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Effects of Video Weather Training Products, Web-based Preflight Weather Briefing, and Local Versus Non-Local Pilots on General Aviation Pilot Weather Knowledge and Flight Behavior, Phase 1

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16. Abstract

This research has two main phases. Phase 1 investigated three major questions:

1) Do video weather training products significantly affect general aviation (GA) pilot weather knowledge and flight behavior in marginal meteorological conditions?
2) How are modern Web-based weather products used during GA preflight briefing?
3) Do local Oklahoma GA pilots differ appreciably from other pilots in either weather knowledge or weather-related flight behavior?

Fifty GA pilots took a general weather knowledge pre-test, followed by exposure to either one of two weather training videos (the Experimental groups) or to a video having nothing to do with weather (the Control group). They next took a post-test to measure knowledge gain induced by the training product. Finally, they planned for, and flew, a simulated flight mission through marginal weather from Amarillo, TX, to Albuquerque, NM.

Question 1: Few highly significant, direct effects were found for the two 90-minute video weather training products all by themselves. Follow-up multivariate modeling implied that a *combination* of higher pilot age, receiving either weather training product, and takeoff hesitancy could significantly, correctly predict 86.7% of diversions from deteriorating weather and 77.8% of full flight completions. However, we must conservatively conclude that weather knowledge and GA weather flying behavior are complex and unlikely to be profoundly changed by a single, brief training product. Phase 2 will address this issue.

Question 2: The data-collecting emulation of *www.aviationweather.gov* suggested that mere *time spent* on preflight briefing was not a good predictor of either *quality* of preflight briefing or subsequent *flight safety*. Nonetheless, these data are just an opening look at what should eventually be a far more intensive study of modern weather briefing and its relation to flight safety.

Question 3: No important differences were seen between local and non-local pilots. These findings imply that CAMI studies are likely to be generalizable to the national population of U.S. GA pilots.

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Effects of Video Weather Training Products, Web-based Preflight Weather Briefing, and Local Versus Non-Local Pilots on G.A. Pilot Weather Knowledge and Flight Behavior, Phase 1

INTRODUCTION

Background

Strategic motivation for this research. The term "adverse weather" involves multiple factors such as restricted visibility due to low cloud ceilings, fog, rain, snow, thunderstorms, or airframe icing. Adverse weather, is a perennial concern to general aviation (GA). Analyses of GA accidents from the 1970s-2000s show that, despite a relatively low incidence rate for weather-related accidents (4-5%, depending on data source and classification scheme), their fatality rate is 3-4 times higher than for other GA accident causes (Bazargan, 2005; Bud, Mengert, Ransom, & Stearns, 1997; NTSB, 1989; NTSB, 2005). This is largely because weather accidents often involve flight into terrain or loss of control, which typically results in a high percentage of fatalities.

The role of training. Training is classically cited as a way to minimize hazards of flying, including weather. Yet, the body of actual research concerning measured effectiveness of weather-related training in GA is small and often involves trying to correlate the implementation of training methods with subsequent reductions in accidents or accident rates (Adams & Ericsson, 1992).

Formal logic asserts that correlation is necessary, but not sufficient, to demonstrate causation. Hence, we are never sure that training increases pilot skill and results in safer behavior. We simply assume it. Yet, a large body of research in perceptual, behavioral, and educational psychology shows that the acquisition and retention of learning is often anything but assumable (Ellis, Semb, & Cole, 1998; Goldstein, 1999; Mackintosh, 1974; Semb & Ellis, 1994).

Characteristically, training is not permanent. Figure 1 shows a simplified learning decay function. New learning starts at some maximum level (e.g., "100%"), after which it decays exponentially with time (assuming it is not refreshed), asymptoting at some lower level (here, an arbitrary "20%").

Also, the amount of initial learning, plus the rate of decay, are two crucial parameters of knowledge retention. Another is how well knowledge is transferred from one domain to another—for example, from the classroom to the real world (Perkins, 1992). Finally, measuring "cognition in the wild" is often a very different set of circumstances from measuring in a carefully controlled laboratory setting (Hutchins, 1995). This makes real-world assessment of training a challenge for researchers.

In the real world, non-instrument-rated pilots are supposed to fly by visual flight rules (VFR). VFR pilots learn they are supposed to avoid weather. However, they sometimes attempt a flight when weather is a factor along their route, either as forecast or unknown. Believing the weather is safely flyable, the VFR pilot is actually ill-prepared to deal with an encounter, since practical weather skill training is usually minimal or absent from the private pilot syllabus. Similarly, a newly minted GA instrument pilot may know intellectually to avoid thunderstorms and icing when flying in clouds but has little practical knowledge and skill to allow him or her to proceed safely.

A final factor involving training has to do with assessment. Following the revelation that pilots can pass the FAA certification examinations without answering the weather-related questions (Wiegmann, Talleur, & Johnson, 2008), the FAA is rethinking the testing

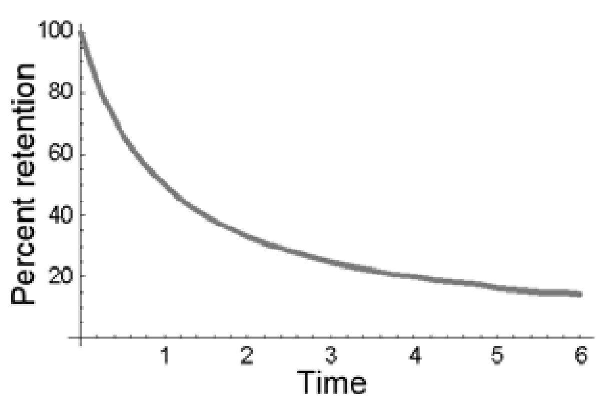


Figure 1. Simplified learning decay function.

procedure. Further data on this subject would be useful to decision makers.

Purpose of this research

Immediate motivation. At the behest of FAA Human Factors Research and Engineering Group program management (AJP-61, see Acknowledgments), Civil Aerospace Medical Institute (CAMI) researchers were tasked by the Flight Standards division (AFS-810) to explore issue #1 below. Issues 2-3 were added because they were useful to the study, addressing general issues of flight simulation methodology critical to both CAMI and the human factors flight simulation research community at large.

1. Do video weather training products significantly affect pilot weather knowledge and flight behavior in the face of potential instrument meteorological conditions (IMC)?
   a. If so, what are the immediate effects?
   b. Do these effects persist over time?
2. How are modern Web-based weather products used during preflight briefing?
3. Do local[1] pilots differ appreciably from non-local pilots in either weather knowledge or weather-related flight behavior?

Issue 1 is consequential for reasons already stated. Issue 2 begins human factors study of what promises to be the future of preflight weather briefing—self-briefing by pilots using Internet-based tools.

Issue 3 addresses the broad question of whether or not local (Oklahoma-based) pilots are representative of pilots within a larger, continental area. Presumably, they are similar but, so far, this has not been directly investigated. Since many of the FAA's general aviation studies are conducted by the Oklahoma-based Civil Aerospace Medical Institute, this is a statistical validity issue calling for study, and one that has bearing on all flight simulator studies.

*Possible types of training product*s. Effective training is usually based on sound learning theory. Learning theories are organized explanations of how we come to know what we know and behave as we behave.

Learning theories fall under three major categories: behaviorism, cognitivism, and constructivism. To each category, three common, fundamental processes apply: Knowledge and behavior can either be acquired, maintained, or extinguished.

[1]A "local" pilot was defined as one living in Oklahoma at the time of the study. For the most part, this meant long-term OK residents (n=18). However, there were 4 instances of pilots living in OK whose state-of-legal residence was not OK because they were attending local flight schools.

Behaviorism explains the acquisition, maintenance, and extinction of learning as related to observable behaviors. Behaviorism asserts that we learn either because instinctive behaviors become associated with environmental stimuli or because trainable behaviors are rewarded or punished (Mackintosh, 1974).

In contrast, cognitivism focus on brain functions—often not directly observable—particularly memory and information processing. Cognitivism suggests that our brains may functionally resemble computers, processing inputs to produce outputs (Waltz & Feldman, 1988).

Finally, constructivism expands on the computer metaphor, but elevates cognition from a relatively straightforward "information vector-transformation" role to a somewhat richer (yet harder to define) "construction of an inner world" (von Glasersfeld, 1995). This "inner world" involves an organized set of mental representations of external objects, their relations, and interactions. Constructivism thus includes the active formation of inner abstractions, concepts, rules, and principles that can both organize current knowledge and predict future outcomes in the environment, based on current behaviors of the actor.

At the risk of oversimplifying the best way to train pilots, behaviorist training methods arguably apply best to well-defined procedural tasks such as stick-and-rudder skills—discrete behaviors that can be practiced until they become habits. Cognitive training methods arguably work best with tasks requiring memorization of information, pattern recognition (e.g., recognizing cloud types), and other tasks requiring the transformation of information from one state to another.

Finally, constructivist training methods involve taking what we already know and adding to that to construct a richer, more accurate "mental model" of the world and how it works. By that logic, since piloting involves understanding a complex machine operating dynamically within a complex environment, constructivist methods may work best when trying to teach aeronautical decision making.

This sketch of learning theory, albeit brief, leads to testable hypotheses. For instance, if a video training product embodying a cognitive training approach were compared to one embodying a constructivist approach, and both were compared to an irrelevant (non-weather related video) Control group—would we see significant differences between groups in pilot weather knowledge and flight behavior, given a simulated flight mission into adverse weather?

To set up a formal null hypothesis (H0) and several alternatives (H1-3):

- H_0: No significant differences exist between control, cognitive, and constructivist training products.
- H_1: Cognitive product will be significantly better than the control product ($H_0<H_1$).
- H_2: Constructivist product will be significantly better than the control product ($H_0<H_2$).
- H_3: Both cognitive and constructivist products will be superior to the Control, plus one will be significantly better than the other ($H_0<H_1<H_2$ or $H_0<H_2<H_1$).

METHOD

The research was conducted in two phases. Phase 1 examined data collected from January to July, 2008, and is the subject of the current report. Phase 2 will be similar in approach and will constitute the second half of a longitudinal study, to be reported at a later date.

Participants

Forty-eight GA pilot volunteers participated with informed consent. Various exigencies ultimately brought the total to 50. The overall group mean age was 41.0 (median = 39, SD = 17.5), mean flight hours was 1314 (median = 268, SD=2709). A few high-hour pilots elevated the flight hours mean, generating a statistical concern that will be addressed later.

We recruited local pilots from a list of pilots who had participated in previous studies and by advertising in local flight schools. Non-local pilots saw an advertisement in *Flying* magazine, which resulted in more than 350 responses. The first 18 respondents were selected blindly. However, after checking their demographics for age and flight hours, a preponderance of higher-hour, older pilots was noticed, relative to the local pilots. This may not be surprising, given the type of pilots likely to read *Flying*. However, to better equilibrate the groups, the remaining six non-local pilots were purposely chosen for being relatively younger and having relatively lower flight hours (Figure 2).

Research design, assignment to groups, and order of treatments

In measuring how training can change a person, changes can occur in what we know and/or how we behave. Therefore, this experiment measured the effects of several independent variables on the dependent variables of both cognitive weather knowledge and pilot flight behavior. This was operationalized as follows:

Primary independent variables

1. Weather training video product (Trg Prod)
   a. Training product 1 (constructivist)
   b. Training product 2 (cognitive)
   c. Control (pilots watched a video on aviation physiology)
2. Instrument rating
   a. Instrument-rated pilots
   b. Private pilots (non-instrument-rated)
3. Pilot's state of residence
   a. Local residents
   b. Non-local residents

Secondary independent variables

4. Age
5. Flight hours

Dependent variables

1. Weather knowledge test
2. Web-based preflight data
   a. Page viewed
   b. Pageview duration
3. Flight simulator data
   a. Flight duration (in minutes)

Figure 2. Pilot demographics.

b. Minimum distance to ABQ (statute miles)
c. Cloud clearance
  i. Minutes spent in IMC
  ii. Minutes spent at < 500' from cloud base (scud running)
d. Ground clearance [minutes spent at < 500' Above Ground Level (AGL)]
e. Takeoff decision (yes/no)

Each pilot was assigned to one of three primary *Training product* groups (Table 1, "Trg product" column). In turn, each *Training Product* group of 16 pilots was sub-divided into two secondary *Instrument Rating* groups ("Rating" column), containing eight instrument-rated pilots (*IFR*, for "instrument flight rules") and eight non-instrument-rated pilots (*VFR*, for "visual flight rules"). Finally, each *Instrument Rating* group of eight was sub-divided into two tertiary *Pilot Residence* groups containing four local Oklahoma pilots and four non-local pilots ("Local" column, 1=local, 0=non-local). Table 1 embodies the resulting experimental structure.

This resulted in a 3x2x2 mixed design with 12 treatment cells. In Phase 1, the variables of training product, instrument rating, and residence could be analyzed as between-groups comparisons, with group means being compared to other group means to look for differences. Conversely, weather knowledge could be analyzed as a within-groups comparison in which each pilot would serve as his or her own statistical control over repeated administrations of different (but equivalent) test forms.

The 12 cells arguably needed to be equilibrated for pilot age and flight hours. Table 1 was therefore set up as an Excel™ spreadsheet, used to allocate pilots to cells while maintaining maximum equivalence in cell means for age and flight hours.

Two variants of weather direction were used as distractors to help divert attention from the fact that the flight scenario would be essentially repeated in Phase 2 ("Flight scenario" column). Variant 45 had weather approaching from 45° (aeronautical coordinates, 0° = North, increasing clockwise), while Variant 135 had weather approaching from 135°. However, note that weather direction was simply a distractor, not otherwise a variable of interest.

Apparatus

Weather training products/control materials. Two well-known video weather training products were selected from a list of candidate products. Given the impossibility of knowing product quality a priori, two publicly prominent products were chosen. The authors of these products graciously provided them on condition of confidentiality; therefore, their wishes for confidentiality shall be respected in this report.

Training product 1 constituted the "constructivist product." This focused mainly on the aeronautical decision-making aspects of weather flight. It offered systematic, mnemonic risk factor checklists applicable to specific factors such as the weather in question, internal pilot factors affecting performance (e.g., skill, health, fatigue), and factors external to the pilot that could affect risk-taking (e.g., passengers needing to arrive at their destination by a certain time). After each video lecture session, it presented hypothetical flight scenarios and asked the student to evaluate these, based on the lecture content presented so far.

Training product 2 constituted the "cognitive product." This focused largely on the recognition of different cloud types, visibility conditions, horizon recognition, and terrain clearance. For instance, still pictures of common weather types were shown, after which pilots were queried as to their appropriateness for VFR flight. This technique has been used in research (Wiggins & O'Hare, 2003). Figure 3 shows a sample picture.[2]

Sample exercises showed still pictures of a weather situation as seen aloft, asking what recognition factors were problematic, and then asking for a go/no-go decision on VFR flight.

A second section presented details of an accident scenario, asking pilots to decide the primary cause. A third section began by discussing factors involved in deciding whether or not to divert because of weather. It then presented a detailed weather flight scenario involving a number of possible alternate landing sites, asking which was most appropriate. Finally, it presented a list of several potential flights, with preflight briefing details of each, next asking for a go/divert decision after presentation of a still photo of in-flight weather, and finally asked for a justified choice of alternate, if diversion was chosen.

The third video group—the Control group—received an FAA-produced video on aviation physiology, having nothing whatsoever to do with weather.

Timer. A timer utility was written by the experimenters to capture the amount of time each pilot spent viewing the training product. This timer was activated by each pilot at the beginning of training and was turned off afterward to capture elapsed viewing time (Figure 4).

Measurement of timing was motivated by the question of whether viewing time might influence the subsequent weather knowledge posttest score, in which case time might be useful as a covariate in statistical analysis.

[2]Simulator fidelity can be an issue in weather studies. While visibility restrictions such as haze and fog are relatively simple to model, even static cloud layers present modeling challenges. Discrete, morphing clouds present the greatest challenge because real clouds act as chaotic cellular automata evolving within a larger multivariate, non-linear, chaotic system. The present study used static, stratiform clouds—among the easiest to model realistically.

Table 1. Experimental structure (the ellipsis "..." denote data purposely omitted to declutter the table).

Order of treatments							Phase 1			Phase 2		
SUBJNO 1st=Trg product 2nd=IFR (1)/VFR(2) 3rd=Scen order 4th=# w/in cell	Trg product	Rating (1=IFR)	Age	mean Age	Flight hours	Mean FH	Know. pretest	Know. posttest	Flight scenario (1=45 deg 1st)	Know. final	Flight scenario (2=135 deg 1st)	Local
1111	Trg product 1	IFR	65	**53**	1043	**2258**	A	B	45 deg	C	135 deg	1
...			...		...			...		...	...	...
1118			47		1500		B	C	45 deg	A	135 deg	0
1221		VFR	39	**30**	170	**176**	A	B	135 deg	C	45 deg	1
...			...		...			...		...	...	...
1228			21		120		A	B	135 deg	C	45 deg	0
2121	Trg product 2	IFR	19	**49**	174	**2384**	A	B	135 deg	C	45 deg	1
...			...		...			...		...	...	...
2128			60		550		B	A	135 deg	C	45 deg	0
2211		VFR	34	**32**	154	**189**	A	B	45 deg	C	135 deg	1
...			...		...			...		...	...	...
2218			28		105		C	B	45 deg	A	135 deg	0
3111	Control	IFR	73	**50**	13000	**2568**	A	B	45 deg	C	135 deg	1
...			...		...			...		...	...	...
3130			22		120		B	A	135 deg	C	45 deg	0
3221		VFR	52	**31**	131	**163**	A	B	135 deg	C	45 deg	1
...			...		...			...		...	...	...
3218			21		77		C	B	45 deg	A	135 deg	0

Figure 3. Would this type of weather be appropriate for VFR flight?

Figure 4. Timer used to record time spent by each pilot on the weather training product.

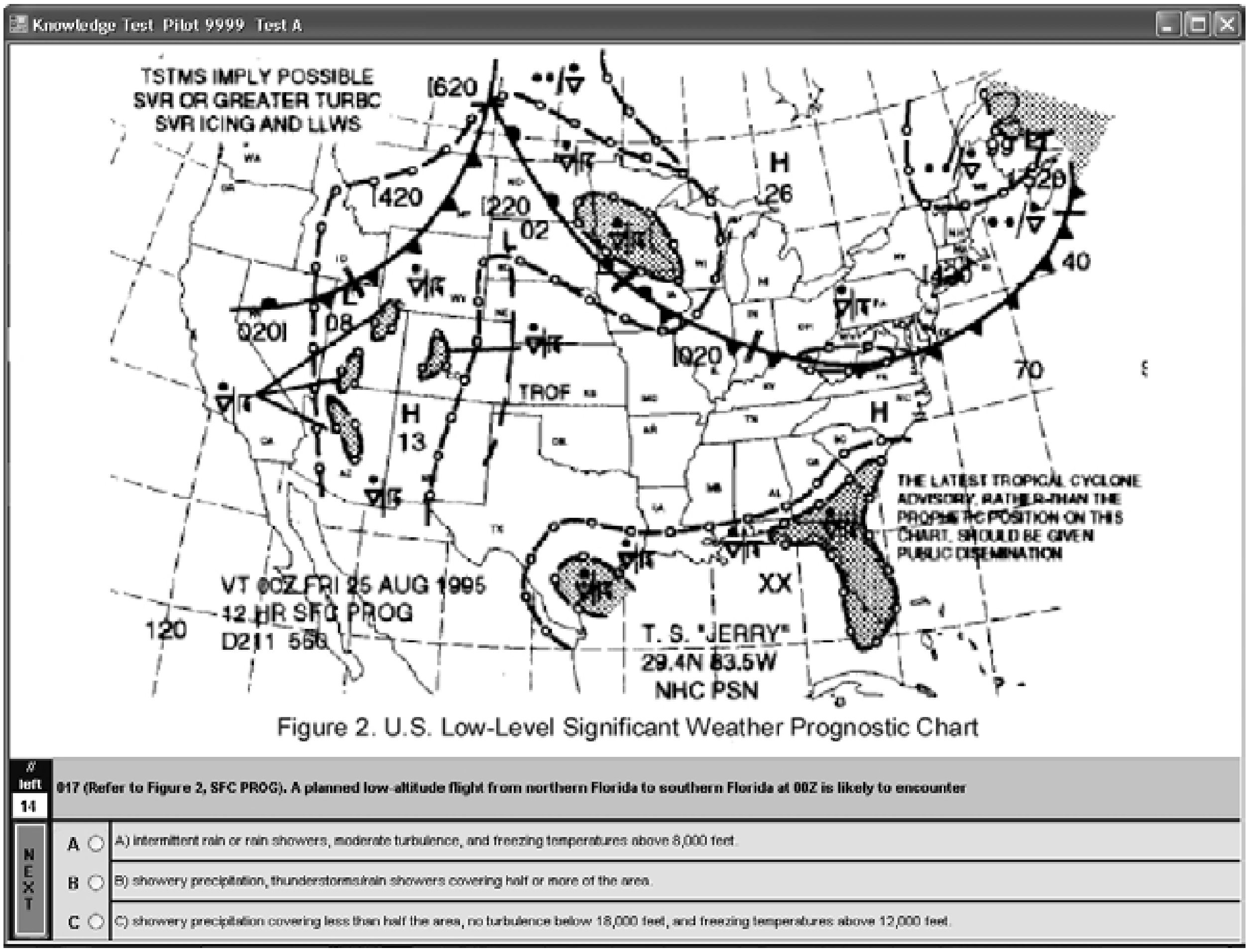


Figure 5. Sample screenshot from the Weather Question Tester program.

Weather knowledge tests. Three parallel forms were constructed of a 30-question general weather knowledge test and were matched on item difficulty, using questions and proportion-correct data provided by FAA's Airman Testing Standards Branch (AFS-630). One-third of the questions on each test were taken from private pilot tests; two-thirds came from instrument rating tests. This was not expected to pose a problem, since pre- minus post-treatment change scores were to be analyzed, which are immune from overall test difficulty as long as the tests are neither impossibly difficult nor trivially easy (i.e., do not suffer from either ceiling or floor effects).

Administration order of the parallel forms was counterbalanced across pilots (see Table 1). This controlled for the event that the 3 forms would not be exactly equivalent in difficulty.

Each test was administered on a laptop computer using software written by the experimenters in Microsoft *Visual Studio 2005*™. Figure 5 shows a screenshot of a sample question.

The program automatically recorded each question, each response, response-correct or incorrect, time spent per response, overall percent correct, and total elapsed time.

Preflight weather briefing materials. Briefing materials included a verbal description of the flight mission, plus standard DFW (Dallas-Fort Worth) and ABQ (Albuquerque) sectional charts.

To simulate Internet weather briefing, we wrote a part-task emulation of the NOAA/NWS Web weather briefing site *www.aviationweather.gov*, also in Microsoft *Visual Studio 2005*. This emulation automatically recorded which pages were viewed and the view duration of each page. Figure 6 shows a sample page. Appendix A shows screenshots of all pages. Appendix B illustrates sample hypertext markup language code used to create the home page. The core html was taken from *www.aviationweather.gov* and modified for use here. Appendix C illustrates code-behind for a sample page. In Visual Studio, code-behind can be written to create dynamic Web pages that respond to events such as mouseovers and button clicks.

Specifically, pages were written to convey information on:

1. SIGMET[3]/AIRMET[4] (Java tool; graphical)

[3] Significant Meteorological Information
[4] Airman's Meteorological Information

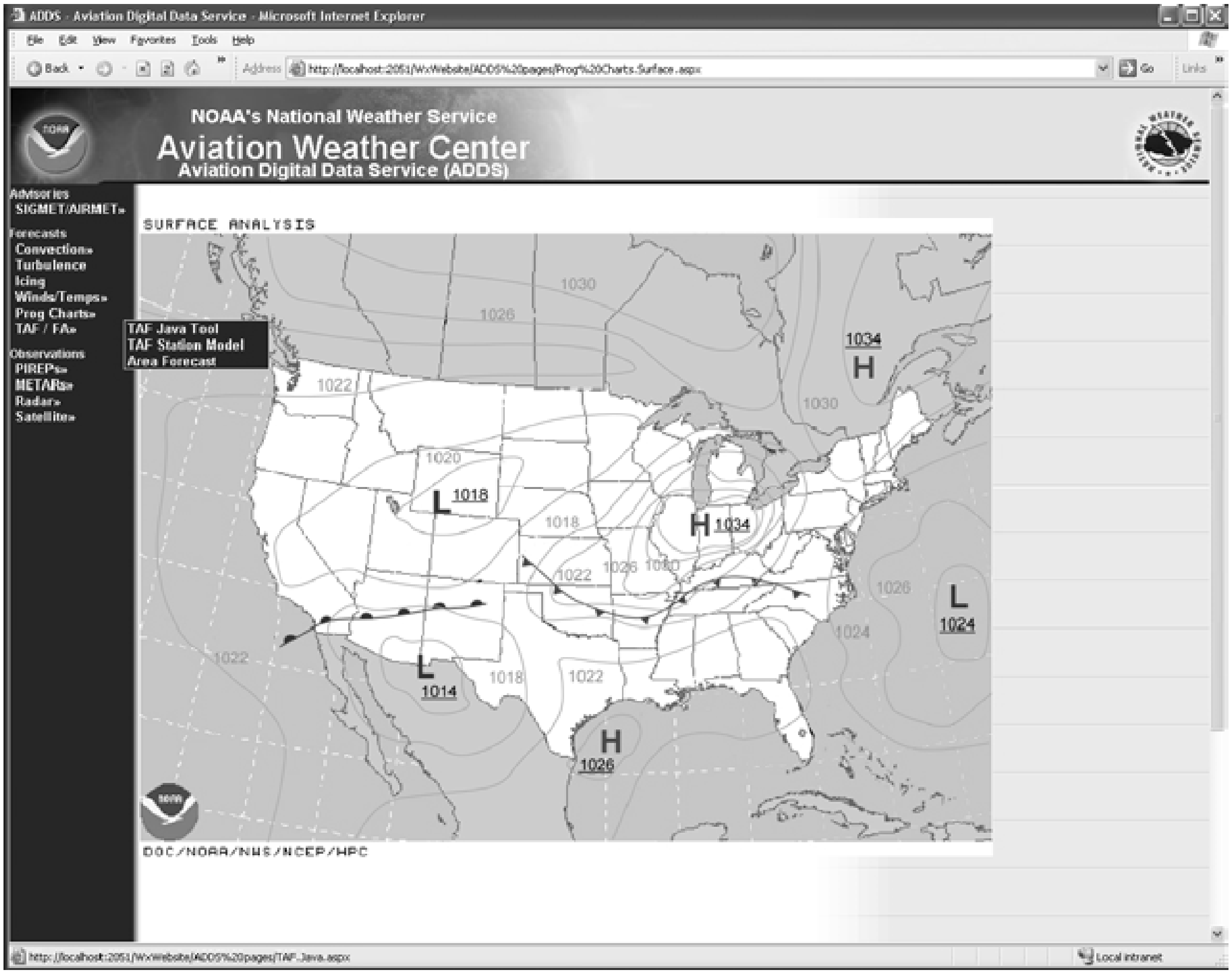


Figure 6. Sample screenshot from the Web-based emulation of www.aviationweather.gov.

2. Convection
   a. Convective SIGMETs (graphical)
   b. CCFP[5] (graphical; looping .gif movie)
   c. Convective outlook (graphical)
3. Turbulence (graphical)
4. Icing (graphical)
5. Winds/Temps (text)
6. Prog charts (graphical)
7. TAFs[6]/FAs[7]
   a. TAF Java tool (graphical, with popup text)
   b. TAF Station model (graphical)
   c. Area Forecast (text)
8. PIREPs[8] (text; not used in this experiment)
9. METARs[9] (Java tool; graphical, with popup text)
10. Radar (graphical; looping NEXRAD[10] .gif)
11. Satellite (graphical; looping cloud cover .gif)

Advanced General Aviation Research Simulator (AGARS)

The AGARS is a real-time, fixed-based flight simulator that can represent complex interactions of environment, hardware, communications, crew resource management, and situational and risk variables for simulated general aviation flight protocols. It provides dynamic, control-loaded responses. Based on current dual-core server class Athlon™ CPUs running the Linux OS (Fedora core 7), it was configured as a Piper Malibu for the purposes of this experiment.

Equipped with a high-resolution visual system with a 150 degree field of view, AGARS allows meteorological conditions to be precisely controlled. It continuously captures up to 150 variables at 30Hz for a four-hour mission and includes up to 85 programmable non-routine events.

Panels and consoles are reconfigurable to allow testing of innovative display concepts created using rapid prototyping software (GLStudio™). It is equipped with

[5] Collaborative Convective Forecast Product
[6] Terminal Aerodrome Forecast
[7] FA=Aviation area 18-h forecast
[8] Pilot Report
[9] Meteorological Aerodrome Report
[10] Next Generation Radar

an experimenter operating station (EOS), an ATC workstation, and a workstation for controlling pseudo-vehicles. During the course of a flight scenario, the EOS allows the experimenter to visually monitor the cockpit and simulation environment. In addition to digital recordings of the flight data, a digital camera is used to record a global view of the cockpit and pilot onto a stand-alone DVD player hard drive and later recorded to DVDs. All cockpit, ATC and experimenter communications are also recorded onto these DVDs (Figure 7).

In-flight weather updates are an option available to the modern GA pilot through automated recorded systems such as the Automated Weather Observation System (AWOS). To emulate AWOS, we wrote a control panel capable of triggering prerecorded METAR information (Figure 8).

Pilots could tune the cockpit radio to one of a set of given frequencies, alerting the experimenter to click the corresponding button on the AWOS control panel, triggering the corresponding recorded METAR, which played back through the pilot's headphones.

The Flight Service Station (FSS) is also an option to GA pilots to receive air traffic control services such as flight following, vectors-to-destination, and weather. To emulate this option, one of the experimenters (Ball) served as a pseudo-FSS briefer during the flight phase.

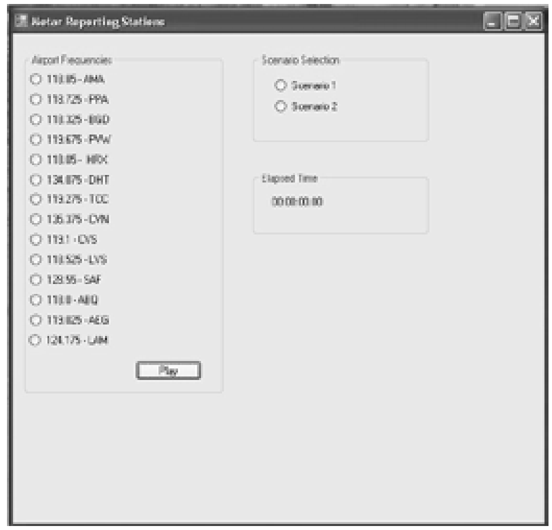


Figure 8. AWOS emulator.

Procedure

Upon arriving at the simulator lab, we asked pilots to plan an east-to-west, VFR flight from Amarillo, TX (AMA) to Albuquerque, NM (ABQ). This route takes approximately 90 minutes to fly in the Malibu with a high speed cruise setting. We instructed pilots to plan the route utilizing the following equipment in the cockpit: 2 VORs (VHF OmniRange Navigation System) and an ADF (Automatic Direction Finder). Additionally, pilots had access to the Web-based weather emulation on a stand-alone PC during preflight planning. Upon finishing

Figure 7. The CAMI Advanced General Aviation Research Simulator (AGARS). Photos used by permission of participant.

their flight plan, pilots took the post-weather knowledge test. Next, we offered a 15-minute convenience break to each pilot. Following the break, each pilot had a 30 to 40-minute training and familiarization session with AGARS. Specific training was provided on the usage of the autopilot, the horizontal situation indicator (HSI), and the flight parameters and characteristics of the Malibu aircraft (e.g., maximum/stall speeds, associated power settings). The time between finishing the preflight planning and the actual flight was approximately 60 minutes. Due to pilot unfamiliarity with the simulator and the complexity of the Piper Malibu, pilots were allowed to ask for assistance with flight settings at anytime during the course of the flight scenario.

The route consisted of gradually rising terrain during the first two-thirds of the flight, followed by a dramatic elevation change during the last one-third of the flight. During the course of the flight, pilots were exposed to deteriorating VFR weather conditions. Initially, the visibility was set at 8 nautical miles and gradually decreased to 5 miles visibility by the time the pilots had flown approximately 2/3 of the route. Concomitantly, cloud ceilings were lowered from 4500 feet AGL to 3500 AGL across the same stretch of terrain, gradually squeezing the pilots closer to the ground.

These terrain issues, coupled with marginal visual meteorological conditions (VMC) and potential rapidly changing barometric pressure, resulted in a potentially dangerous flying situation with hazardous encounters throughout the course of the flight. Shortly into the flight, the barometric pressure dropped from the preflight planning level of 30.10 to 29.98. This afforded a potential error between actual and intended altitude for pilots not receiving a barometric update (either from AFSS or AWOS) after departure. Specifically, pilots failing to update their Kollsman setting would fly an actual altitude approximately 120' *below* their intended altitude. The authors acknowledge that, given the aircraft's blind transponder encoder plus the departure airspace, in real life an air traffic controller would have normally detected the altitude discrepancy and issued a correction to the pilot. However, since the study's specific purpose was specifically to study both errors of commission and omission, we purposely skipped this correction to study the consequences.

RESULTS

Correction of results for familywise error

In statistical analysis, when a large number of tests are conducted, it is likely that a small percentage may falsely indicate "significant" results of treatment effect or correlation. Given, say, 100 tests at a significance level of $p<.05$, *by definition* we expect 5 of those, on average, to be falsely positive because that is precisely how "p = .05" is defined.

In statistical practice, a mathematical correction for experiment-wide ("familywise") error can be applied to each individual test result to account for the effect of multiple comparisons. However, while this makes the analysis less prone to Type 1 error (a "false alarm" = declaration of effect where there is none), it also elevates Type 2 error (a "miss" = failure to declare true effect where, indeed, one exists).

In preliminary studies (such as this), it is commonplace to omit the familywise error correction because misses are considered equally as important as false alarms. Such will be the case in the results that follow. The practical cost is *lower reliability* than it might seem, merely looking at p-values and effect sizes. The reader is hereby alerted to that possibility. The benefit, of course, is *increased sensitivity* to effects and relations within the data. Good practice simply demands that the situation be clearly stated.

Preliminary examination of data (frequency distribution normality, outliers)

It is also true that parametric statistics are usually more powerful—meaning more likely to detect treatment effects when they truly exist. However, to justify their use, score frequency distributions need to be approximately normal. Otherwise, distributions should either be mathematically normalized, or distribution-free (nonparametric) statistics should be used. Following convention, the first task was to check distributional normality, particularly to rule out floor and ceiling effects, which indicate that tasks were either too easy or too difficult.

Normality of pilot age and flight hours. Despite the dynamic spreadsheet used to assign pilots by age and flight hours, the flight hours data showed serious non-normalities for the collapsed score distribution, evidenced both by probability-of-z test for skewness and kurtosis

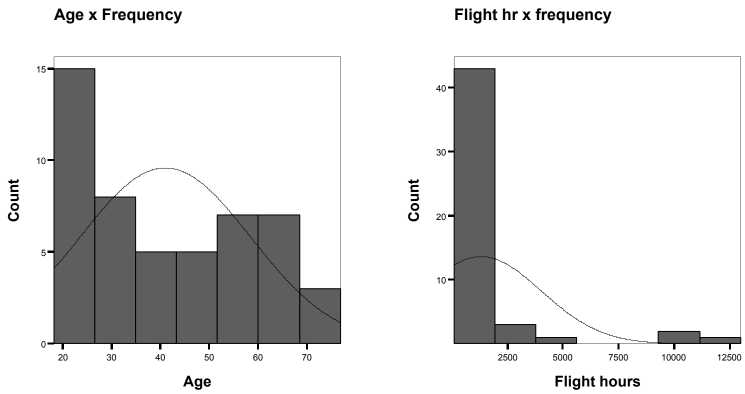


Figure 9. Frequency histograms for numbers of pilots (y-axis) by age and flight hours (x-axis).

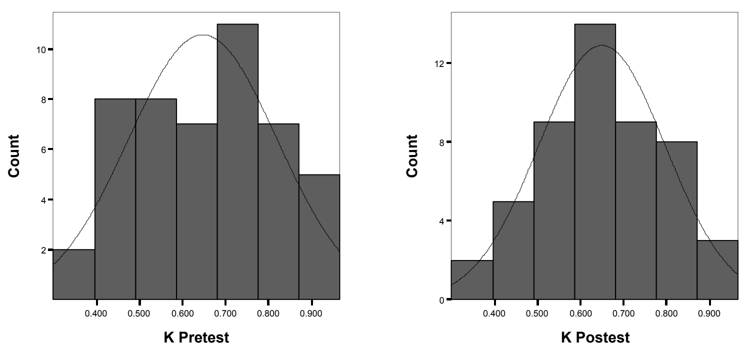


Figure 10. Frequency histograms for numbers of pilots (y-axis) by weather knowledge pre- and post-tests (x-axis).

($p(z(skew)) < .001$, $p(z(kurt)) < .001$) and by failure of the Kolmogorov-Smirnov test ($p < .001$). This was primarily due to the presence of a small number of very high-hour pilots. Figure 9 shows the frequency histograms.

Normality of weather knowledge test scores. As a main dependent variable, weather knowledge pre- and post-test scores did appear to be normal, as Figure 10 shows. This was supported by 2-tailed Shapiro-Wilk tests of normality ($p_{pre\text{-}test}$ =.297, $p_{post\text{-}test}$ =.786, both non-significant (NS).

Grouped by instrument rating, knowledge scores did not significantly deviate from normality (2-tailed Kolmogorov-Smirnov $p_{non\text{-}IR}$ =.143, p_{IR} =.200, both NS). Figure 11 shows the average-score[11] histograms.

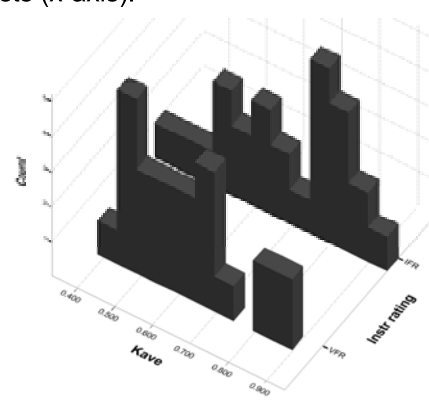


Figure 11. Frequency histograms for numbers of pilots (y-axis) by average weather knowledge ((pre + post-test)/2) scores (x-axis).

Normality of Web-based weather information data. Because the Web-emulation data presented considerable problems with normality, we used medians and percentiles to describe those data. During their pre-flight planning, we instructed pilots to close out the Web-based weather briefing tool after finishing with it. This was necessary to capture the page view time duration of the final page viewed. Nonetheless, on the basis of observed pilot behavior, plus analysis of page view durations, we concluded that a considerable number of pilots forgot to close out the final page. Inspection of durations for final pages revealed that at least 15 of 53 sessions appeared inordinately long (e.g., > 5 SD above the mean), versus 30 of 1024 non-final pages ($p(X^2)$= 5.04E10^{-15}).

To complicate the matter, some pilots moved back and forth between some pages and the sectional, even before the final page was opened. These individuals were obviously not forgetting anything. They were merely comparing the

[11] This was based on average combined pre-test and post-test scores ((pre-test score + post-test score)/2).

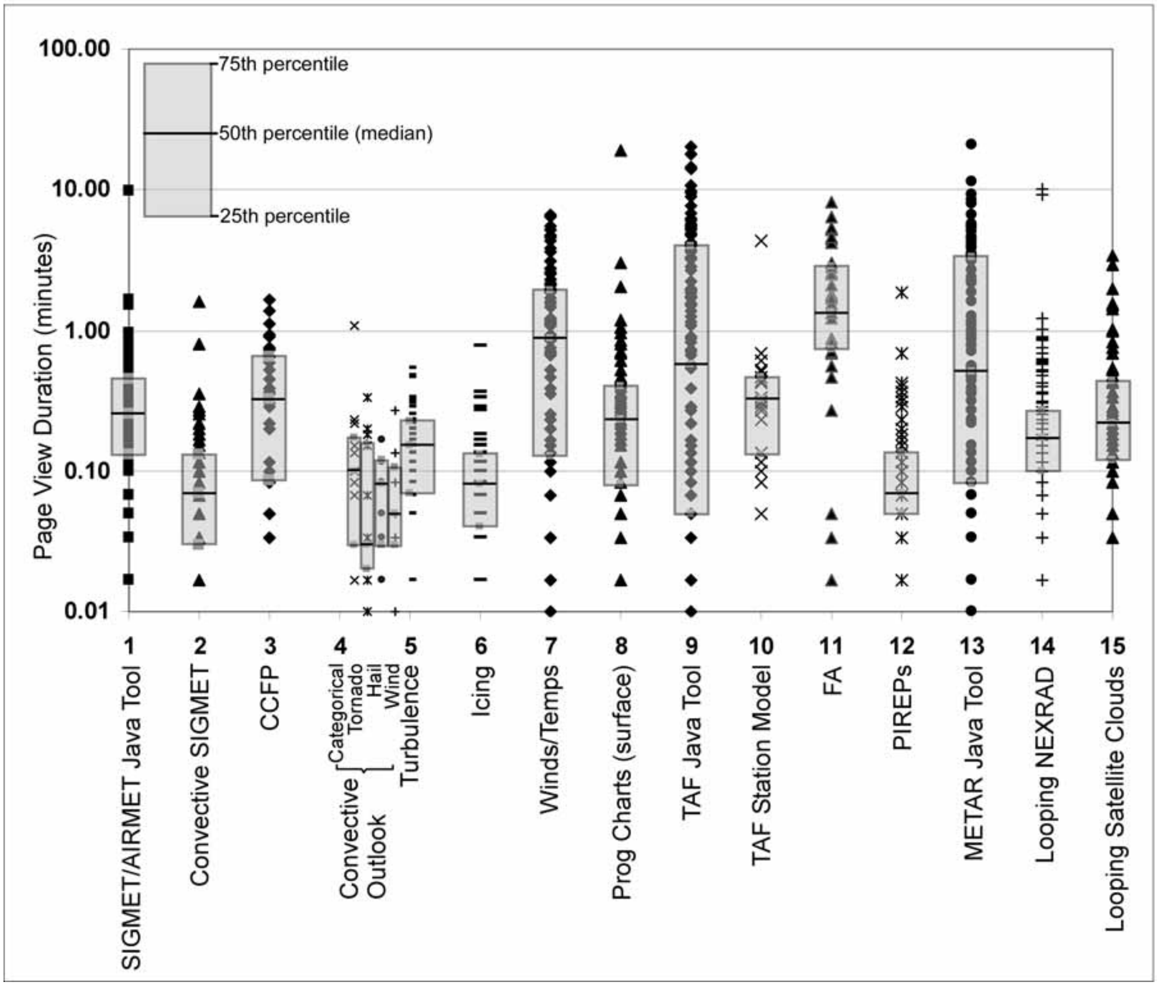


Figure 12. Whole-group (N=50) page view durations for the part-task emulation of *www.aviationweather.gov.* Partial box plots show 25th, 50th, and 75th percentiles. Note that the y-axis is logarithmic.

Web information with the more detailed information on the sectional—a perfectly legitimate real-world strategy. However, this strategy resulted in normality problems for page view duration. In total, some 45 page views were suspected of being outliers, which seriously inflated those page category means and standard deviations, making parametric analysis unjustified.

Figure 12 shows the page view duration data.

Normality of flight simulator data. The normality check for flight simulator data involved:

- Flight duration
- Minimum final distance to Albuquerque (ABQ)
  - » Cloud clearance
  - » Time spent in IMC
- Scud running (time spent at < 500' from cloud base)
- Ground clearance (time spent at < 500' AGL).

Figure 13 visually illustrates the fact that only flight duration met the Kolmogorov-Smirnov test of normality.

In fact, the "poor" normality of most of these data was actually a predictable artifact of good scenario design. A good flight scenario is challenging but not impossible. Twenty of 50 pilots (40%) made it all the way to Albuquerque. The remaining 30 (60%) diverted to alternates. Therefore, the scenario was challenging, but not impossible. In fact, to obtain normal-looking data for all variables would have required a scenario so difficult that few pilots would have made it to ABQ—a certain way to overtax pilots and discourage them from returning for Phase 2 of the study.

Training product study time. We instructed pilots to use the timer utility (Figure 4) to monitor how long they studied their training product. Unfortunately, due to scheduling constraints, most pilots had to study the

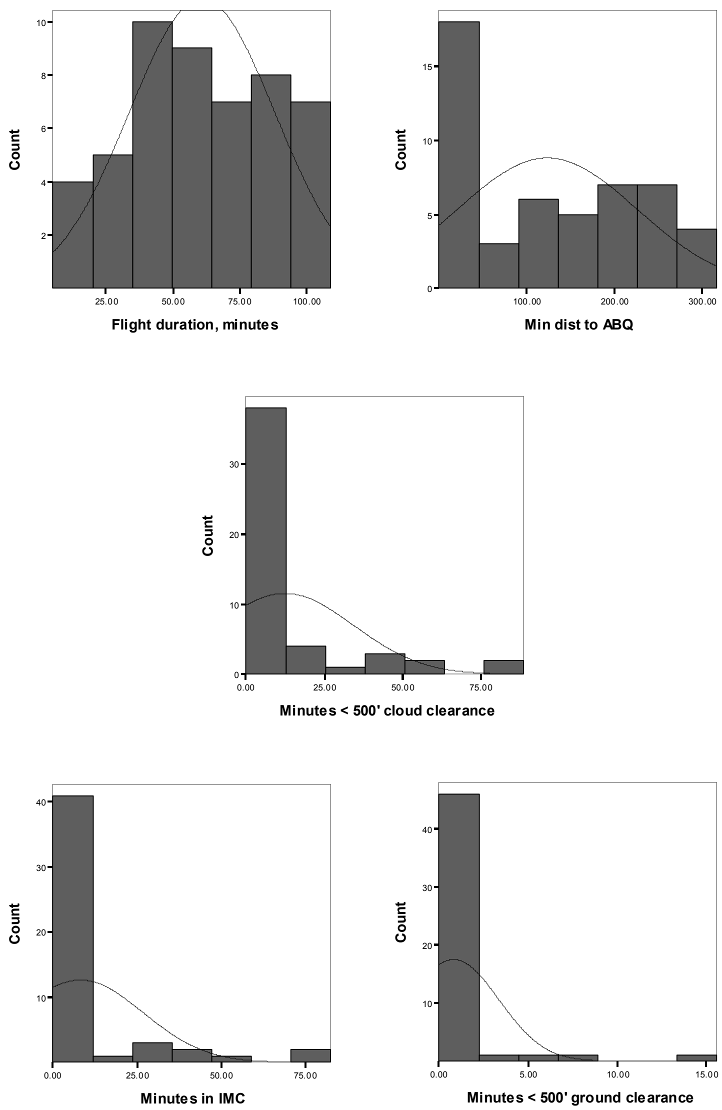


Figure 13. Frequency histograms for numbers of pilots (y-axis) by flight duration, minimum distance to Albuquerque, minutes below 500’ cloud clearance (scud running), minutes in IMC, and minutes below 500’ ground clearance (x-axis).

training product the night before their simulator session. Compliance with session timing proved to be low, with useful data collected on just 29 pilots. Table 2 shows the number of pilots per group (n), means, and standard deviations (SD) for compliant pilots.

Despite a significant Kruskal-Wallis group difference (p = .002), the 31 missing data points made this result suspect. Therefore, study time was not used as a covariate in subsequent analysis.

Conclusion. Most of these data were simply too extreme to be corrected by any standard mathematical transform such as a log or square root. Therefore, most analysis needed to be done using distribution-free (non-parametric) statistics.

Overall data relations

Table 3 shows correlations between key variables. Statistically significant correlations are highlighted in gray. *P*-values approaching .05 significance are also included for the sake of interest. Spearman correlations (r_s) are nonparametric, being based on rank order. Point-biserial correlations (r_{pb}) are used when one variable is dichotomous, the other continuous. However, r_{pb} is still a mean-based statistic, therefore not purely non-parametric. As such, r_{pb} may be subject to higher Type I error when the continuous distribution is non-normal. Some caution is appropriate.

Table 2. Minutes spent viewing each training product (instruction-compliant pilots only).			
	n	Mean	SD
Trg prod 1	7	93	34
Trg prod 2	9	58	17
Control	13	109	52
n_{total}	29	89	

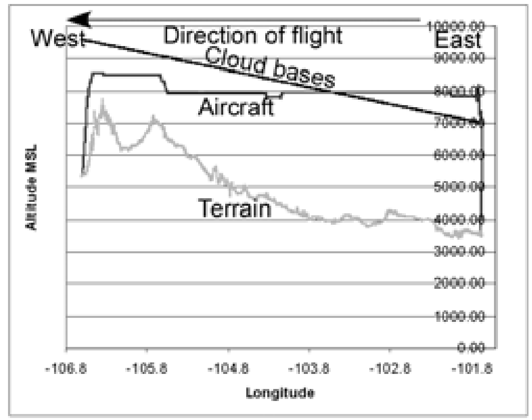


Figure 14. Flight profile of a pilot immediately climbing into IMC and maintaining level flight thereafter. Similar profiles occurred for 20% of pilots.

Table 3. Correlations between key variables (see Fig. 18 for a graphical representation of these data).

Variable 1	Variable 2: Instrument rating (1=instrument -rated)[1]	Locality of residence (1=Local)[1]	Pilot age[2]	Pilot flight hours[2]	Ave. wx Knowledge[2]	Web pre-flight duration[2]	Flight duration[2]	Minimum dist to ABQ[2]	Minutes scud running[2]	Minutes in IMC[2]
Instrument Rating	1.0									
State of Residence	[3]	1.0								
Pilot Age	.523[1] (.0001)	[3]	1.0							
Pilot Flight Hours	.401[1] (.004)	[3]	.757 (<.001)	1.0						
Ave. Wx Knowledge	.233 (.057)	.271	-.035	.086	1.0					
Web Preflight Duration	.020	**-.348** (.013)	**.417** (.003)	.227	.204	1.0				
Flight Duration	-.039	.042	**-.423** (.002)	-.270	-.010	-.222	1.0			
Minimum Dist to ABQ	.013	.013	**.422** (.002)	.303 (.032)	.029	.242	-.936 (<.001)	1.0		
Minutes scud running	-.013	-.012	.051	.107	-.054	.027	.013	-.042	1.0	
Minutes in IMC	-.020	-.005	-.089	-.084	-.123	-.124	.028	-.035	.676 (<.001)	1.0
Minutes < 500' AGL	-.281 (.048)	.144	-.167	-.289 (.041)	-.229	-.039	**.379** (.007)	**-.384** (.006)	-.095	-.174

[1] r_{pb} = Point-biserial correlation; [2] r_s = Spearman rho correlation; Low *p*-values are in parentheses (all others are non-significant (NS)); [3] No correlation run because sample had been partitioned for these factors.

Recognizing trivial relations. Five of the 8 largest correlations are statistically significant but trivial. These cells are marked in the lighter shade of gray. To summarize:

1. Instrument rating x Pilot age (r_{pb} = .523) merely means that instrument-rated pilots tend to be older. All pilots start out non-instrument-rated, and at least some time elapses before a fraction (about half) go on to get their instrument rating, making this correlation anticipated.
2. Instrument rating x Flight hours (r_{pb} = .401) simply means that instrument-rated pilots tend to have more flight hours. This follows logic similar to Point 1.
3. Pilot age x Flight hours (r_s = .757) merely means that as pilots get older, they tend to accumulate flying time.
4. Flight duration x Minimum distance to ABQ (r_s = -.936) only means that the longer pilots flew, the closer they tended to get to the destination (ABQ).
5. Scud running x IMC penetration (r_s = .676) was partly a side effect of the way scud running was defined (as time spent with < 500' cloud clearance). Figure 14 demonstrates.

Oddly, visual inspection of the flight profiles revealed a substantial number of pilots who flagrantly penetrated IMC immediately after takeoff. The issue, then, was that the clearance threshold used to determine "scud running" was exceeded as pilots simply flew level out of the steadily rising cloud layer. This was logically different from intentional scud running. Therefore, in the future, it may be necessary to consider some method of filtering out such unintentional scud running to distinguish it from the intentional variety.

Marginal relations. Given the 50 correlations computed, two-three can be expected to appear "significant" near p = .05 merely due to chance. These marginal cells are highlighted in a darker gray, but the text is not boldfaced. They should be considered tentative.

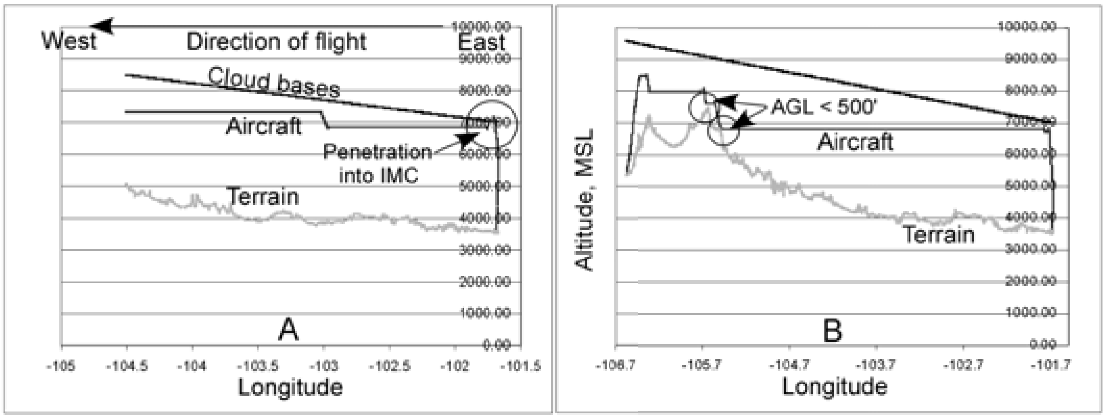


Figure 15. Flight profiles for two pilots. Since the flight was basically east-to-west, the x-axis is drawn as degrees longitude by feet altitude-above-MSL on the y-axis.

1. Instrument rating x Minutes < 500' AGL (r_{pb} = -.281)
2. Pilot flight hours x Minimum distance to ABQ (r_s = .303)
3. Pilot flight hours x Minutes < 500' AGL (r_s = -.289)

The first correlation implies that instrument-rated pilots had slightly less tendency to spend time too close to the ground. However, the effect size was small, accounting for $r^2_{pb} = (.281)^2$ = only 8% of the measurement variance.

The second correlation (.303) implies that pilots with higher flight hours tended to stay slightly farther away from ABQ. This effect size was about 9%.

The third correlation (-.289) implies that pilots with higher flight hours also tended to spend slightly less time too close to the ground (effect size 8%). All 3 correlations coincide with common sense, if we assume that more training and experience tend to produce more cautious pilots.

Non-trivial relations. Beyond trivial and marginal relations, a few others emerged. In Table 3, these cells are highlighted in a darker shade of gray, with boldfaced text. They are:

1. Locality of residence x Web preflight duration (r_{pb} = -.348)
2. Pilot age x Web preflight duration (r_s = .417)
3. Pilot age x Flight duration/ Minimum distance to ABQ (r_s = -.423/.422)
4. Flight duration/minimum distance to ABQ x Minutes < 500' AGL (r_s = .379/-.384)

Correlation 1 (-.348) implies that local Oklahoma pilots tended to spend slightly less time using the Web preflight briefing tool than non-Oklahoma pilots did ($\bar{x}$ = 20.31 v. 13.66 min). The effect size was modest, accounting for r^2_{pb} = 12% of the variance.

Correlation 2 (.417) implies that older pilots tended to spend somewhat more time using the Web tool than younger pilots did. Effect size was 18%.

Correlations 3 (-.423/.422) imply that older pilots tended to have somewhat shorter flights (and, hence, to end up farther away from ABQ). Effect size was about 18%.

Finally, Correlations 4 (.379/-.384) represent the flight scenario's tendency to "squeeze" pilots between clouds and terrain near ABQ. The farther one flew, the more one got squeezed. Figure 15 illustrates this with two sample flight profiles illustrating a) IMC penetration and scud running, and b) violation of ground clearance. Profile B clearly shows the mountains near ABQ, with the "squeeze" this could pose. Another way to view this is that the majority of scenario danger tended to be concentrated near the destination.

Specific effects

Effect of the weather training products on GA pilot weather knowledge. Did viewing a weather training product significantly improve pilots' weather knowledge test scores? Seemingly not. Repeated measures analysis of variance (ANOVA) for posttest-pretest score gain x training product interaction yielded a non-significant p_F = .734.

Relation between pilot weather knowledge and subsequent flight safety. Were pilots with higher weather knowledge safer pilots? Seemingly not. As Table 3 showed, average weather knowledge ((pre+posttest score)/2) did not correlate significantly with any flight behavior variables. Spearman correlations between weather knowledge scores and flight duration, minimum distance to ABQ, minutes scud running, minutes in IMC, and minutes < 500' AGL all ranged from $-.229 \leq r_s \leq .029$, all NS.

At least as measured by these test questions, weather knowledge did not seem strongly influenced by age, flight hours, or instrument rating (r_s = -.035, .051, r_{pb} =.233 [respectively], all NS). Although instrument-rated pilots showed a slightly higher average knowledge score (67.6%) than did non-instrument-rated pilots (60.8%), this just missed the statistical criterion for reliability (1-tailed p_t = .057, NS).[12]

Effect of Web preflight briefing time on subsequent flight safety. Were pilots who spent more time on their Web-based weather briefing safer pilots? Not significantly. Spearman correlations of Web preflight duration with flight duration, minimum distance to ABQ, minutes scud running, minutes in IMC, and minutes < 500' AGL ranged from $-.222 \leq r_s \leq .242$ respectively, all NS.

Takeoff hesitancy. We told pilots that the best way to give good flight data was to treat this mission as if it were a real flight. Given those instructions, 12 of the 50 pilots initially stated that having to fly this mission VFR, they would choose not to even take off. This was perhaps predictable, given the weather and being scrutinized by FAA officials at an FAA facility.

Therefore, to overcome any reservations they might understandably have about being scrutinized, pilots who declined to take off were explicitly asked to take off and fly at least briefly. All complied.

What kind of pilot tended to hesitate? Locality of residence had no reliable statistical effect—18% of local (Oklahoma) pilots hesitated versus 32% of non-local (non-Oklahoma) pilots (2-tailed p_{X^2} = .251, NS). If we had predicted an effect, it would have trended the way it did, since locals would be more likely to know the terrain and be skilled in handling the high winds typical of the Midwestern U.S.

Instrument rating did not demonstrably matter (15% hesitancy for instrument-rated v. 33% for non-instrument-rated, 2-tailed p_{X^2} = .138, NS). This, too, trended in the anticipated direction, since one would expect somewhat greater confidence from instrument-rated pilots.

Despite the confidence-building tendencies often associated with experience, neither age nor flight hours seemed to affect hesitancy (2-tailed Mann-Whitney U, p_U = .146, .625 respectively, NS).

So, overall, the cause of this takeoff hesitancy initially appeared mysterious.

Effect of takeoff hesitancy on subsequent flight safety. Did the 12 hesitators end up flying safer than the remaining 38 pilots? Not remarkably. There were no significant differences between hesitators and non-hesitators for minutes spent in IMC, minutes scud running, or minutes < 500' AGL (2-tailed Mann-Whitney p_U = .102, .147, .498 respectively, all NS). However, hesitators did seem to continue their conservatism into their flight, making significantly briefer flights (p_U = .002), with consequently less penetration into the marginal weather close to ABQ (p_U < .001).

Table 4. Takeoff hesitancy.

<table>
<tr><th></th><th></th><th>Trg Prod 1</th><th>Trg Prod 2</th><th>Control</th></tr>
<tr><td rowspan="2">Initial takeoff decision</td><td>Yes</td><td>12 (12.2)</td><td>9 (12.2)</td><td>17 (13.7)</td></tr>
<tr><td>No</td><td>4 (3.8)</td><td>7 (3.8)</td><td>1 (4.3)</td></tr>
<tr><td rowspan="3">Pairwise odds-ratios, 1-tailed p</td><td></td><td colspan="2">← .152 →</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">← .004 →</td></tr>
<tr><td></td><td colspan="3">← .037 →</td></tr>
</table>

Effect of the weather training products on takeoff hesitancy. So, what caused takeoff hesitancy? It could have been the weather training products. Table 4 shows the number of pilots who initially hesitated versus the values expected by chance (in parentheses). The exact form of p_{X^2} is .035, implying that the training groups differed. Pairwise tests of odds-ratios implied that the unusual group was the Control, where 17 of 18 pilots showed no hesitancy to take off.

In other words, studying a weather training product may have made pilots more hesitant to take off into deteriorating weather. However, *cognitive priming* is an alternate hypothesis we will consider in the Discussion section.

Effect of the weather training products on subsequent flight safety. Did viewing a weather training product affect flight safety? Not significantly. Limited signs point to *yes*, but the overall effect seems to be *no*.

The Control group showed significantly less takeoff hesitancy, as we have seen. It also displayed greater flight duration and, consequently, lower minimum distance to ABQ (Kruskal-Wallis p_{KW} = .007, .005, respectively). Follow-up pairwise Mann-Whitney U tests implied that the Control group was significantly different from both weather training products ($p_{U\text{-}TRG1 \times CONTROL}$ = .011, .004 respectively and $p_{U\text{-}TRG2 \times CONTROL}$ = .004, .005, respectively), although the 2 weather products themselves did not differ significantly (p_U = .867, 1.0 respectively, NS).

Now—because the maximum hazard of this flight lay near the destination—we might be tempted to conclude that the longer flights of the Control group should predict greater risk exposure. As Table 3 showed, this was supported by a moderate correlation (.379, p=.007) between flight duration and minutes < 500' AGL.

However, we found no significant overall differences between the 3 training groups for subsequent minutes spent in IMC, minutes scud running, or minutes < 500' AGL (p_{KW} = .245, .158, .812 [respectively], all NS). Even though the Control group showed less hesitancy and longer flight duration, and even though longer flight duration

[12] This was based on average combined pre-test and post-test scores ([pre-test score + post-test score]/2).

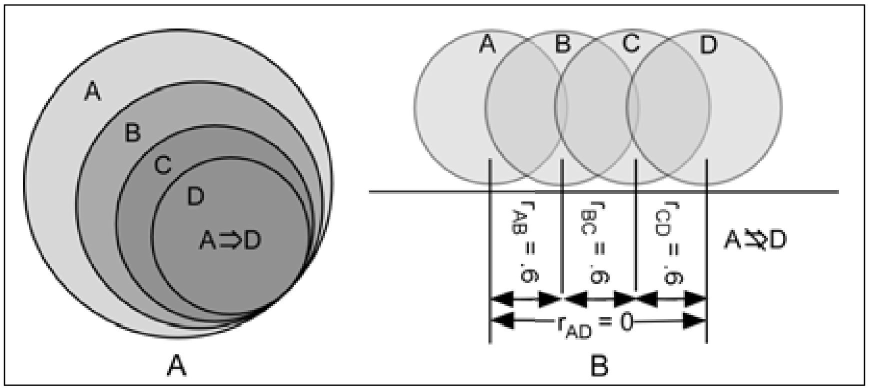


Figure 16a. Venn diagram embodying causation A ⇒ B ⇒ C ⇒ D; **b)** Venn diagram embodying correlation A r_{AB} B r_{BC} C r_{CD} D.

correlated significantly with minutes < 500' AGL, the net effect of the weather training videos on subsequent flight safety seemed nonsignificant.

So, how can there be no significant differences in flight safety among the 3 training groups? If seeing the weather training video related to takeoff hesitancy, and takeoff hesitancy related to flight duration, and flight duration related to minutes spent < 500' AGL—how could weather video not relate to minutes spent < 500' AGL?

The answer lies in the nature of causation versus correlation. If each factor perfectly *caused* the next factor in the chain, then the first factor would perfectly predict the final factor. In symbolic logic, A ⇒ B (A implies B), and so on, so A ⇒ B ⇒ C ⇒ D, therefore A ⇒ D. This is easy to see in a Venn diagram (Figure 16a). But, if each factor only *partially predicts* the next factor, then the overall relational strength between the first and last factors can theoretically be zero (Figure 16b).

IMC penetration. IMC penetration ranged in duration from 0.02-86.6 minutes. The majority of pilots avoided IMC altogether. However, 16 pilots spent more than 1 minute in IMC. Ten spent more than 4 minutes. Given the instruction to fly VFR, why any pilot should spend this much time in IMC was curious.

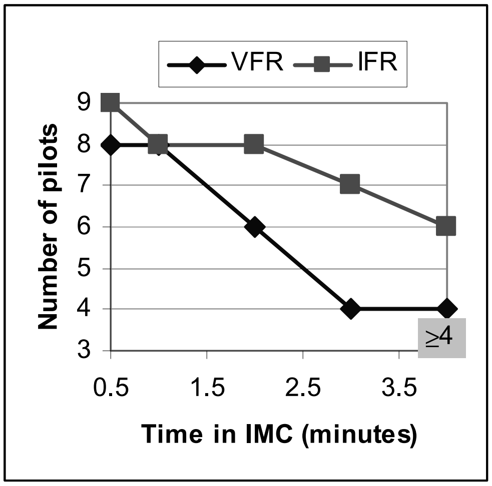
Instrument rating did not demonstrably influence long-duration IMC penetration. Instrument-rated pilots made 6 "long-duration" penetrations (>4 minutes), compared to 4 made by non-instrument-rated pilots ($p_{binomial}$, 2-tailed = .754, NS). Furthermore, as Table 2 indicates, neither did age, flight hours, or location of residence affect long-duration IMC penetration. In short, factors that *did* influence it remain unclear at this point in the analysis.

Individual differences. Pilots' approaches to preflight briefing and flight behavior were quite varied. Extensive notes were taken while each pilot flew the mission to capture these nuances. We also graphed out all 50 flights pictorially, similar to Figures 14 and 15. We will study and elaborate upon these notes and graphs in the Phase 2 technical report. However, the following anecdotes are noteworthy:

1. Many IFR pilots stated that, if this were a real mission, they would simply file an IFR flight plan and fly. Therefore, the VFR mission felt somewhat artificial to them.
2. As stated earlier, 16 pilots spent more than 1 minute in IMC, and 10 spent more than 4 minutes.
3. At least one pilot admitted to becoming lost near the end of the flight.
4. Over half the pilots volunteered concerns that the weather questions on their FAA certification tests were often only marginally relevant to real-world flying.
5. One pilot experienced controlled flight into terrain (CFIT).

The CFIT was a perfect illustration of how a simple lapse of terrain proximity (AGL) awareness can become fatal. Contrary to expectations, the pilot was actually instrument-rated, a Certified Flight Instructor, and older and more experienced than most (in the 90th percentile for age, the 94th percentile for flight hours). On approaching the mountains east of Albuquerque, while busy studying the sectional, head-down, the pilot simply flew into a peak. Similar incidents have been documented; for example, a CFIT involving a Piper PA-28-181 on 25 Mar. 2008 near Bridger, MT (NTSB, 2008). The pilot survived this incident and was able to verify lapse-of-attention during the NTSB interview.

Rule violations. Despite this being stressed as a VFR-only flight, some pilots appeared to disregard that instruction. Figure 17 (a) shows the numbers of the 50 pilots who spent 0.5, 1, 2, 3, and ≥4 minutes in IMC. Figure 17 (b) shows the same pilots, but over the entire time range from 0.5-82.6 minutes in IMC.



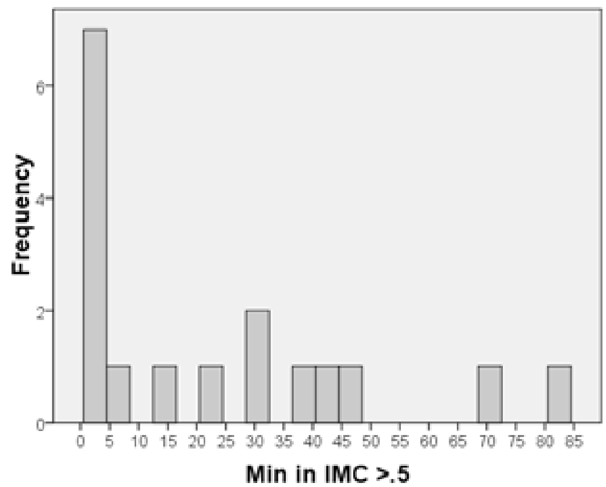


Figure 17 a. (top). This shows number of pilots (y-axis) by time-spent-in-IMC (x-axis) for VFR and IFR pilots with at least 0.5 min in IMC.
Figure 17b. More detailed frequency counts spanning the time range 0.5–82.6 min, for VFR and IFR combined.

We can argue that those who spent less than a minute in IMC probably did so inadvertently. But, strangely, 10 pilots (20%) spent significant time (≥4 minutes) in IMC. Nine spent more than 10 minutes. The characteristic pattern of these violations involved nearly equal numbers[13] of instrument-rated and non-instrument-rated pilots ascending into IMC right after takeoff, and then flying fairly level, accidentally emerging from the clouds downrange because the cloud layer itself rose slowly. Figure 14 shows an example. It was as if these pilots were practicing terrain avoidance planning—setting their base altitude above all known obstacles—but in complete disregard of visual flight rules.

This behavior may have been due to willful rule violation. An alternate hypothesis is that perhaps IMC was merely difficult to see in AGARS. Simulators sometimes suffer from such difficulties. The mathematics of trying to accurately model clouds, fog, haze, and mist are actually quite challenging (Hill, 1990).

Several factors discount this lack-of-saliency hypothesis, however. First, AGARS represents a capital investment of over $1M U.S., and great care was devoted to ensuring visual fidelity. More objectively, 80% of pilots managed to avoid significant IMC, meaning they spent < 4 minutes above the cloud base. The average time-in-IMC for this 80% was only 24 s, with 28 pilots (56%) spending no time at all in IMC. This suggests that most pilots who entered IMC did so very briefly, realized it, and self-corrected, implying that they did indeed perceive the physical stimulus. In contrast, the flight profiles of the high-time-in-IMC pilots typically involved climbing straight into the clouds and staying there in level flight—implying a conscious decision to maintain altitude despite being able to see the ground.

A third plausible set of related hypotheses is that many, if not all, of these pilots simply either forgot the instructions, failed to take a simulated flight as seriously as they would a real one, succumbed to old habit patterns (the IFR pilots), or may have simply been overwhelmed trying to deal with an unfamiliar aircraft over unfamiliar terrain. Otherwise, we are left with the unpalatable and implausible notion that some 20% of GA pilots willfully fly VFR-into-IMC.

This issue is serious enough to be revisited in a Phase 3 report, to see if those data shed any light on the situation. Should this behavior greatly decrease, then a case might be made for these violations being inadvertent, rather than willful.

Modeling flight behavior.

Cluster analysis. One of the most interesting questions we wanted to answer is: "What differentiated pilots who chose to complete the flight through deteriorating weather from pilots who chose not to complete the flight?" To investigate this question meant constructing models—simplifications of the situation that still captured its major, essential features.

Cluster analysis is one approach to modeling. Cluster analysis starts with a set of measurements ("variables") taken on individuals ("cases"—here, individual pilots). It then explores the relations between variables by combining individual cases into groups ("clusters"). The end goal is to group cases so that those within the same cluster are more similar to each other than they are to cases from different clusters. This similarity is operationalized by calculating a "mathematical distance" between cases. Once done, it becomes the job of the researcher to interpret what each cluster means in logical and practical terms.

[13] Slightly more IFR pilots did this than VFR pilots, but the differences were not statistically significant.

Here, we used a "TwoStep" cluster analysis procedure (SPSS, 2001) to classify the pilots based on demographic characteristics as well as behavioral responses to the simulated flight scenario. Schwarz's Bayesian Criterion (BIC) was used as the clustering criterion and the log-likelihood was used as the distance measure. The number of clusters was determined automatically within the two-step process (maximum set to 15). In the first step, sequential clustering calculated the BIC for each cluster within a specified range and used that to estimate the initial number of clusters. In the second step, the estimate of clusters was reduced by finding the largest increase in "mathematical distance" between the two closest clusters using an agglomerative hierarchical clustering method (SPSS, 2001).

SPSS's "TwoStep" cluster analysis works with both categorical and continuous variables when using the log-likelihood method. Assumptions of normality often tend to be relaxed in cluster analysis, so nonparametric follow-up tests were used to examine individual relations (see below).

We selected candidate variables based upon logic and prior results of correlational analysis (e.g., Table 3). The initial *categorical* candidate variables were:

1. Weather training product (1, 2, or Control [C])
2. Pilot's rating (VFR or IFR)
3. Local pilot or not (Locality of residence)
4. Go/NoGo takeoff decision (TO Decision)
5. Did they make a preflight weather call prior to takeoff?
6. Number of en route weather updates
7. If they inadvertently flew into Instrument Meteorological Conditions (IMC) during the simulation
8. Final flight decision (discussed below)

Final flight decision was initially divided into 4 categories, a) Return to AMA, b) Divert to alternative airport, c) Go direct to ABQ, or d) Go indirectly to ABQ by flying north or south around the nearby mountain range. Logically, a and b represented diversions, whereas c and d represented completed flights to ABQ. Therefore, after excluding the single CFIT from analysis, final flight decision was simplified by collapsing the initial 4 categories into a binary (2-category) categorical variable *To ABQ* ("Did a given pilot complete the entire flight to ABQ, yes or no?").

The following *continuous* candidate variables were also considered for cluster analysis:

1. Age
2. Total flight hours
3. Minimum final statute miles from ABQ (*MDABQ*)
4. Minutes spent in IMC
5. Minutes spent less than 500' below the cloud ceiling (scud running)
6. Minutes spent at less than 500' AGL
7. Number of weather rechecks after the 30-45 min preflight ground delay (*Recheck*)

Note that weather knowledge scores were excluded for non-significance (see Table 3).

Summary of the cluster analysis

The analysis excluded 2 additional cases for incomplete data. The remaining cases sorted into just 2 clusters. Individual variable results were then significance-tested, both by SPSS confidence intervals and cross-checked by alternate tests.

Table 5 shows all significant (p <.05) Cluster 1-2 differences. To summarize Table 5, compared to the 32 Cluster 1 pilots, the 16 Cluster 2 pilots tended to be

1. younger, (*Age*)
2. lower flight hours, (*FH*)
3. closer final minimum distance to ABQ, (*MDABQ*)
4. more minutes flying less than 500' AGL, (*M<500AGL*)
5. usually did *not* receive a weather training product, (*Trg Product*)
6. greater % "Go" responses for takeoff (100%), (*Takeoff [TO] Decision*)
7. less likely to recheck weather just before takeoff, (*Recheck*, Y=Yes)
8. greater % flew all the way to ABQ (100%), (*To ABQ*)

Interestingly, 100% of the 16 Cluster 2 pilots flew direct to ABQ through the nearby mountain pass, whereas only 1 pilot in Cluster 1 did so. In stark contrast, over 84% of Cluster 1 pilots decided to divert or return to the departure airport (AMA). Of the 4 Cluster 1s who did fly to ABQ, 3 did so by flying completely around the troublesome mountain range.

Together, these results support the notion of Cluster 2 pilots as greater risk-takers.

Table 5. Cluster analysis, significant results ($p < .05$).

							Trg Product			TO Decision		Recheck?		To ABQ?	
					Min<500AGL		1	2	C	NoGo	Go	N	Y	N	Y
Cluster	n	Age[1]	FH[1]	MDABQ[1]	Mean	Median	n	n	n	n	n	n	n	n	n
1	32	48.5	482	197.6	.25	0.0	12	13	7	12	20	7	25	27	4
2	16	23.0	132	4.8	1.96	0.0	2	3	11	0	16	9	7	0	16
$p_{difference}$		<.001[2]	.004[2]	<.001[2]		.006[2]	.007[3]			.005[3]		017[3]		1.0E-8[3]	

[1]Median. [2]Mann-Whitney U test. [3]Chi-square test. n=number (frequency count).

In contrast, there were no significant differences between Cluster 1 and Cluster 2 for instrument rating, locality of residence, number of en route weather updates, minutes spent in IMC, or minutes scud running.

Binary logistic regression analysis. From Table 3, we recall that some of the candidate variables in the cluster analysis were significantly correlated (e.g., $r_{s\_age\text{-}flighth} = .757$). Therefore, to further simplify the model, we used stepwise forward likelihood-ratio binary logistic regression to cull out redundant (highly correlated) variables. Binary logistic regression makes no assumptions about the distributions of the predictor variables (Tabachnick & Fidell, 2001). It can take a candidate set of variables, categorical or continuous, and select only those demonstrating significant orthogonal (uncorrelated) ability to help predict a binary outcome.

Specifically, we wanted to predict which pilots would or would not risk flying completely through the deteriorating weather (*To ABQ* = 1/Yes or 0/No). Table 6 summarizes the smallest set of variables capable of doing that reliably.

Table 6. Binary logistic regression for To ABQ

	B	$p_{if\ term\ removed}$
Age	- 0.081	.002
TO decision	-21.20	.016
Control[14]		.006
Trg Prod 1	- 3.08	
Trg Prod 2	- 2.53	
Constant	4.64	
Nagelkerke R^2 = .640		

Note that *TO Decision* reflects "takeoff hesitancy" as discussed earlier, and that training product is broken out into its 3 groups. Negative B-weights mean that a *positive* value for the independent variable subsequently related to a *reduced* groupwise tendency to fly all the way to ABQ.[14] For example, pilots hesitant to take off (TO Decision = 1) subsequently showed a reduced tendency to fly all the way to ABQ. Similarly, pilots receiving either weather training product subsequently showed reduced tendency to fly all the way to ABQ, compared to the Control group.

In practical terms, this is a moderately strong model, accounting for 64.0% of the explainable (Nagelkerke) variance in the data. It implies that pilot experience (flight hours) may work in combination with an instinctive reaction to a weather situation to affect ultimate continuation into adverse weather. Impulsivity may be further reduced by the presentation of a training product. This contrasts somewhat with the null conclusion reached earlier about training product, so we will revisit that theme in the Discussion section.

Table 7 compares the prediction success rate for completed flight to ABQ made by logistic regression (boldface) versus cluster analysis (italics, in parentheses). Grey cells represent successful predictions.

Table 7. Success rate for **binary logistic regression** versus *(cluster analysis)*

Observed *To ABQ*	Predicted *To ABQ*		
	Did not make it to ABQ	Made it to ABQ	% correct
Did not make it to ABQ	**26** *(27)*	**4** *(4)*	86.7 *(87.1)*
Made it to ABQ	**4** *(0)*	**14** *(16)*	77.8 *(81.3)*
Overall % correct	Base logistic prediction rate = 62.5%		83.3 *(91.5)*

This shows that a simplified logistic model containing only pilot age, initial takeoff decision, and training product correctly predicted 83.3% of these pilots' overall decisions whether or not to fly through the deteriorating weather all the way to ABQ. The model was slightly better at predicting those who did not make it to ABQ (86.7% correct) than it was at those who did (77.8% correct).

Overall, this 3-variable model produced a gain of about 21% from the base rate predicted by a constant only (62.5%, p=.000004). Compare this to the 8-variable cluster model's correct predictions of 91.5%, versus a "complete" 15-variable logistic regression (not shown) where 100% of all cases were predicted correctly. However, note that the "complete" model was vastly overfitted, meaning it contained too many predictors given the number of cases. A case/predictor ratio of $\geq$ 10/1 is typically a rule of thumb in regression analysis, implying that our models should arguably be limited to 48/10 = 4-5 predictors. This shows that modeling involves a tradeoff. Simpler models, while offering somewhat less accurate predictions, compensate with greater reliability.

Finally, recall our earlier statements that completing the entire flight to ABQ did not always reflect dangerous behavior (as measured, for example, by time spent < 500' AGL). In fact, we cross-checked the logistic regression model against regular linear regression[15] by substituting the original binary outcome variable *To ABQ* with the continuous flight risk outcome variable *Minutes < 500' AGL*. This showed no effect of the "FH+TO Decision+Training Product" model on actual flight risk (p = .612, NS). So, again, we

[14] B-weight functions similarly to a correlation coefficient, except that it is not restricted to $-1 \leq r \leq 1$. The Control group has no B-weight because SPSS essentially used it as an "invisible baseline," in relation to which the B-weights Trg Prod1 and Trg Prod2 could then be compared. For example, B_{TP1} = -3.08, which is less than 0, means that TrgProd1 pilots were less likely to complete the flight to ABQ than were Control group pilots.

[15] However, bear in mind that this was not technically a reliable analysis because flight hours and minutes < 500' AGL were both severely non-normal distributions, which violates the assumptions of linear regression.

need to consider the distinction between mere flying and the subsequent hazard of flying.

Cognitive versus constructivist training product. In assessing the training products, a goal was to ascertain outcome differences due to a cognitive training product versus a constructivist training product. Cognitive learning theory relies heavily on notions of memory and information processing. In contrast, constructivist learning theory assumes that people construct an inner representational world based on symbols and their relations. We therefore hypothesized that perhaps one or the other training product might show greater effect on weather knowledge versus subsequent weather-flight behavior.

However, the collected results above show no significant support for either paradigm. The results perhaps do favor the conclusion that both training products were reliably distinct from the Control group, but otherwise not from each other. Nonetheless, training products *by themselves* did not seem to influence flight behavior. Instead, training products may act in concert with other factors (flight hours and initial takeoff decision) to predict whether or not a pilot tends to press on to the destination in the face of adverse weather.

DISCUSSION

The purpose of Phase 1 of this research was to investigate 3 major questions:

1. Do video weather training products significantly affect general aviation (GA) pilot weather knowledge and flight behavior in the face of potential instrument meteorological conditions?
2. How are modern Web-based weather products used during preflight briefing?
3. Do local Oklahoma GA pilots differ appreciably from others in either weather knowledge or weather-related flight behavior?

Question 1

Summary. No highly significant effects were found for two 90-minute video weather training products all by themselves on weather knowledge or subsequent flight safety on a simulated flight involving deteriorating weather. Effects could not be measured because the "signal" of the training product was small compared to the "noise" of individual variability between pilots.

The training products did demonstrably affect some aspects of flight behavior to a degree. Viewing either training product suppressed both initial willingness to take off and subsequent flight duration. However, that may have been due to pilots being cognitively primed to act conservatively, given the nature of the study. With encouragement from an authority figure, all the hesitators did fly. Nonetheless, their subsequent safety records were not discernibly different from the Control group, which received no weather training product.

We conclude that weather knowledge and GA weather flying behavior are likely too complex to be profoundly changed by any single, brief training product. However, it is similarly absurd to conclude that weather training products have "no effect." An apt analogy is building a house. Just as it takes many bricks to build a house, it takes many study sessions to master the complexities of weather and to greatly affect subsequent weather flying behavior.

Method. In Phase 1 of this project, 50 GA pilots participated in a study that was designed to test pilot

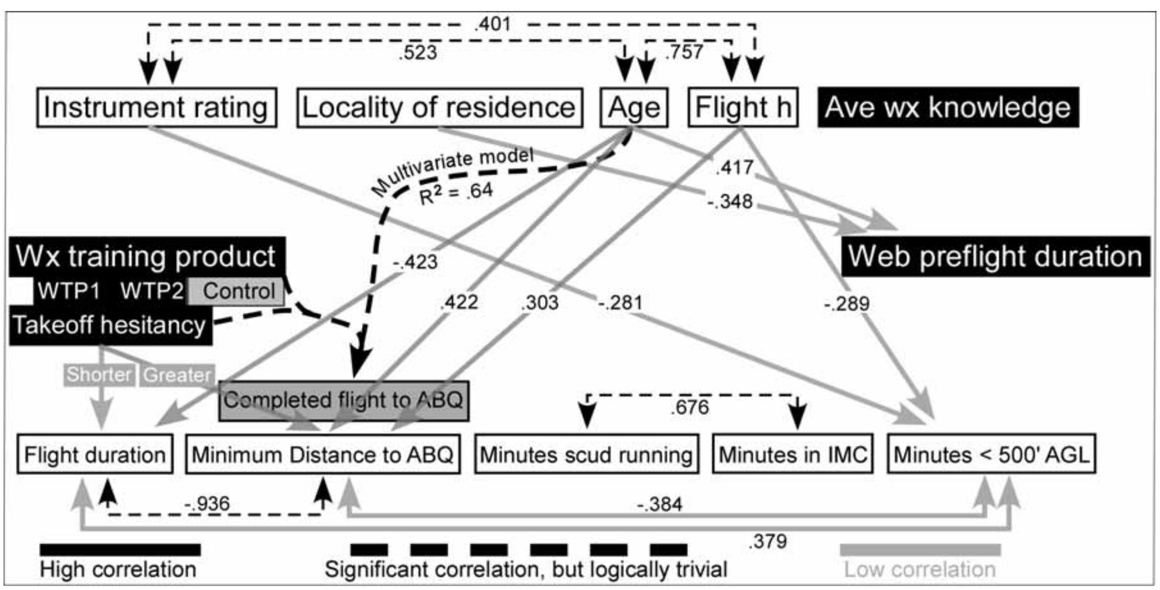


Figure 18. Graphical summary of major relations between single variables.

weather knowledge and flight behavior. Pilots took a general weather knowledge pre-test, followed by exposure either to 1 of 2 weather training videos (the experimental groups), or to a video having nothing to do with weather (the Control group). They then took a knowledge post-test to measure knowledge gain induced by the training product. Next, they planned for, and flew, a simulated flight mission through marginal weather from Amarillo, TX (AMA) to Albuquerque, NM (ABQ). Numerical flight data were collected and flight behaviors noted.

Results. In Figure 18, arrows graphically depict significant relations between variables, with correlation values overlaid. Single-headed arrows imply directional causation (e.g. instrument rating could conceivably cause minutes < 500' AGL to vary, but the reverse would not be true). Double-headed arrows make no assumption about what might cause what.

First, viewing a single 90-minute weather training product did not all by itself demonstrably improve pilots' general weather knowledge test scores. This is unsurprising, given the briefness of the training product compared to the great complexity of weather.

Second, as Figure 18 shows, relations between variables were complex. By itself, viewing a training product showed no *direct* effect on flight safety. Instead, compared to the Control group, both training products seemed to induce a mediating effect of *takeoff hesitancy* in the face of deteriorating weather. "Hesitators" flew only after direct encouragement by the experimenter. In contrast, 17 of 18 Control group pilots took off without any encouragement.

Subsequently, hesitators continued their conservatism, tending to make significantly *shorter flights* than non-hesitators. Since the bulk of the scenario danger lay near the flight's destination, we might imagine a chain of events—that the training product induced takeoff hesitancy, which induced shorter flights, which led to lower groupwise risk exposure. However, these separate events, though individually related, did *not* result in a statistically significant event chain from beginning to end. Figure 16 depicted that graphically—the beginning-state, independent variable of training product by itself did not significantly correlate with any of the end-state, dependent flight-risk variables (time scud running, time in IMC, or time at < 500' AGL).

Otherwise, there were no *single* distinguishing pilot characteristics (such as age, instrument rating, locality of residence, or flight hours) that seemed to explain takeoff hesitancy—other than having viewed either training product. If anything, the two separate factors most likely to produce hazardous behavior (as measured by minutes spent < 500' AGL) were simply lack of an instrument rating and low flight hours.

Single-variable correlational analysis was, therefore, followed up by multivariate modeling. In modeling flight behavior, we saw that a *combination* of higher pilot age, receiving either weather training product, and takeoff hesitancy correctly predicted 26 of 30 diversions (86.7%) from deteriorating weather (Tables 6-7, and Figure 18). Successful flight completions (full penetration into the weather) were harder to predict with the same model (14 of 18 correct = 77.8%). This suggests that the reasons why pilots *divert* may be slightly more homogeneous than the reasons why they *press on* into deteriorating weather.

An alternative explanation for these results. Objectively, some behavioral results for the weather training products might be explained by an alternate hypothesis unrelated to what we otherwise might expect. In a *cognitive priming hypothesis*, exposure to a particular stimulus "primes" the participant's subsequent sensitivity to similar members of that category (James, 1890). For instance, presenting the word "nurse" tends to lower subsequent recognition response time for the word "doctor" more than it does for the word "lawyer." Applying the priming concept here, exposure to the training product could, in effect, "tip off the participants" that the following study was to be about weather. Given the context of FAA officials conducting an experiment within an FAA facility, one could argue that some subsequent behavioral effects might owe more to the experimental groups (and, particularly, the older pilots within them) being primed to think about weather and risk than to a strict training effect of the video products themselves.

This issue of true learning versus priming will be revisited in Phase 2 of this study. If the hesitancy effect and/or the shorter-flight effect persist over time, a stronger argument may be made for true learning to have taken place. This remains to be seen.

In the meantime, it should not be construed that weather training products "have no effect." The proper conclusion is simply that weather and pilots are both complicated subjects. For a pilot to understand weather takes time and effort. Just as we do not build an entire house from one brick, we do not arrive at a deep understanding of weather from one 90-minute training module. It takes many.

Other findings. There were a few statistically significant-but-logically trivial relations.

- Instrument-rated pilots tended to be older and have more flight hours. Older pilots tended to have more flight hours. Longer flights tended to bring one closer to the destination.
- Beyond the trivial, there was a slight-but-significant tendency for older pilots to spend a bit more time on their Web-based preflight briefing. This is consistent with the plausible assumption that older pilots may be less familiar with Web-based preflight briefings.

- Instrument-rated pilots spent slightly less time too close to the ground (< 500' AGL). So did higher- flight hour pilots. However, instrument-rated pilots also tended to be older, *with* higher flight hours. So, it is subtle to pinpoint whether rating, age, or flight hours was most related to ground clearance.
- There was also a slight tendency for older pilots and higher flight hour pilots to fly shorter flights (meaning they penetrated the weather slightly less). Age and experience may engender some risk aversion (Hunter, 2002). Alternatively, younger pilots might have been merely "gaming the system," treating the flight more like a game than a real flight. It is difficult to say, because either or both effects could operate, yet produce the same net result on measurable behavior.
- Finally, the one instance of actual CFIT seen in this study underscores the rather humbling methodological point that genuine accidents rarely follow the exact pattern implied by group statistics. This incident happened because of nothing more elaborate than momentary in-flight attentional lapse while the pilot was studying the sectional. This was a Control group pilot, but not younger or lower-flight hour, as our models would lead us to believe. So, once again, Nature reminds us that correlation does not imply causation.

Question 2

The construction of a data-collecting emulation of *www.aviationweather.gov* was a significant, reusable achievement. However, its use as a research tool proved far from simple, as Figure 12 shows.

Table 3 suggests that mere *time spent* on preflight briefing was not a good predictor of either *quality* of preflight briefing nor subsequent *flight safety*. Nonetheless, these data are just the opening salvos in what will eventually have to be a far more intensive study of modern weather briefing and its relation to flight safety.

Question 3

We did not see important differences between local pilots and non-local pilots. The only significant finding was that the locals took slightly less time to brief for this relatively local flight. But, Oklahoma pilots are arguably more familiar with their own local terrain and weather patterns and need less briefing time for a flight such as this, so the issue is probably trivial.

More importantly, these findings directly address the issue of whether CAMI studies are generalizable to the national population of U.S. GA pilots. The fact is that U.S. pilots study a fairly uniform curriculum (largely driven by the licensing exams). This guarantees a measure of pilot uniformity. What is certainly far more important to research planning is the individual variation in knowledge and skill present between one pilot and another—not where a particular pilot happens to live. Yes, there are specific regions where certain flying skills are more called-upon than others. The high winds in the Midwestern U.S. are a good example. But—unless the task to which a given group of pilots is put depends critically on some small, specific set of skills—geographical region-of-residence probably will not matter a great deal.

What this means is that researchers simply need to adhere to standard practices in selecting pilots and assigning them to treatment conditions. As long as designs are counterbalanced, and pilots are reasonably well-matched for age, flight hours, and instrument rating over treatment cells, there is probably only an occasional need to recruit non-locally. Our final cost figures put the human effort and dollar cost of testing a non-local pilot at approximately 5-10 times the expense of recruiting a local pilot. Therefore, what non-local pilots are best used for is precisely when an elite sample is required but not locally available. For instance, if high-hour, young, VFR pilots were needed for some reason, then we would probably want to consider recruiting non-locally.

Implications of this research for pilot training

The first training implication of this research has to do with the value of specificity. For commercial reasons, many flight training products are general, seeking to appeal to as broad an audience as possible. While a degree of generality can be good, when it comes to weather training, there is much to be said for specificity. Just as flight instructors teach pilots specifically how to recover from stalls and spins, there is arguable merit in teaching specific recovery strategies to fit specific weather encounters. For instance, the Aircraft Owners and Pilots Association offers an array of interactive on-line courses, many of which deal with weather recognition and decision making.

This leads to a second implication of this research, namely that certain kinds of learning are best done with real-world experience. However, for reasons of common sense and liability, VFR flight training purposely excludes bad weather encounters. Even IFR training typically avoids known extreme weather hazards. This leaves pilots to experience these hazards *ab tempestas*—by "encounter with storm," that is, by accident, the hard way.

Finally, during this experiment, many pilots informally expressed the opinion that the future of weather briefing looks increasingly Internet-based, as opposed to coming solely from the Flight Service Station. If the future is, as we suspect, Web-based and graphical, rather than simply text-based, then pilot training will need to address these new technologies and trends. Pilots will have to become skilled at self-briefing through products such as www.aviationweather.gov, and these products themselves will become the subject of human factors research scrutiny through such methods as content analysis and usability testing.

All in all, the future looks hopeful. We have new technologies that can place up-to-date weather information within reach of any pilot with access to an Internet-enabled computing device. We also have video instruction technologies capable of helping pilots learn how to cope with the complexities of weather. The twin tricks will be to enable universal access to this weather information and to teach pilots how best to use it. In summary, what the current study has taught us is that, no matter how well we provide information and how well we teach pilots how to use it, weather is, and will remain, a formidable opponent.

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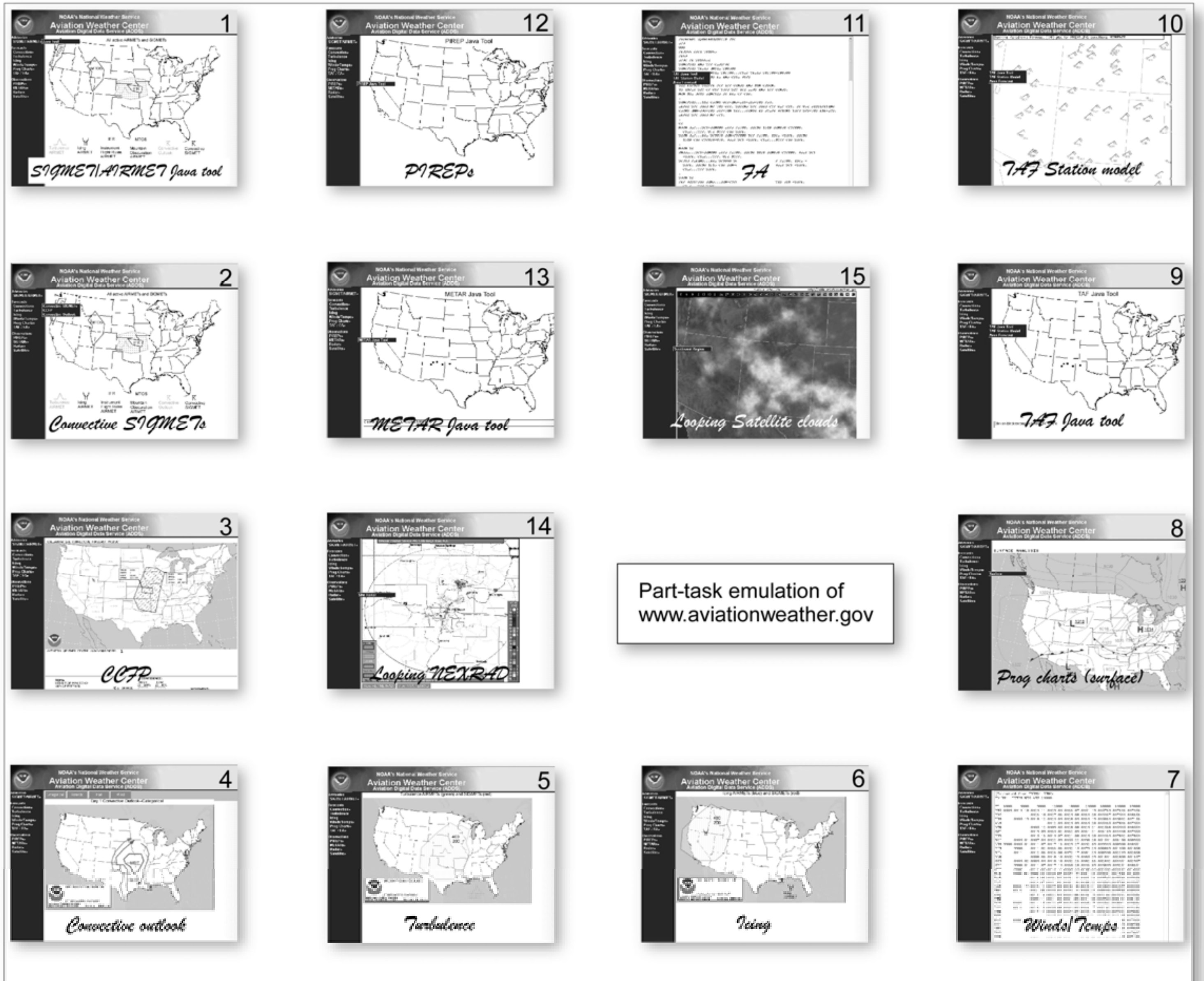
APPENDIX A

Web preflight briefing screenshots



APPENDIX B

Sample hypertext markup language (html) code used to emulate the *aviationweather.gov* home page in Microsoft Visual Studio. The core html was taken from *www.aviationweather.gov* and modified for use here.

```
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turbulence, and convection."
name=description>
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type=text/css rel=StyleSheet><LINK
href="ADDS - Aviation Digital Data Service_files/flyout.css" type=text/css
rel=StyleSheet><LINK href="ADDS - Aviation Digital Data Service_files/main.css"
type=text/css rel=STYLESHEET><LINK href="/layout/ops/favicon.ico"
rel="shortcut icon">
<STYLE type=text/css>BODY {
FONT-SIZE: 10pt; MARGIN: 0px; COLOR: #000000; FONT-FAMILY: Verdana, Arial, Helvetica, sans-serif
}
.bc {
FONT-WEIGHT: normal; FONT-SIZE: smaller; FONT-STYLE: normal; FONT-FAMILY: sans-serif
}
</STYLE>

<SCRIPT language=JavaScript type=text/javascript>
<!--
function setNavChildren(node) {
  if (node.nodeName == "LI") {
    node.onmouseover=function() {
      this.className="over-" + this.className;
    }
    node.onmouseout=function() {
      this.className=this.className.replace("over-", "");
    }
  }
  for(var child = node.firstChild; child != null; child = child.nextSibling) {
    setNavChildren(child);
  }
}
var startList = function() {
  if (document.all && document.getElementById) {
    navRoot = document.getElementById("nav");
    if (navRoot) {
      for (i=0; i < navRoot.childNodes.length; i++) {
        setNavChildren(navRoot.childNodes[i]);
      }
    }
  }
}
// It has to be in a function or the prevLoad variable will cause infinite recursion
function addStartList() {
  var prevLoad = window.onload;
  window.onload = function() {
  if (prevLoad) {
    prevLoad();
    }
    startList();
  }
}
```

```
addStartList();
//                          -->
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   border=0></A> <A href="http://weather.gov/"><SPAN
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      href="http://adds.aviationweather.gov/"><SPAN
      class=regionwhite>Aviation Digital Data Service
    (ADDS)</SPAN></A></TD></TR></TBODY></TABLE>
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  <TD align=right><A href="http://www.nws.noaa.gov/"><IMG height=78
   alt="NWS logo - Click to go to the NWS homepage"
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   href="http://www.weather.gov/organization.php">Organization</A></TD>
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   </TD>
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   name=v:project> <INPUT maxLength=256 name=query>   <INPUT type=submit value=Go> </TD>
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        <LI><A href="http://adds.aviationweather.gov/airmets/">US
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        <LI><A
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        </LI></UL></LI>
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        Outlook</A> </LI>
        <LI><A
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        <LI><A href="http://www.spc.noaa.gov/products/md">Mesoscale
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       </LI>
       <LI><A href="http://adds.aviationweather.gov/icing/">Icing</A>
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        <LI><A
        href="http://adds.aviationweather.gov/winds/">Winds/Temps
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    </LI>
    <LI><A href="http://aviationweather.gov/">AWC Home</A>
   </LI></UL></LI>
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   <LI><A href="http://aviationweather.gov/std_brief/">Standard
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  <LI><SPAN class=yellow>Contact Us</SPAN>
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   <SPAN class=indicator>»</SPAN></A>
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  alt="USA.gov is the U.S. Government's official Web portal to all Federal, state and local government Web resources and services."
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              src=”ADDS - Aviation Digital Data Service_files/noaabullet.gif”
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             <TD width=”95%”>December 6, 2006: A new icing
              product (CIP-SEV) has been made operational, see
              the <A
              href=”http://adds.aviationweather.gov/icing”>icing
              page</A> and its <A
              href=”http://adds.aviationweather.gov/icing/description3.php”>FYI/Help</A>
              for more details. In addition, a site update has
              been released. Please see the <A
              href=”http://adds.aviationweather.gov/info/ops_whats_new.php”>information
              page</A> for more details.
         </TD></TR></TBODY></TABLE></TD></TR></TBODY></TABLE></TD></TR>
       <TR vAlign=top>
        <TD align=left width=250>The <STRONG>Aviation Digital Data
         Service (ADDS)</STRONG> makes available to the aviation
         community text, digital and graphical forecasts, analyses, and
         observations of aviation-related weather variables. ADDS is a
         joint effort of NCAR Research Applications Program (<A
         href=”http://www.rap.ucar.edu/”>RAP</A>), Global Systems
         Division (<A href=”http://www.esrl.noaa.gov/gsd/”>GSD</A>) of
         NOAA’s Earth System Research Laboratory (<A
         href=”http://www.esrl.noaa.gov/”>ESRL</A>), and the National
         Centers for Environmental Prediction (<A
         href=”http://www.ncep.noaa.gov/”>NCEP</A>) Aviation Weather
         Center (<A href=”http://aviationweather.gov/”>AWC</A>). <BR
         clear=all> <BR><B>Current AIR/SIGMETs:</B><BR><A
         href=”http://adds.aviationweather.gov/data/airmets/airmets_ALL.gif”><IMG
         height=160 alt=”Current AIR/SIGMETs” hspace=0
         src=”ADDS - Aviation Digital Data Service_files/airmets_ALL_sm.gif”
         width=250 border=0></A> </TD>
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         href=”http://www.nws.noaa.gov/”>National Weather Service</A>
         operationally supports this site as well as the following
         operational products:</STRONG><BR><BR>
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            METARs</STRONG><BR> ?<STRONG>
            TAFs</STRONG><BR> ?<STRONG>
            PIREPS</STRONG><BR> ?<STRONG>
            AIR/SIGMETs</STRONG><BR> ?<STRONG>
            Satellite</STRONG><BR> ?<STRONG> Radar</STRONG> </TD>
           <TD align=left> ?<STRONG> Analysis &amp; Prognostic
            Charts</STRONG><BR> ?<STRONG> Graphical wind &amp;
            temperature charts</STRONG><BR> ?<STRONG> National
            Convective Weather Forecast</STRONG><BR> ?<STRONG>
            Current &amp; Forecast Icing
            Potential</STRONG><BR> ?<STRONG> Graphical
            Turbulence Guidance</STRONG> </TD></TR></TBODY></TABLE><BR
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            href=”http://www.faa.gov/”>Federal Aviation
            Administration</A> funds and directs the continuing
            development of ADDS as well as other experimental
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          products being developed by the <A
          href=”http://www.faa.gov/aua/awr”>FAA Aviation Weather
          Research Program</A> (AWRP).<BR><BR>The results of the
          latest ADDS development efforts along with new
          experimental AWRP algorithm results can be viewed on the
          <A
          onmouseover=”self.status='http://weather.aero'; return true”
          onmouseout=”self.status=''; return true”
          href=”http://adds.aviationweather.gov/layout/ops/jump_exp.php”>experimental
          ADDS site</A>.
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           News</B>  (Updated: December 7, 2006)</FONT>
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           alt=”News Bullet”
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          <TD>07 December 2006: <A
           href=”http://www.weather.gov/os/notification/tin06-59aaa_graph_turbulence.txt”>TIN
           announcement for the GTG product update.</A> The update
           scheduled for January 8 2006 has been postponed until
           further notice. </TD></TR>
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          <TD vAlign=center align=middle width=28><IMG
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           src=”ADDS - Aviation Digital Data Service_files/secbullet.gif”
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          <TD>20 April 2006 : Link provided to Space Weather
           Prediction Center?s (SWPC) experimental <A
           href=”http://www.sec.noaa.gov/aviation/”>Space Weather
           for Aviation Service Providers</A> on ?<A
           href=”http://aviationweather.gov/testbed/”>Aviation
           Testbed</A>? page. </TD></TR>
         <TR>
          <TD vAlign=center align=middle width=28><IMG
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           border=0> </TD>
          <TD>COSPAS-SARSAT will cease satellite monitoring of the
           121.5 MHz frequency on February 1, 2009. If you fly an
           aircraft with an ELT, please visit <A
           href=”http://www.sarsat.noaa.gov/”>http://www.sarsat.noaa.gov/</A>
           for further information.
      </TD></TR></TBODY></TABLE></TD></TR></TBODY></TABLE></TD></TR></TBODY></TABLE>
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       href=”http://adds.aviationweather.gov/convection/”>Convection</A>    
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   href=”http://adds.aviationweather.gov/satellite/”>Satellite</A>    
   <A class=linkWhite
   href=”http://adds.aviationweather.gov/radar/”>Radar</A><BR><FONT
   style=”COLOR: #ffffff”>0</FONT><BR>Page loaded:   <A
   class=linkWhite href=”http://www.time.gov/”>22:20 UTC</A><BR>03:20
   PM Pacific  |   04:20 PM
   Mountain  |   05:20 PM
   Central  |   06:20 PM Eastern
</TD></TR></TBODY></TABLE>
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summary=”This table is used for formatting purposes only” border=0>
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    border=0><TBODY>
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      <HR>
     </TD></TR>
    <TR vAlign=top>
     <TD class=gray align=left bgColor=#ffffff><A
      href=”http://www.noaa.gov/”><SPAN class=gray>NOAA’s</SPAN></A>
      <A href=”http://www.nws.noaa.gov/”><SPAN class=gray>National
      Weather Service</SPAN></A><BR><A
      href=”http://www.ncep.noaa.gov/”><SPAN class=gray>National
      Centers for Environmental Prediction</SPAN></A><BR><A
      href=”http://adds.aviationweather.gov/”><SPAN
      class=gray>Aviation Weather Center</SPAN></A><BR><SPAN
      class=gray>7220 NW 101st Terr., Room 118</SPAN><BR><SPAN
      class=gray>Kansas City, MO 64153-2371</SPAN><BR><A
      href=”mailto:ncep.awc.adds@noaa.gov”><SPAN class=gray>Contact
      ADDS Internet Services</SPAN></A><BR><SPAN class=gray>Page
      last modified: February 07, 2007 </SPAN></TD>
     <TD align=left bgColor=#ffffff><A
      href=”http://www.weather.gov/disclaimer.php”><SPAN
      class=gray>Disclaimer</SPAN></A> <BR><BR><A
      href=”http://www.weather.gov/credits.php”><SPAN
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      href=”http://www.weather.gov/glossary”><SPAN
      class=gray>Glossary</SPAN></A> </TD>
     <TD align=right bgColor=#ffffff><A
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      class=gray>Privacy Policy</SPAN></A> <BR><BR><A
      href=”http://www.weather.gov/admin.php”><SPAN class=gray>About
      Us</SPAN></A> <BR><BR><A
      href=”http://www.weather.gov/careers.php”><SPAN
      class=gray>Career Opportunities</SPAN></A>
  </TD></TR></TBODY></TABLE></TD></TR></TBODY></TABLE></TD></TR></TBODY></TABLE></BODY></HTML>
```

APPENDIX C

Code-behind for a sample page emulation of *aviationweather.gov*. In Visual Studio, dynamic Web pages use code-behind to respond to events such as mouseovers and button clicks.

```
Imports System
Public Class _Default
  Inherits System.Web.UI.Page
  Protected Sub Page_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles Me.Load
    pnl_msgbox.Visible = False
    btn_Overwrite.Visible = False 'Comment this out to enable the Overwrite
  End Sub
  Protected Sub btn_Begin_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles btn_Begin.Click
    'Below, we check to make sure a valid data file name has been typed in
    If TxtBox_EnterID.Text = "" Then
      Label1.Text = "ENTER AN ID#"
      Panel1.BackColor = Drawing.Color.Red 'NOTE: Not all colors will work
    Else
      Panel1.BackColor = Drawing.Color.White
      myGlobals.currentURL = "ADDS pages/ADDS Homepage.aspx"
      myGlobals.dataFilename = "Pilot data files/Wx06 " & TxtBox_EnterID.Text & ".txt" 'Name the path/filename
      If My.Computer.FileSystem.FileExists(myGlobals.dataFilename) Then
        ' We have to avoid erasing the datafile if a S wants to initiate a second session
        pnl_msgbox.Visible = True
      Else
        Do_Stuff()
      End If
    End If
    lbl_BriefingEnded.Visible = False
  End Sub
  Protected Sub lnkbtn_End_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles lnkbtn_End.Click
    Session.Abandon()
    lbl_BriefingEnded.Visible = True
  End Sub
  Private Sub Do_Stuff()
    'Call up the ADDS home page in a separate window
    Response.Write("<script language=" & Chr(34) & "JavaScript" & Chr(34) & " type=" & Chr(34) & "text/javascript" _
        & Chr(34) & ">window.open(" & Chr(34) & myGlobals.currentURL & Chr(34) & "," _
        & Chr(34) & "_blank" & Chr(34) & ")</script>")
    ' Record start of session
    Dim sr2 As StreamWriter, currentTime As Date, temp As String
    currentTime = Date.Now
    temp = currentTime.ToString & ControlChars.Tab & "Session start"
    sr2 = File.AppendText(myGlobals.dataFilename)
    sr2.WriteLine(temp)
    sr2.Close()
  End Sub
  Protected Sub btn_Append_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles btn_Append.Click
    Do_Stuff()
  End Sub
  Protected Sub btn_Overwrite_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles btn_Overwrite.Click
    ' Erase the old file
    Dim sr1 As New StreamWriter(myGlobals.dataFilename)
    sr1.Close()
    Do_Stuff()
  End Sub
  Protected Sub btn_Cancel_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles btn_Cancel.Click
    ' Do nothing
  End Sub
End Class
```