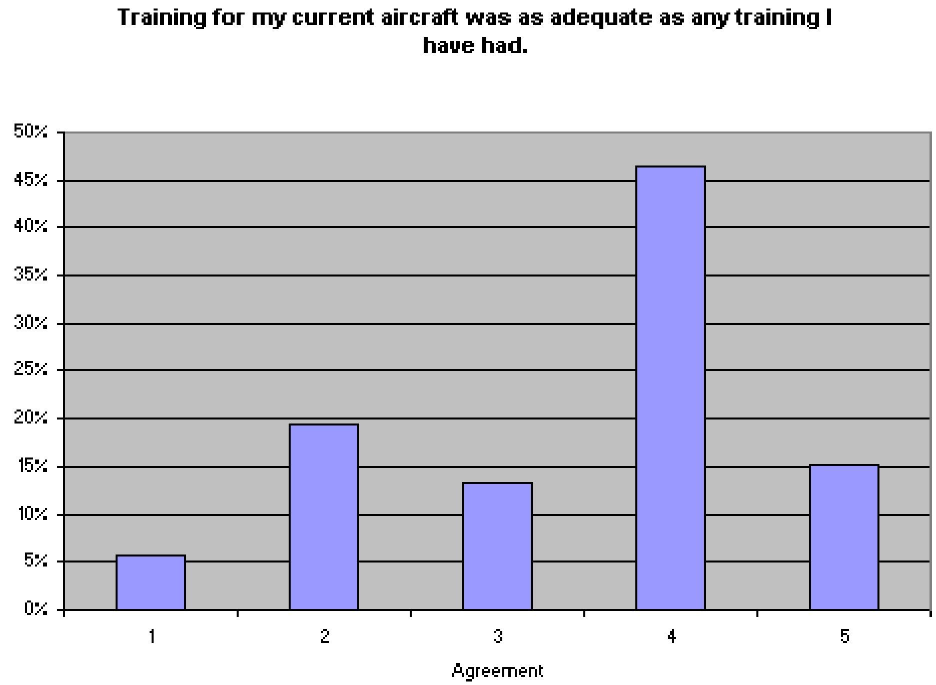
Agreement


Training for my current aircraft was as adequate as any training I have had.
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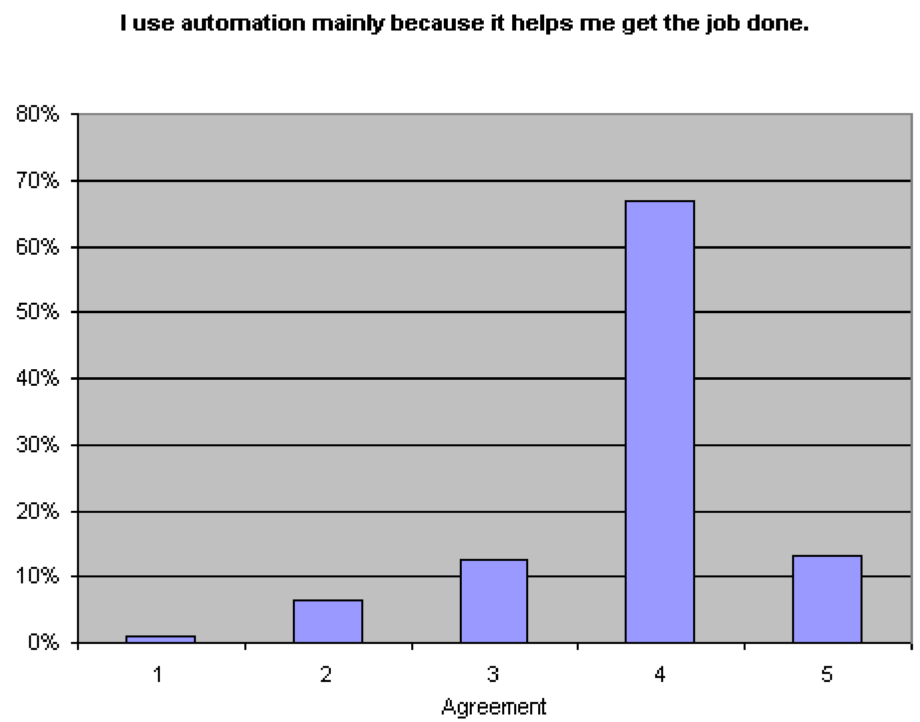
Agreement


I use automation mainly because it helps me get the job done.
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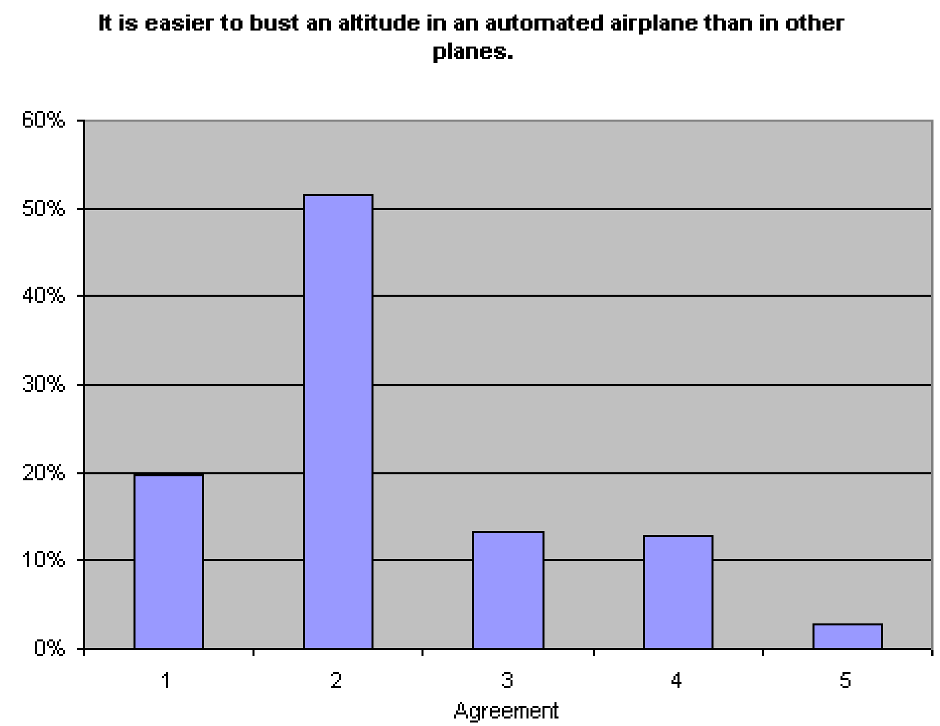
Agreement


It is easier to bust an altitude in an automated airplane than in other planes.
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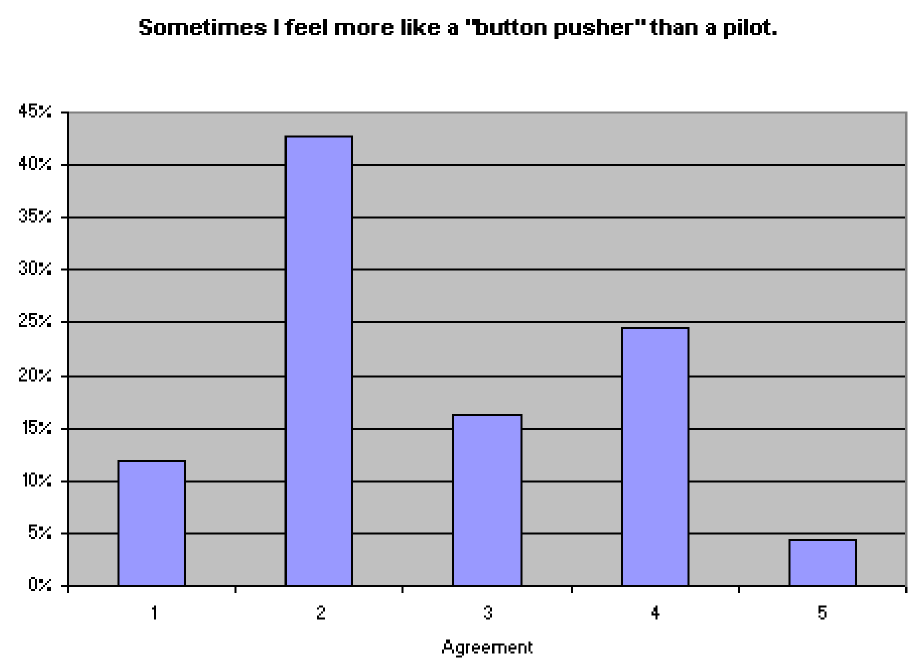
Agreement


Sometimes I feel more like a "button pusher" than a pilot.
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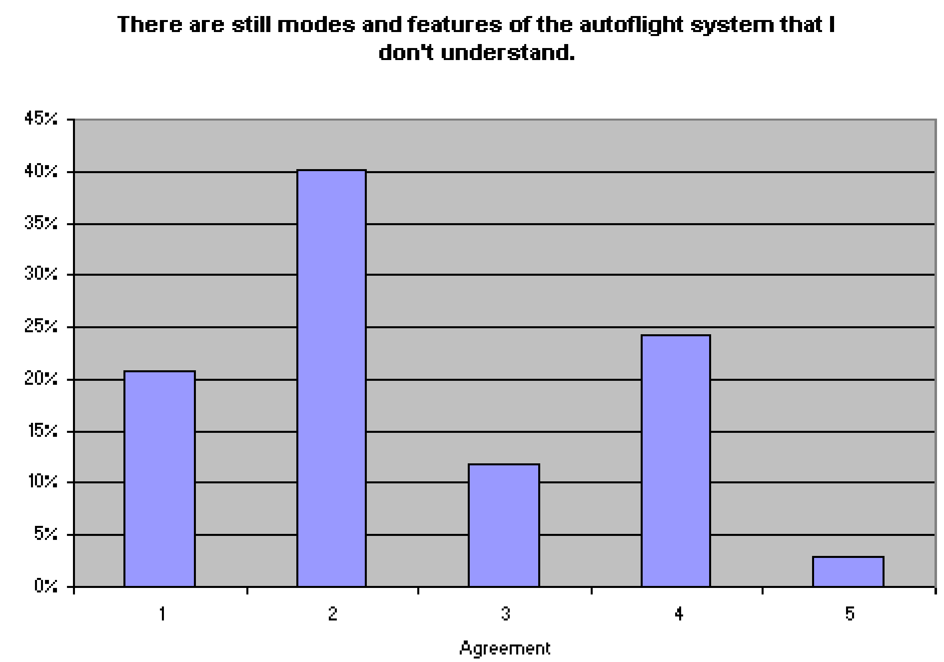
There are still modes and features of the autoflight system that I don't understand.
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Agreement

About this document ...

This document was generated using the **LaTeX**2HTML translator Version 98.2 beta6 (August 14th, 1998)

The command line arguments were:
latex2html automation-attitudes.tex

The translation was initiated by Ed Hutchins on 1999-08-02

Ed Hutchins
1999-08-02