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14. ABSTRACT

During the month that I gave the paper, an article appeared - again - in the August Flying Magazine by Peter Garrison) in which he asserted that there is no problem in turning downwind. I have watched the subsequent issues of Flying but have not seen any mail responses from the crop dusters. They have either given up or are being "filtered out" by the aviation press. Also, the August 16 issue of Newsweek contained an article about Making Small Planes Safer (Science and Technology). This article indicates the FAA statistics attribute 1,022 general aviation accidents from 1976 to 1992 to "Spatial Disorientation". That's 64 accidents per year to this problem, one piece of which is the turning downwind problem. It also states that: "The way human beings perceive their own movement is fairly well understood." I'm not so sure.

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CONQUERING THE DOWNWIND TURN – SFTE PAPER FOLLOWUP

By

Herman Kolwey

I would like to take this opportunity to up-date some of the events and knowledge base that have happened, both before and after the publication/presentation of my paper at the SFTE Symposium in August 1999.

During the month that I gave the paper an article appeared - again – in the August Flying Magazine by Peter Garrison (Technicalities – Page 130) in which he asserted that there is no problem in turning downwind. I have watched the subsequent issues of Flying but have not seen any mail responses from the crop dusters. They have either given up or are being "filtered out" by the aviation press. Also, the August 16 issue of Newsweek contained an article about Making Small Planes Safer (Science and Technology). This article indicates that FAA statistics attribute 1,022 general aviation accidents from 1976 to 1992 to "Spatial Disorientation". That's 64 accidents per year to this problem, one piece of which is the turning downwind problem. It also states that: "The way human beings perceive their own movement is fairly well understood." I'm not so sure.

On a personal note, with regard to the paper, the following things have happened:

First – Winds aloft/Airspeed Calibration

I got E-mail from retired USAF performance engineer Wayne Olson wanting an advance copy of the paper, which I sent him. He had an airspeed calibration method and 2 1/3 level turns worth of F-16 GPS/INS data and wanted to compare his calibration method to whatever I was proposing. He did so, and I tried to show the comparison during the presentation in August. Unfortunately my slides were not up to snuff so you could not read them. His comparison arrived at EXACTLY the same airspeed error for the two methods (0.01 Kt. difference). One part of these two methods is also determination of the Winds Aloft. Either of these methods can be used to determine the Wins Aloft very accurately. I have attached a copy of his comparison to this article as Enclosure 1. Read his comparison for yourselves and I am sure that Wayne would be happy to provide you with a copy of his A/S calibration method. *The Airspeed calibration and Winds Aloft methods proposed in the August 1999 paper are confirmed by a different independent method proposed by Wayne Olson resulting in identical answers*

Second – Vortex Ring State

The work of analyzing the British Super Puma oilrig accident that I noted in the paper was completed in September 1999 for the Vortex Ring State technology area by some extraordinary work by Lt. Dave Varnes doing his Masters Thesis at USNPGS Monterey, CA. He has up-dated the knowledge base definition of the threat area (to Gao and Xin) and then defined the algorithms to provide the pilot with a warning on crossing the boundary. This technology was implemented on the "Gadget" moving map display, grabbing control from the map being displayed and presenting a plot on the kneeboard, showing an alternately flashing red and white background. An irritating voice warning "Were gonna CRASH! - You ain't doing it right!" was announced for the pilot in his thesis demonstration. A copy of his thesis is available from USNPGS, Monterey, CA. Also, he has a nice article on his work in the January 2000 Rotor & Wing, Page 60, entitled "Conquering Vortex Ring State". Plans are in work to conduct a flight test of the technology this summer. *Lt. David Varnes at USNPGS has demonstrated a Vortex Ring State pilot warning methodology in a Masters Thesis. Implement the VRS pilot warning methodology in Fleet helicopters*

Third – Fleet pilot and Flight Test Engineer (FTE) FEEDBACK

Several Fleet pilots and Flight Test Engineers, including Lt. Varnes (above) have provided me some extremely useful feedback via E-mail and discussion on the "downwind turn phenomenon" and related their experiences with this problem to put on the following plot. The other data points on the figure are adequately described in the August paper.

Lt. Dave Varnes (two points labeled H-46A and H-46B)

The first of these inputs was from Lt. Varnes, who sent me an un-solicited statement out of his CH-46 flight experience. He had a problem with TURNING DOWNWIND in a 45 Kt. wind and worked out a "solution" to the problem and flew the "solution" for about 2 hours or so. It struck me that, in his experience, I had a "before" (H-46A) and "after" (H-46B) pair of data points at 45 Kt. wind. I have included a summary of the E-mails with Lt. Varnes as Enclosure II. I put this data on a plot format that I had presented in a prior (1991) SFTE paper and wondered how the rest of the accidents that I described and Lt. Varnes' experience would all fit on the plot. When I started putting the points on the plot I was amazed that they all appeared to line up across the page at just over a 0.6 Wind Speed Ratio (WSR).

Kari Seppanen (point labeled Navion)

Later, E-mail discussions with Kari Seppanen (Flight Test Engineer – FTE, Boeing Seattle) and discussions about energy methods wind axis or earth axis yielded another experience base of flying his Navion against a pickup truck going about 45 Mph in very low wind. This yielded another data point, though not quite the same piloting task and without a turning problem. Kari's experience is recorded in enclosure III. Kari is also working on what he calls his "crop duster" performance model that relates aircraft potential and kinetic energy to the earth axis so that wind effects are properly represented.

Mark Hardesty (point labeled Schweitzer)

Another FTE, Mark Hardesty (Boeing, Mesa AZ) had sent me a copy of a Soaring article entitled "Sensory Overload" describing his sailplane accident while TURNING DOWNWIND. It is referenced in the paper (Ref. Q) and presented on the plot in this article. What, you might ask, is the difference between "Sensory Overload" and "Spatial Disorientation", cause and effect?

Gary Klein (point labeled H-46 Max Wind)

Finally, a chance discussion with another FTE Gary Klein (an ex CH-46 Fleet pilot and now Boeing V-22 flight test engineer at Pax River) yielded the final (and highest WSR - though not the same piloting task) experience at 60 Kt. wind for the data points plotted on Figure 1. His experience as it was related to me is in Enclosure IV.

The WIND SPEED chart

Figure 1 presents a plot format from a 1991 SFTE paper (Figure 19) that I did. It is Ref B of last August's paper. I have added the following VISUAL WORKLOAD LEVEL logic based on a discussion with flight instructor Bob Miller (FTE, civilian helo flying qualities instructor at USNTPS and civilian GA flight instructor):

Question: When you send a student (safe for solo) out to fly turns about a point on the ground, what wind speed limit would you use?
FI: 15-16 Kt.
Question: Flying what airspeed?
FI: 80 Kt.
Question: What wind would you limit him to if he were flying at 100 Kt.

FI: Probably 20 Kt
Question: If you were flying the same exercise at 100 Kt. how much wind do you think you, the FI, could handle?
FI: Probably 40 Kt.

These three points are presented on the Wind Speed chart, Figure 1, as X1 (16/80=0.2), X2 (20/100=0.2), and X3 (40/100=0.4) respectively and are the basis of the "Pilot Visual Workload" definitions for the "Student limit" and "Instructor limit" on the Y-axis. The "Too Hard" limit at 0.6 WSR I defined after seeing that the accident/incident data points from the paper lined up at just over 0.6. At 1.0 there is a "No Return" limit which comes from the fact that after you turn downwind with the aircraft trimmed at the wind speed you will never get back to your original location if you stay trimmed on that airspeed. I have also added speed ranges below the X-axis for different categories of aircraft (with help from test pilot Larry Higgins). It is evident that crop-dusters and airline pilots are apples and oranges, because a "Visual Workload" of 0.4 for the crop duster with 24 Kt wind flying at 60 Kt. is equivalent to the airline pilot at 150Kt with a 60 Kt. wind.

My definition of the assumed task in the turn is "vary your bank angle in a level turn so that your turn radius in the air mass matches a circle on the ground". That is very much a visual coordination task and is what all of the pilots shown on the plot were doing (or at least ended up doing), with the exception of the two points labeled Navion and H-46 Max Wind.

Apparent Limit

Figure 1 presents the data points from the August paper plotted on a Wind Speed chart, along with the excellent feedback I have gotten from some Flight Test Engineers and Fleet pilots. Figure 1 summarizes all that I was trying to say in the paper and then some. All the points where the pilot had problems (shaded points are accidents) fall in a line at just over 0.6 WSR. Lt. Varnes (H-46A) has the second-highest number initially at 0.64 WSR (highest for a FIXED ground point case), but his "solution" brought him down the 45 Kt wind line to an acceptable, even though difficult, manually-flown solution at 0.45 WSR. His point is near that of the Navion, also at 45 Kt. "wind". The pilot task is slightly different, and the Navion has very low ambient wind so very low variability and a higher airspeed at 120 Vs 100. I think that these factors account for the differences in pilot visual workload, since the Navion was at 0.38 WSR and is described as not too difficult and smooth. The pilot of the data point with 60 Kt. wind (H-46 Max Wind) did not have a specific ground point to fly around, but instead was trying to stay "in the area near the ship". He also had a problem, but worked out a solution by having the AFCS maintain his airspeed, as he COULD NOT DO IT MANUALLY. From the accidents noted and feedback that I have received, the problem seems to be that at just above WSR = 0.6 the pilot's ability to judge and resolve the wind solution for turning about a point on the ground reaches a limit. This problem was encountered in helicopters, gliders, and fixed wing light planes and includes Stall, Vortex Ring State, Settling With Power, and possibly LTE. The conclusion to be reached, in my opinion, is that the problem is a pilot Human Factors problem (e.g.: The ability of the pilot to monitor and scan specifically his airspeed indicator and resolve it with the outside visual scene)

Why the Limit?

I don't know why it becomes "too hard"; maybe the clue is in the "Schweitzer" article by George Thelan. He titled the article "Sensory Overload". We ought to be able, ultimately, to determine what thing, or combination of things is bothering the pilot. There is some good work to be done here in the areas of simulation and human factors. All of this analysis is based on a STEADY WIND solution. Someone should have access to data that would indicate "gustiness" or variability of the wind as a function of the wind speed but I have not seen it. It certainly figures into the real world problem. Perhaps the answer lies in the cross-track angle, or the speed variation or both. At WSR = 0.5, for instance, there is a 100 % variation (from -50% to +50%) of the trimmed airspeed reflected in the ground speed). I have included in Figures 2 and 3 plots of ground speed variation with WSR and ground track angle with WSR. The reference "Aerodynamics for Naval Aviators" contains a plot of percent of takeoff or landing distance as a function of wind speed ratio (Figure 2.33, Page 189). Consider figures 2 and 3 an in-flight extension of that wind speed ratio concept – 40 years later. Lets stop telling pilots not to worry about turning downwind. It DOES fly the same if you do it right, but if you exceed a visual WSR limit of 0.6 (0.37 for the Cardinal) it CAN KILL you. *I have concluded that Garrison and Schiff are right in that, if flown properly, the aircraft doesn't care which way it is turning (e.g. into or out of the wind). However, there appears to be a limit to the pilots ability to solve the visual relative motion problem for outside-the-cockpit turn cues with WSR's of over 0.6 (0.38 if fatigued and distracted, or a student). Accidents occur during downwind turns above these limiting conditions when flown to a visual ground reference, as the crop dusters have continuously asserted.*

Cessna Cardinal

Finally, why didn't the folks in the Cardinal make it? Fatigue, gustyness, poor visibility, concern with a water tower, being hurried to get out before the storm, and a 70-90 deg. head-turn to monitor airspeed all contributed to that crash. It would have paid to have the "student" or her father in that aircraft constantly calling out airspeeds (e.g. the Crew Coordination concept). This all assumes that the instructor was flying the aircraft. If he wasn't, the "student" was WAY OVER HER HEAD with this "Visual Workload" problem.

Figure 1 provides a convenient format for understanding the factors that are involved with the turn-about-a-point-on-the–ground exercise and the downwind turn. The NTSB should use the format of figure 1 for plotting accident data, to analyze and confirm the theory proposed here. The information presented should be used in pilot training as there IS still a turning downwind problem related to wind speed ratios of above 0.6 arising from a pilot VISUAL WORKLOAD limit. The wind speed curves indicate a way of mitigating the effects of the wind as two pilots have successfully done in their descriptions (one by speeding up, the other by letting the flight control system maintain the airspeed) and one in an exercise to simulate the wind. Finally, use this approach as a way for both students and flight instructors to judge "proficiency" as the Turn-About-A-Point on the ground task is practiced. *I recommend Figure 1 as a means of judging pilot proficiency, mitigating wind effects, and analyzing accident statistics relative to visual ground-referenced turns*

CONCLUSIONS

1. *The Airspeed calibration and Winds Aloft methods proposed in the paper are confirmed by a different independent method proposed by Wayne Olson resulting in identical answers.*
2. *Figure 1 provides a convenient format for understanding the factors that are involved with the turn-about-a-point-on-the–ground exercise and the downwind turn.*
3. *Garrison and Schiff are right in that, if flown properly, the aircraft doesn't care which way it is turning (e.g. into or out of the wind). However, there appears to be a limit to the pilots ability to solve the relative motion problem for outside-the-cockpit turns with WSR's of over 0.6 (0.38 if fatigued and distracted, or a student). Accidents occur during downwind turns above these limiting conditions when flown to a visual ground reference, as the crop dusters have continuously asserted.*
4. *Lt. David Varnes at USNPGS has demonstrated a Vortex Ring State pilot warning methodology in a Masters Thesis.*

RECOMMENDATIONS

1. *Use the Winds Aloft and Airspeed Calibration methods proposed in the paper or that proposed by Wayne Olson for accurate winds aloft determination or airspeed calibration in situ.*
2. *Implement the VRS pilot warning methodology in Fleet helicopters*
3. *Use the format of Figure 1 for accumulating accident statistical data for turning downwind accidents.*
4. *Use Figure 1 for pilot training, judging pilot proficiency and for mitigating the effects of the wind for visual ground-referenced turns.*

Kolwey, Herm G

From: WAYNEOPERF@aol.com
Sent: Friday, July 30, 1999 1:48 AM
To: kolweyhg@navair.navy.mil; Frank.Brown@412tw.edwards.af.mil; Fred.Webster@412tw.edwards.af.mil
Subject: Comparison of Two Methods for Air Data Cal in Turn

COMPAR~1.PDF

To: Herman Kolwey (NAWC)
Frank Brown & Fred Webster (AFFTC):

Attached is an informal memo I wrote comparing Herman's method of computing winds in a turn and mine. They are substantially different mathematically, but I got essentially exactly the same answers for horizontal winds and an error in true airspeed using the Max thrust turn data presented in my as yet unpublished (but cleared for public release) paper "Air Data Calibration from Turning Flight".

I used that data with Herman's method outlined in Appendix B of his paper "Turning Down Wind? Don't Lose The Axis!!" to be presented at this years SFTE symposium in St. Louis.

Enjoy!
WayneO
PS:
If you have trouble reading the attached file , you need Version 4 of the Adobe Acrobat Reader. It can be downloaded free at www.adobe.com

ENCLOSURE I

Comparison of Airspeed Calibration During Turn Methods

By Wayne Olson
July 28, 1999

This is an informal memo evaluating two methods of determining the horizontal components of wind and an error in true airspeed from turn data. The first method is one suggested by Herman Kolwey of the Naval Air Warfare Center in his SFTE paper "Turning Down Wind? Don't Lose The Axis" and the second is one I discuss in my paper "Air Data Calibration from Turning Flight". The data I use for this comparison is a turn presented in my paper. The following time history plot (Figure 1) is indicated true airspeed versus elapsed time. Indicated true airspeed is pitot-static derived true airspeed without any corrections applied. As you can see, there is a considerable variation in the indicated true airspeed. The following list gives the statistics for indicated true airspeed during this turn which is a 3 g turn at 0.85 Mach number and 30,000 feet with an F-15. I should note that this data has been cleared for public release. The data was sampled at one sps and is 140 seconds in duration.

Mean = 504.97 knots
Minimum = 483.74 knots
Maximum = 517.95 knots
Standard deviation = 8.61 knots

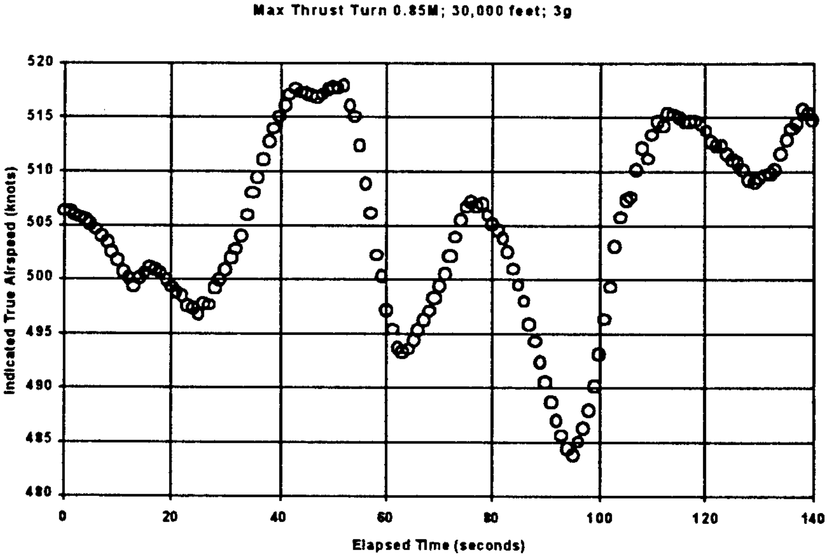


Figure 1. Indicated True Airspeed

The aircraft was equipped with what is called an EGI (Embedded GPS, INS). That is a device that uses inputs from both an INS and a GPS to give a filtered value for velocities. As such you get the best of both worlds. The INS is a good "instantaneous" device, updating at a high rate, but loses accuracy over a period of time. The GPS yields very accurate velocities, but only updates at one sps. The spec accuracy of horizontal velocities for a GPS is 0.1 m/sec (0.19 knot).

As you can see in the next plot (Figure 2) of ground track angle versus time the period of the turn was almost exactly 60 seconds, so we have about 2 1/3 turns here. The track angle was computed from the North and East ground speeds from the EGI.

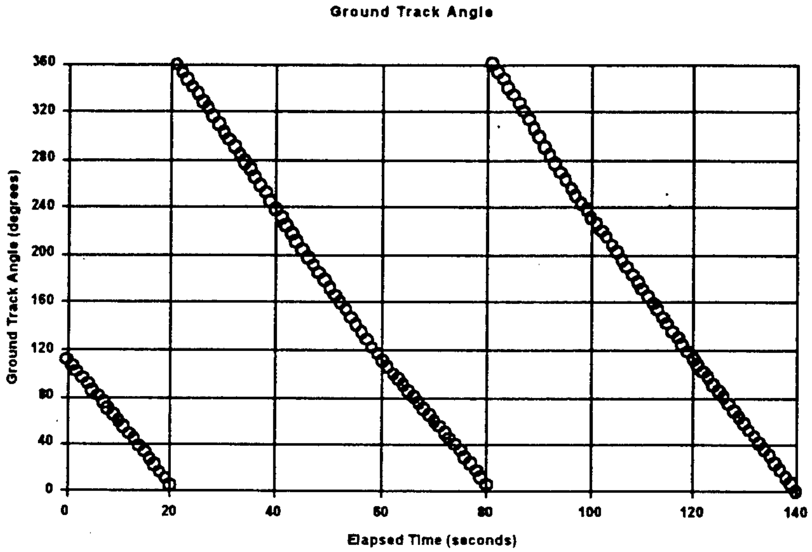


Figure 2. Ground Track Angle

Next, is a plot (Figure 3) of the two horizontal components of ground speed versus elapsed time.

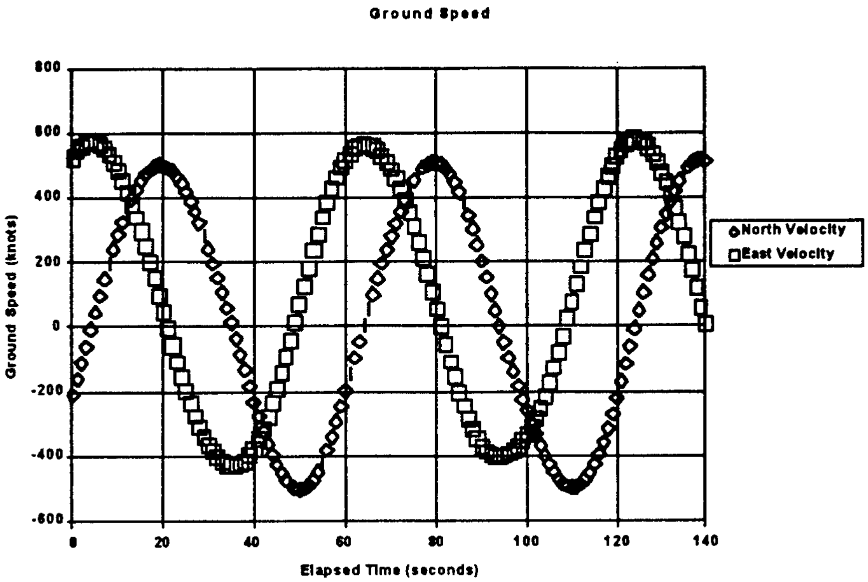


Figure 3. North and East Ground Speed

The method I use to compute the two components of wind and an error in true airspeed is detailed in my paper. The method I'll be comparing to is in "Appendix B : Determination of Winds Aloft From Ground Track Time History" of Herman's paper. Quoting from that appendix:

"On a zero wind day, a pilot can fly a level turn, maintaining bank angle, turn rate, radius of turn, etc. and – without watching the ground – he will consistently come back to his starting point. In a steady wind, flying the same maneuver will put him back to the starting point, but drifted downwind by a distance equal to the wind speed times time for the turn. In the air mass, however, the pilot is back at the starting point as though it were a zero wind day."

"The test method involves doing a procedure level turn as follows: Roll into a level turn. Once stabilized in the turn, select an up-coming heading and call out "mark" on the heading, on "mark" start a stopwatch. Continue turning for a complete turn (360 deg) back to the same heading and call "mark" again. On this "mark" stop the stopwatch. In this procedure, you have done a 360 deg level turn in the air mass, arriving back at the starting point (same as on a no-wind day). The vector distance on the ground track from first to second "mark" represents the wind vector."

So, I took the turn data set and computed North and East distances. The computation was just numerically integrating the ground speeds. I then took points that were exactly (to within 0.1 second) of 360 degrees apart in ground track angle. The data was available at 1 sps and I linearly interpolated to get to 0.1 second. Then, I broke the turn up into segments of 360 degrees with start times every 10 seconds. The following (Table 1) represents the times, incremental distances and computed wind speeds. Note the wind speeds are of opposite sign as the wind "vector". That is to make the relationship of true airspeed to ground speed be true airspeed equals ground speed *plus* wind, which is the usual convention in aeronautics and meteorology.

Table 1. Computation of Wind Speeds

Start Time (seconds)	End Time (seconds)	North Distance (feet)	East Distance (feet)	Wind North (knots)	Wind East (knots)
0	59.8	1502	6391	-14.9	-63.3
10	70.1	1586	6474	-15.6	-63.8
20	80.2	1683	6623	-16.6	-65.2
30	89.4	1182	6927	-11.8	-69.1
40	98.9	1002	7616	-10.1	-76.6
50	109.8	635	7299	-6.3	-72.3
60	120.2	228	7662	-2.2	-75.3
70	129.5	98	7124	-1.0	-70.9
80	139.1	-94	6949	0.9	-69.7
			Average	**-8.61**	**-69.58**

Well, let me discuss the above results a bit. I did the first time segment (0 to 59.8) and got the "answers" for the wind speeds in the first row. I knew the "answers" I was looking for – namely the wind speeds I computed in my paper. I was hoping they would be identical. They were in the same ballpark, but no cigar, so to speak. So, I figured, I try a bunch of segments and maybe the average of several segments would be better. It was, in fact, much better, but still there was a difference. I could also compute a mean velocity error, by computing true airspeed using winds as follows:

$$V_t = \sqrt{\left[\left(V_{gN} + V_{wN}\right)^2 + \left(V_{gE} + V_{wE}\right)^2 + V_{gD}{}^2\right]} \tag{1}$$

This was not a "perfectly" level turn, however, the down velocity term makes a very small contribution. I included it, mostly, because I included it in my paper. By taking the difference between the above true airspeed and the indicated true airspeed we get a correction to be added to true airspeed as follows:

$$\Delta V_{t_i} = V_t - V_{ti} \tag{2}$$

By taking the average of the ΔV_t, we get a single value of the correction. Table 2 compares the results from my first iteration on Herman's method and my results in my paper.

Table 2. Wind and Delta True Airspeed Comparison

	Kolwey	Olson
Wind North V_{wN} (knots)	-8.61	-9.61
Wind East V_{wE} (knots)	-69.58	-74.23
Delta True Airspeed ΔV_t (knots)	-5.18	-5.66

We could say, what the heck, with 70 plus knots of wind we get the correction to true airspeed within ½ knot of each other for the two methods. Close enough for government work, huh!

Stay tuned, I think I know what the problem is but haven't figured out how to account for it.

29-Jul-99

I'm back! Think I've got it. The problem is this is not a "steady" turn. There is substantial airspeed variation during the turn as evident in Figure 1. So, some fraction of what we are calculating as "wind" is really a variation in airspeed. We need to subtract out the variation in airspeed from each of the turn segments. We have a first estimate of wind speeds and delta true airspeed as shown in Table 2. We will calculate an "air distance" or the net distance components that the aircraft travels with respect to the air mass. We still assume that the wind speed remains constant. The following formulas were used to compute the North and East components of airspeed.

$$V_t = \sqrt{\left[\left(V_{gN} + V_{wN}\right)^2 + \left(V_{gE} + V_{wE}\right)^2\right]} \qquad (3)$$

Note that equation (3) is identical to (1), except we have ignored the vertical component.

$$V_{tN} = \left(V_{ti} + \Delta V_t\right) \cdot \frac{\left(V_{gN} + V_{wN}\right)}{V_t} \qquad (4)$$

$$V_{tE} = \left(V_{ti} + \Delta V_t\right) \cdot \frac{\left(V_{gE} + V_{wE}\right)}{V_t} \qquad (5)$$

Table 3 shows the results with the North and East distances deleted since they are the same as in Table 1:

Table 3. Wind Speeds Adjusted For Airspeed Variation – 1st Iteration

Start Time	End Time	Wind North	Wind East	Air North Distance	Air East Distance	True Airspeed North	True Airspeed East	Adjusted Wind North	Adjusted Wind East
0	59.8	-14.9	-63.3	586	-890	-5.8	8.8	-9.08	-72.14
10	70.1	-15.6	-63.8	650	-810	-6.4	8.0	-9.23	-71.81
20	80.2	-16.6	-65.2	668	-810	-6.6	8.0	-9.99	-73.16
30	89.4	-11.8	-69.1	301	-276	-3.0	2.8	-8.79	-71.85
40	98.9	-10.1	-76.6	70	447	-0.7	-4.5	-9.38	-72.11
50	109.8	-6.3	-72.3	-272	-9	2.7	0.1	-8.99	-72.41
60	120.3	-2.2	-75.3	-671	283	6.6	-2.8	-8.83	-72.5
70	129.5	-1	-70.9	-812	-124	8.1	1.2	-9.06	-72.17
80	139.1	0.9	-69.7	-989	-231	9.9	2.3	-8.97	-71.98
							Average	**-9.15**	**-72.24**

The average true airspeed correction (ΔV_t) computes to –5.47 knots. Using these new values of winds and delta true airspeed, we can proceed to iterate. Table 4 is the results of the second iteration.

Table 4. Wind Speeds Adjusted For Airspeed Variation – 2nd Iteration

Start Time	End Time	Wind North	Wind East	Air North Distance	Air East Distance	True Airspeed North	True Airspeed East	Adjusted Wind North	Adjusted Wind East
0	59.8	-14.9	-63.3	559	-1022	-5.5	10.1	-9.34	-73.45
10	70.1	-15.6	-63.8	622	-942	-6.1	9.3	-9.5	-73.11
20	80.2	-16.6	-65.2	721	-821	-7.1	8.1	-9.47	-73.26
30	89.4	-11.8	-69.1	277	-406	-2.8	4	-9.03	-73.14
40	98.9	-10.1	-76.6	46	318	-0.5	-3.2	-9.62	-73.41
50	109.8	-6.3	-72.3	-294	-93	2.9	0.9	-9.2	-73.24
60	120.3	-2.2	-75.3	-694	150	6.8	-1.5	-9.06	-73.81
70	129.5	-1	-70.9	-833	-256	8.3	2.5	-9.27	-73.49
80	139.1	0.9	-69.7	-1098	-365	11	3.7	-10.07	-73.32
							Average	**-9.40**	**-73.36**

The delta true airspeed is now –5.57 knots. Let's now tabulate our results versus iteration and compare with my results from my paper. These are shown in Table 5.

Table 5. Comparison of Winds and Delta True Airspeeds

	Kolwey	Kolwey	Kolwey	Olson
	Initial	1st Iteration	2nd Iteration	
Wind North V_{wN} (knots)	-8.61	-9.15	-9.40	-9.61
Wind East V_{wE} (knots)	-69.58	-72.24	-73.36	-74.23
Delta True Airspeed ΔV_t (knots)	-5.18	-5.46	-5.57	-5.66

It sure seems the iterations are closing in on my values. Lets do more iterations.

Table 6. Comparison of Winds and Delta True Airspeeds - Iterations

	Kolwey	Kolwey	Kolwey	Olson
	Initial Value	3rd Iteration	4th Iteration	
Wind North V_{wN} (knots)	-8.61	-9.47	-9.50	-9.61
Wind East V_{wE} (knots)	-69.58	-73.93	-74.21	-74.23
Delta True Airspeed ΔV_t (knots)	-5.18	-5.63	-5.65	-5.66

I think we've shown that these two methods with distinctly different mathematics came up with the same answers — exactly! The last row of delta true airspeed is what we were after; the winds were secondary results. However, when doing a series of these tests, the wind values are a measure of the variability of atmosphere if nothing else. Also, it may be that the test objective is to measure winds in which case the turn is an excellent test technique to measure the winds independent of the pitot-static system. That's not quite true as you do need a pitot-static system to determine how closely the turn is "steady" with respect to airspeed.

Either method determined the mean error in true airspeed. During the turn evaluated, the angle of attack varied from about 9 degrees to 12 degrees. Figure 6 in my paper shows the variation in delta true airspeed with angle of attack. That figure is reproduced in the following Figure

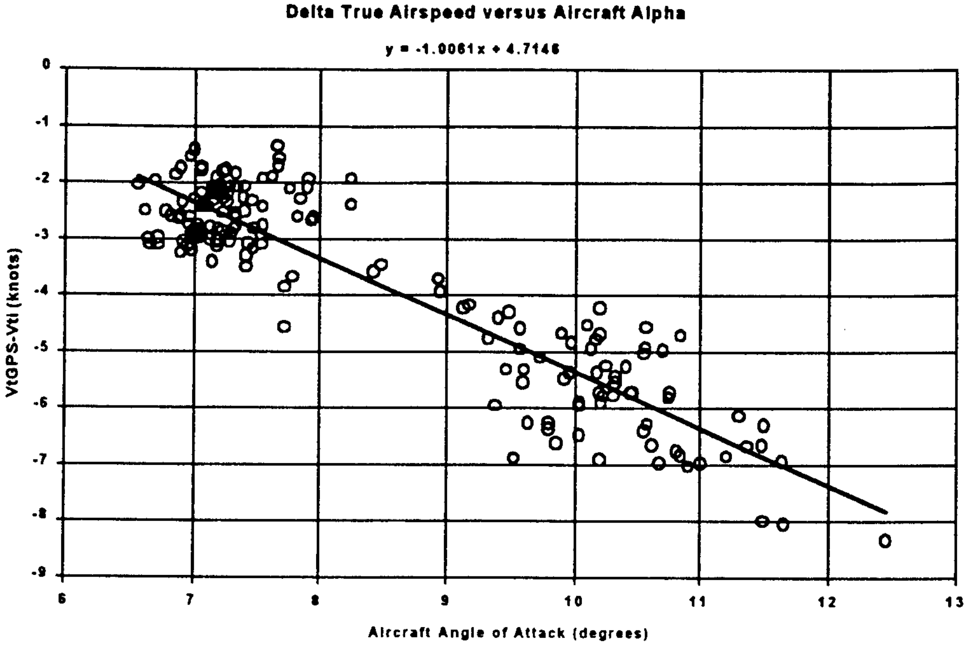


Figure 4. Delta True Airspeed versus Aircraft Angle of Attack

The data points above 8 degrees alpha are from the Max thrust turn evaluated in this memo. The other points are from a Mil thrust turn flown on the same flight at the same Mach number and altitude.

Fig 1A Def. &
Workload Feedback

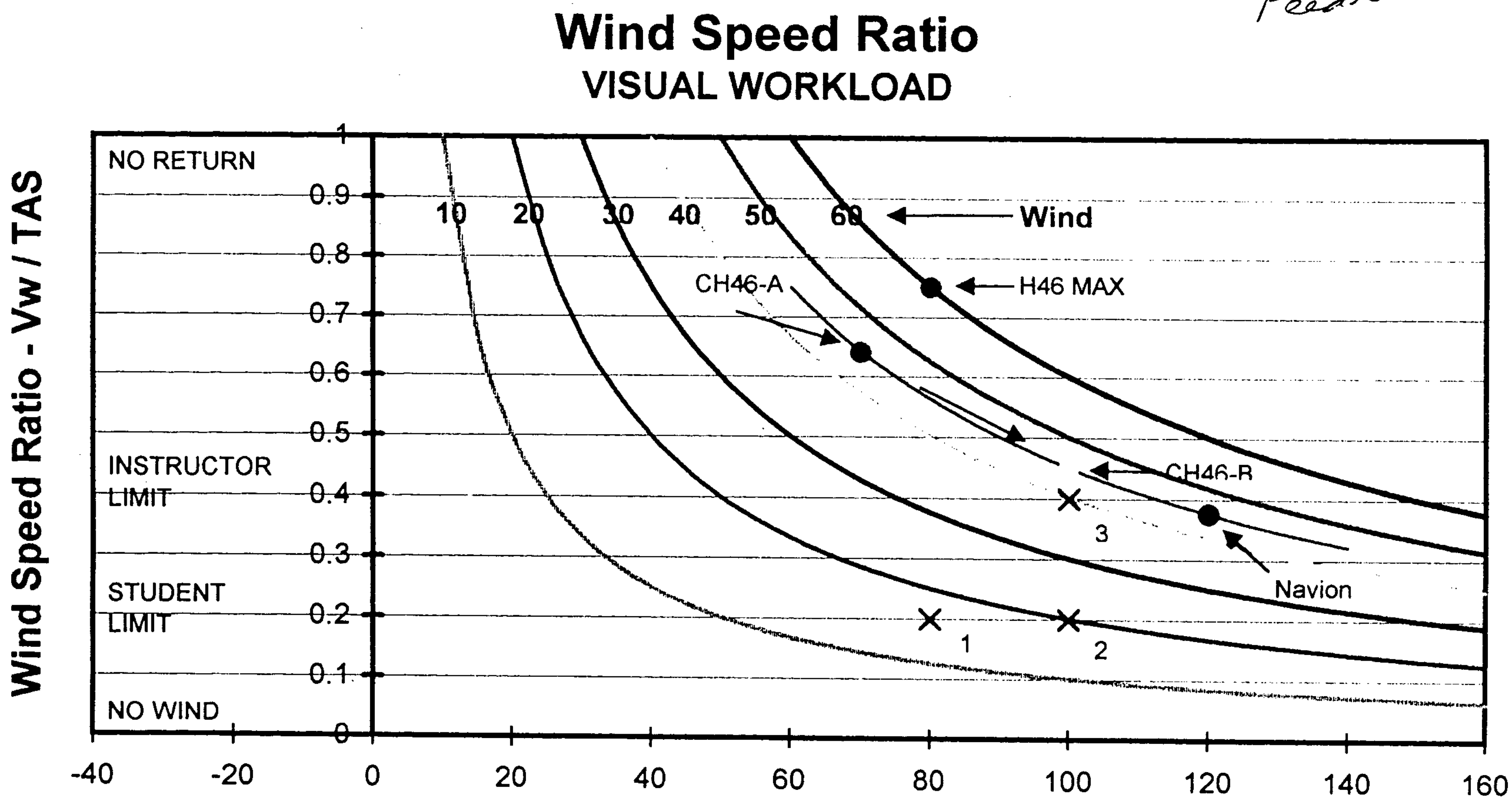


FIGURE 1

Trimmed Airspeed - TAS (same units as wind)

Fig
1B
Accident
Data.

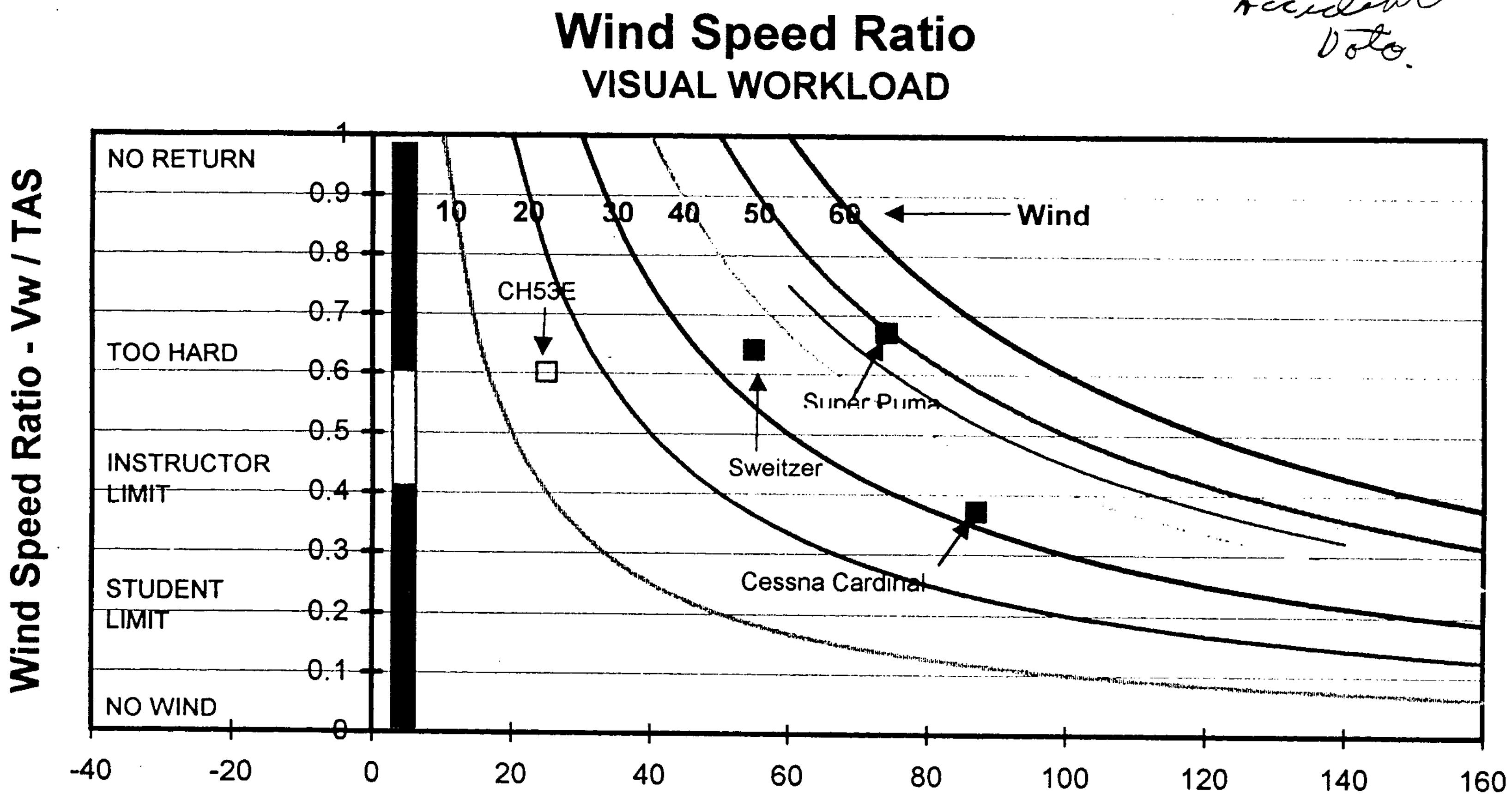


FIGURE 1

Airspeed - TAS (same units as wind)

Fig 1C
Why Airline
Pilots can't
Relate

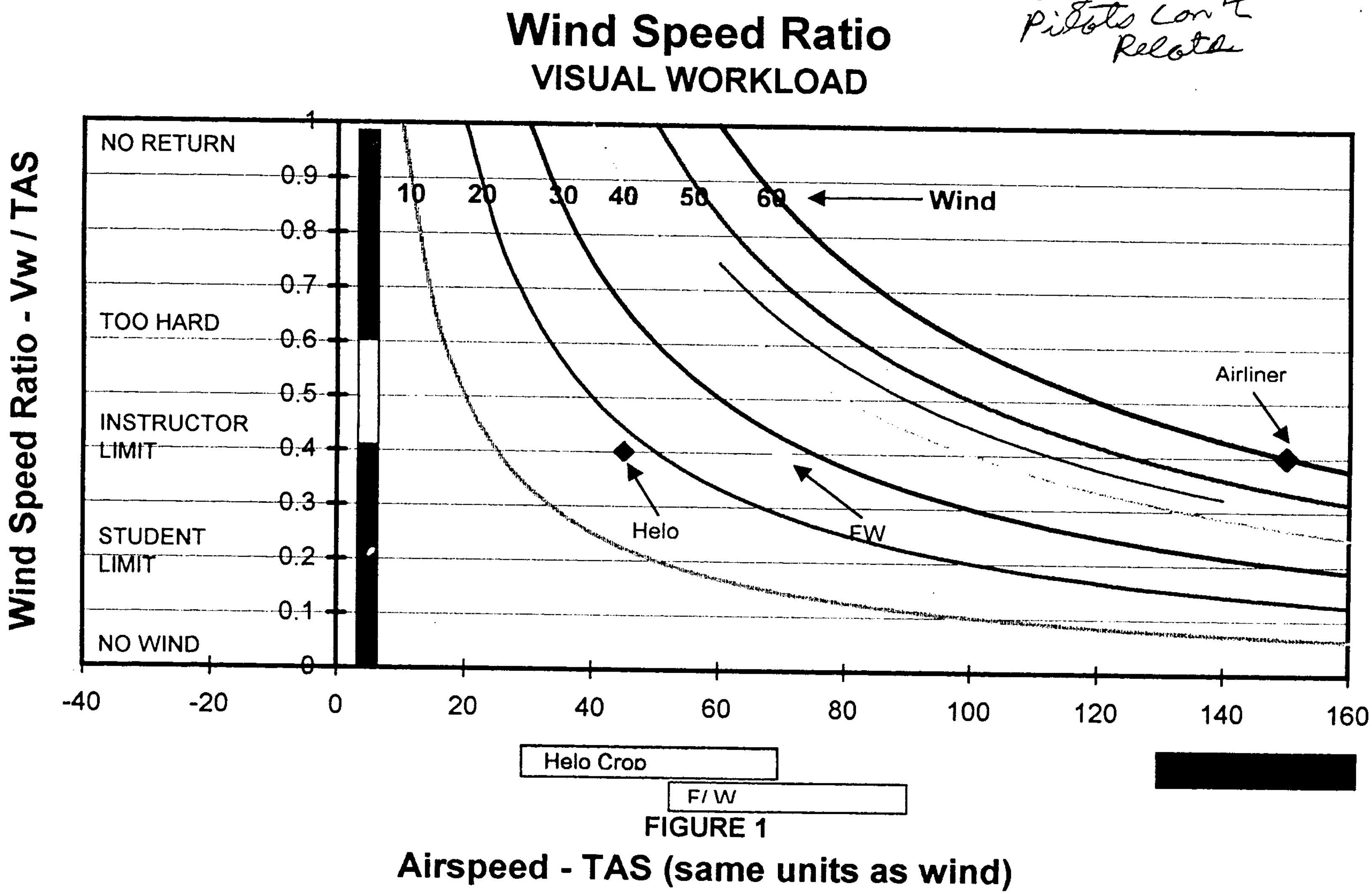


FIGURE 1

Fig 3 ?
Track Angle

Figure 2

Ground-Track Angle with WSR

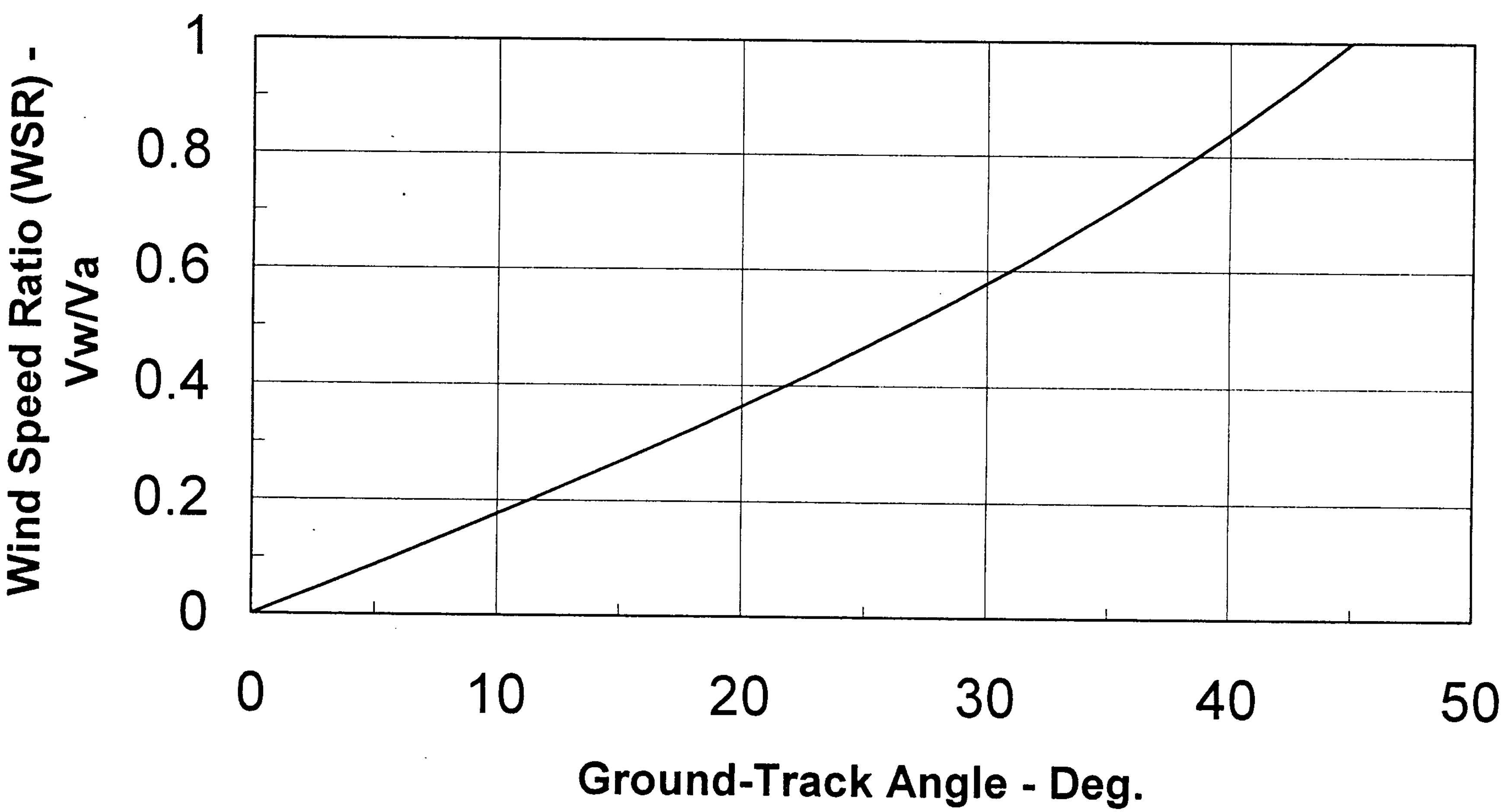
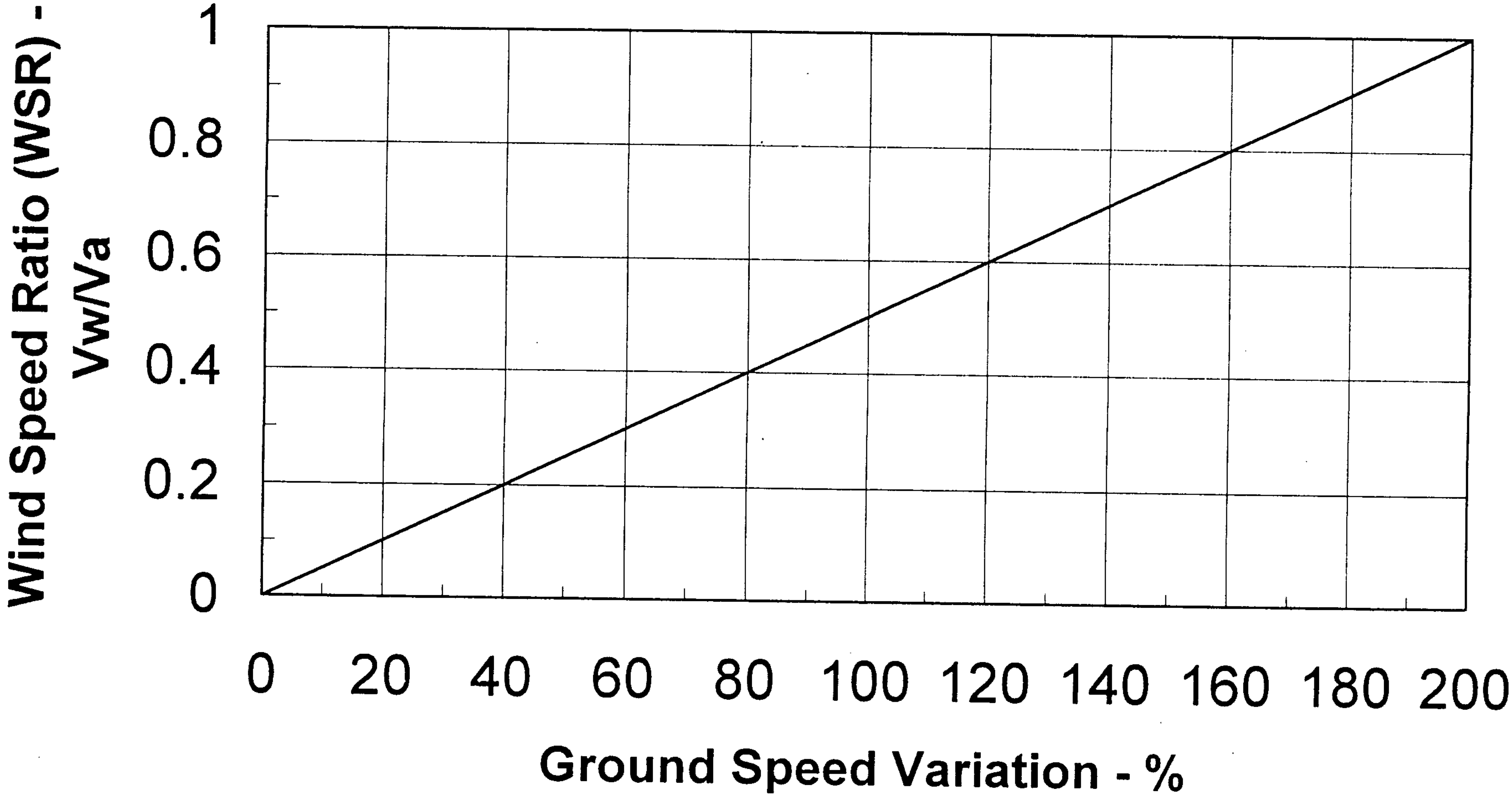


Fig 2 ?
Speed Variation

Figure 3

Ground Speed Variation with WSR



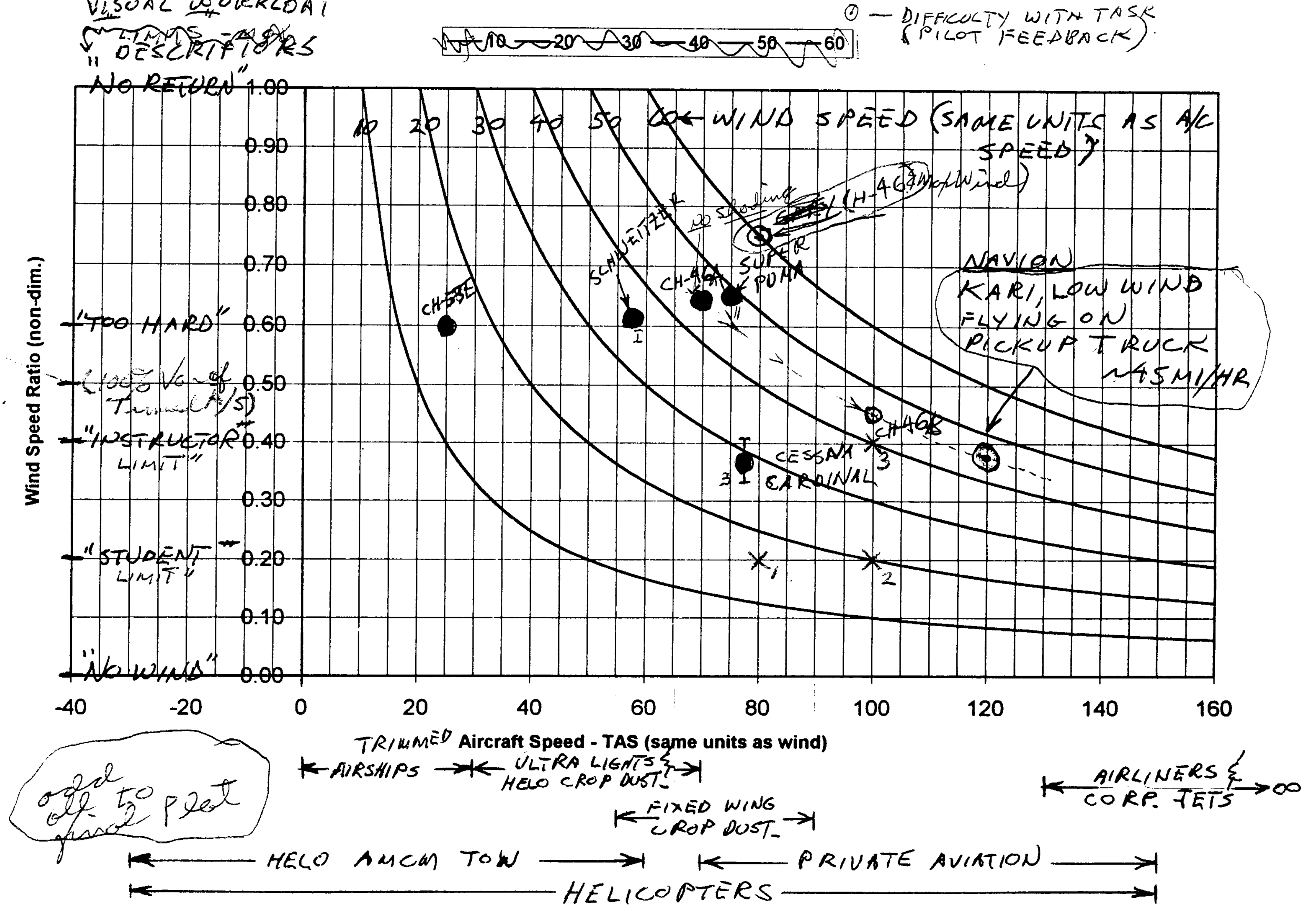
“Data Points”

FIGURE 1

© [illegible] ~~1999~~ 2000

VISUAL WORKLOAD

WIND SPEED CHART



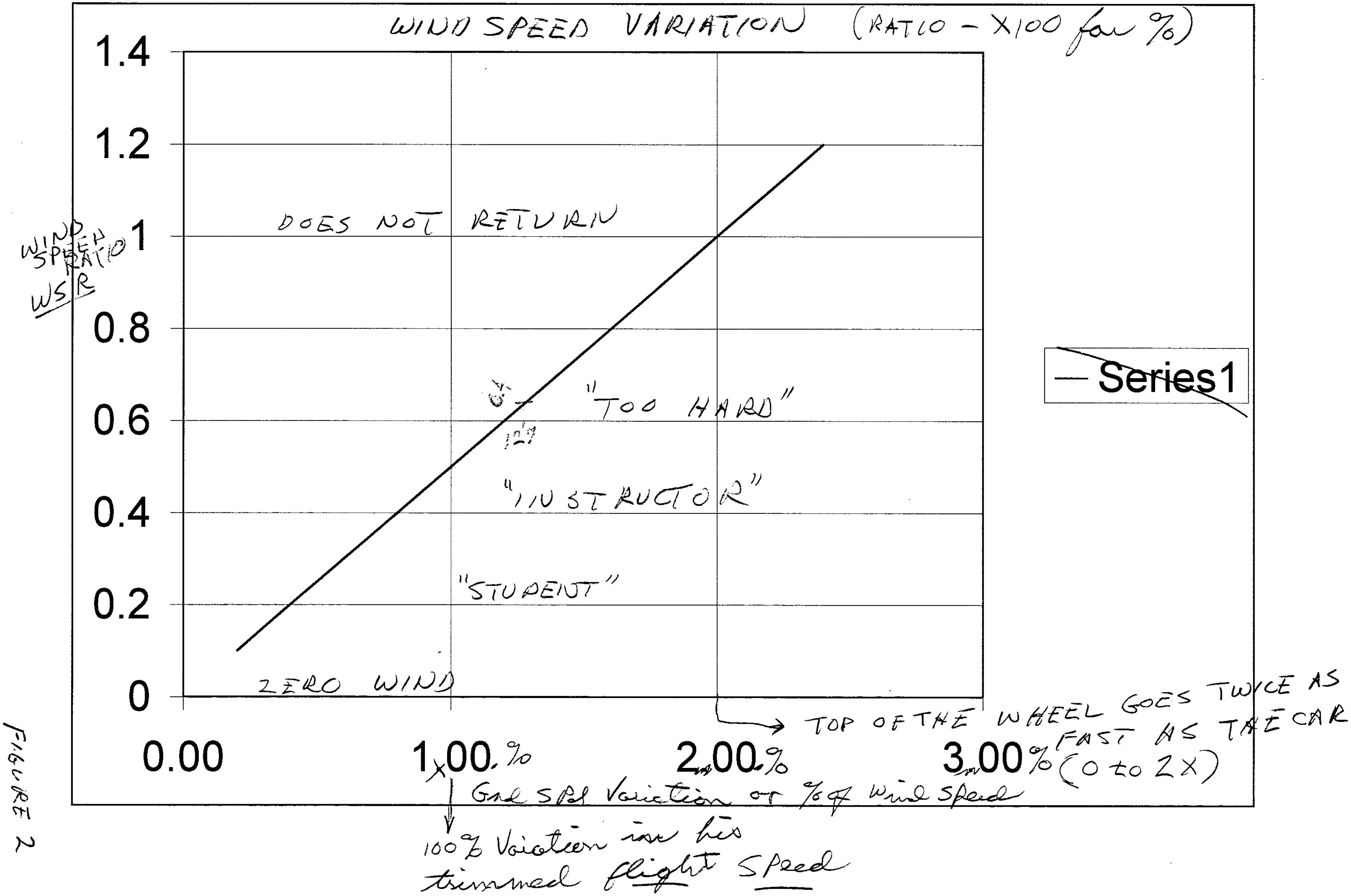

WIND SPEED VARIATION (RATIO - X100 for %)
WIND SPEED RATIO
WSR
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00
1.00 %
2.00 %
3.00 %
DOES NOT RETURN
"TOO HARD"
64
"INSTRUCTOR"
"STUDENT"
ZERO WIND
Series1
TOP OF THE WHEEL GOES TWICE AS FAST AS THE CAR (0 to 2X)
Gnd Spd Variation or % of Wind Speed
100% Variation in his trimmed flight speed

FIGURE 2

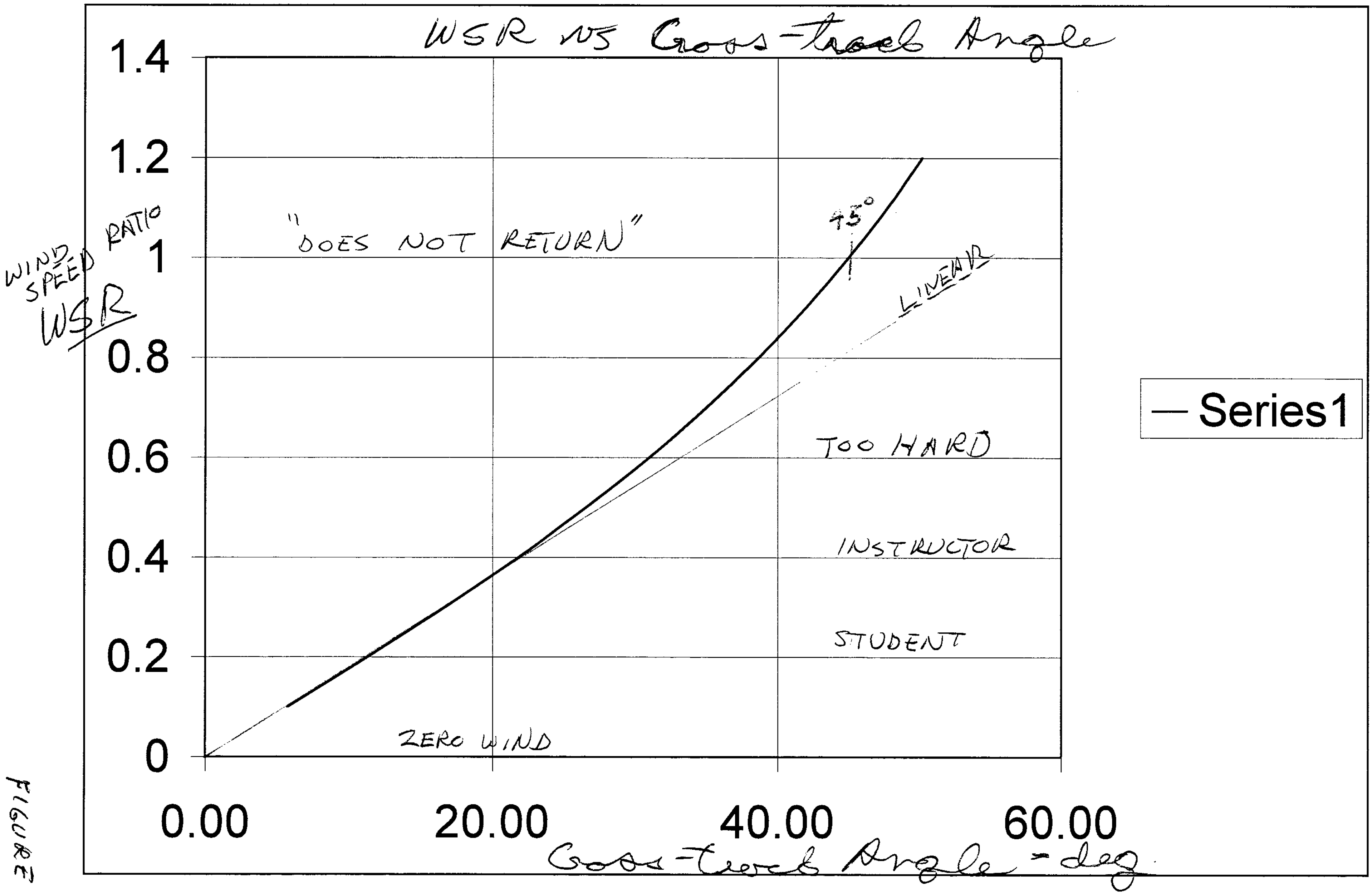

WSR vs Cross-track Angle
WIND SPEED RATIO
WSR
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00
20.00
40.00
60.00
Cross-track Angle - deg.
"DOES NOT RETURN"
45°
LINEAR
TOO HARD
INSTRUCTOR
STUDENT
ZERO WIND
Series1

FIGURE 3

SUMMARY OF E-MAIL MESSAGES REGARDING LT. VARNES EXPERIENCE DURING GULF PICKUP TURNING DOWNWIND.

(NOTE: Text in Lt. Varnes words except italics and underline. Kolwey's words added/changed in Italics, and underlining for emphasis.)

From: Lt. Dave Varnes
Sent: July 28, 1999
To: Herman Kolwey
Subject: Turning Downwind

Mr. Kolwey,

I recall during a rescue we were involved with in the Gulf, the winds were 45 kts + and the ship *that was* in trouble had lost steerageway. Flying at 70 kts in a racetrack pattern to conserve fuel (As we waited to see if the crew was going to abandon ship) was more difficult than it should seem, particularly when we were trying to maintain a relatively close distance to the distressed ship (Within about a mile and a half). Into the wind at 70 kts no problem, low torque and with, I guess, about 20-25kts ground speed, which meant we weren't getting anywhere in a hurry. Of course, <u>turning downwind</u> was a whole different story. Immediately the back end (CH-46) would get kicked around, the torque would shoot up from our collective application and the airspeed would drop to as low as 20 kts, sometimes lower. When we were fresh with fuel we reached a settling with power situation *and* our Nr would slowly start to bleed off -- pretty scary for just going downwind (We did this racetrack for a couple of hours). I did not anticipate this very well at first and so the worst effects happened on those first few turns downwind. At this point it was my wish to fly needle, ball and airspeed, to keep the helicopter from falling out of the sky. That tremendously skewed our pattern to the point *that* we were almost spending several minutes flying upwind just to get back to the Ship. We adjusted our pattern to fly further upwind past the ship, increase speed to almost 100 kts just <u>prior to turning downwind</u> so we would not lose so much airspeed. This also meant that we spent less than a minute flying downwind so as not to distance ourselves too far from the ship. *This was a* battle between the need to stay within the aircraft's capabilities and to be fixed on the sea/ship so as not to be far from the distressed vessel. Never have I experienced a situation

ENCLOSURE II

quite like that. *It was* one that I will not soon forget. This also started to cause us problems during the actual rescue when we had to approach the ship in a manner so that we could maintain visual reference with the superstructure. As the ship lost steerageway, this caused us to approach the ship not always directly in the wind. *The* same situation applied, once we were in the hover affecting a rescue. The ship would turn and we would need to turn with it in order t keep it in sight. A challenge indeed. We were lucky *that* this was in broad daylight with fairly clear skies. Just freak wind and sea conditions. Anyway, thought you might want to hear another story. By the way we successfully rescued all 12 aboard, hoisting the captain up as the ship sank below us.

Take care,
Dave

From: Herman Kolwey
Sent: August 02, 1999
To: Dave Varnes

Dave,
Congratulations on the rescue. Most pilots, unless they have had to "fight the wind" at some time and fly in a visual environment won't realize how difficult it can be. That's the problem of the crop dusters *are having getting their message out.*

I didn't understand, from your description, if you over flew the ship and then did a racetrack pattern to the side, or if you flew up one side and did a racetrack offset on the other or which way the turn was. Also, you didn't say how far you were from your ship or shore. How much fuel did have when you landed?

Regards, Herman Kolwey

From: David Varnes
Sent: August 02, 1999
To: Herman Kolwey

Mr. Kolwey,
To answer a few of your questions; First we were orbiting the vessel with a racetrack pattern with it essentially being the center. It was a turn to the right, and we were about 50 miles or so from *the* shore *of* Bahrain. I don't remember exactly how much fuel we had when we landed, but our ship was less than a mile from the vessel in distress. We were concerned about fuel, even though our ship was close by, because of the unknown element: specifically, how much danger they were in. We didn't want to be stuck on our ship refueling when it hit the fan. Basically, they requested our presence (orbiting) and didn't want us to leave. I don't think they knew how much time they had left on the ship or how quickly they were going to abandon. We took off all but 4 fairly soon after the situation started. The 4 wanted to stay on *board* to see if they could save the ship. We ended up taking one more off, an older gentleman, and told the Captain that we were going to bring him to our ship since he was fading in and out. The Captain emphatically requested us to stay with his ship. Less than a few minutes later he started screaming that the hatch blew and before we knew it we had three in the water with most of the ship's cargo. We were on scene for

about 3 hours. Our other det*achment* helicopter, which had picked *up* a few early on when they first started abandoning the ship, *had* shut down for maintenance. They fired back up when the Captain started screaming on the radio. They launched but, by the time they got off the deck, we were already picking up the last guy.

Hope that answers your questions.

LCDR David J. Varnes

From: Herman Kolwey
Sent: October 12, 1999
To: David Varnes

Dave,
Please give me a phone call when you have time. I need to ask you some questions about your Gulf pickup. What I am looking for is a statement about "how hard you were working on the task", first - at the 70 Kt airspeed, and second - after working out the 70/100 Kt airspeed procedure and turning downwind condition. Any word descriptors about your workload will do. Your gulf pickup input is very important because you solved the "wind problem".
Herman Kolwey

(Phone calls feedback: my interpretation of his words)

Lt. Varnes

Obviously, I could not do it initially, but after working out the 70/100 Kt. airspeed variation procedure prior to turning downwind it was a procedure that was difficult to do in day VFR. It was a definite challenge and I probably could not have done it at night.

From: Dave Varnes
Sent: October 13, 1999
To: Herman Kolwey

Mr. Kolwey,

I was reminded of something while we talked on the phone today. I also believe *that* we tried to orient our racetrack so that the long axis was perpendicular to the wind, in order not to fly "downwind" so long. I know we tried that, but also had to make similar corrections for our turns, as we would naturally turn into or out of the wind to get to the heading for our long crosswind leg. The same corrections would apply to this type of turn as well in order to maintain the same relative pattern around the boat.

Lt. Varnes

SUMMARY OF E-MAIL MESSAGES REGARDING KARI SEPPANEN EXPERIENCE FLYING TURNS ABOUT A PICKUP TRUCK IN LOW WINDS

(NOTE: Text in Kari's words except italics and underline. Kolwey's words added/changed in Italics, and underlining for emphasis)

Herman,

*D*uring training for my commercial rating, I got bored doing repeated turns around a point with *the* Very light winds. I convinced my *flight* instructor that I could simulate higher winds by doing my turns around a truck travelling down a straight country road. It worked great but she worried about finding the same truck on the day of my check ride.

Cheers,
Kari J. Seppanen
Flight Test Engineering Analysis
Aerodynamic Performance Group

Kari,

In the downwind turn problem, I think two things are at work: 1. Visual perception of changes in airspeed (or ground speed if you are flying "needle/ball/airspeed"), and 2. Changes in the ground track angle. The paper presents the proper ground track for a don't-look-at-the-ground level turn.

Your use of a truck as a reference works to *either* enhance or eliminate the wind problem. If the truck is going downwind at wind speed that's the same as a no-wind day. Did you pick a truck at random and did you know how fast he was going?

V/R Herman Kolwey

Herman,

Good point about the truck working both ways. However, the winds were pretty light, which is why the normal turns around a point exercise wasn't very challenging. The truck was picked pretty much at random, not a very busy road. I would guess based on the road in question that

ENCLOSURE III

the truck might have been going about 40 to 50 mph, much faster than any tailwind. I was flying my Bonanza so my AWR was still reasonable and I could maintain a fairly constant radius of turn. That's three possible reference frames instead of the usual two.

Kari J. Seppanen

Kari,

I have some more questions for you.
1. Are you familiar with *the* Cooper-Harper *pilot workload rating scale*? If yes give me a number for what you remember of the exercise with the truck. If not, give me some words that describe how hard it was.
2. What was your experience level?
3. Could the instructor handle more truck speed? (Your judgement call)
4. What was the trimmed airspeed of your Bonanza (TAS)?

This may sound like 20 questions, but there is a method to my madness here and I will eventually send you a plot that shows you where I am going. One more thing. I have re-thought my definition of the turn about a point on the ground. New one is as follows: Pilot is incrementally varying the bank angle in a level turn so that the radius of turn segment that he is flying in the air mass matches a circle on the ground (or with respect to the truck).

V/R Herman Kolwey

Herman,

*H*ere are the answers to your questions. I haven't used Cooper-Harper for a while so I don't remember the descriptions corresponding to the numbers. It was very controllable and after a couple of turns was fairly smooth. An added advantage is since the actual wind was light there wasn't as much turbulence as there would be with real winds. I didn't need any power changes to maintain altitude. I think I was probably using my IFR approach power setting, which would give about 120 mph. I had about 1200 hr total and over 200 in this Bonanza. Margo didn't try to see if she could do any better.

More later,
Kari J. Seppanen

Kari,

Now there you go, I found the problem. If you are flying in the air mass, it is defined by the weather balloon you release and track and get its velocity with respect to the ground. Or for visibility use a Hot-Air Balloon (Re/Max). But if you are flying with respect to the Truck, put a guy in the back with an anemometer, call it the Pace Vehicle and "wind speed", XXX throw that away - use "velocity", is 40 or 50 MPH (adjust it for the days *low* wind). That converts to about 35 or 43.5 Knots respectively in our "Navy" lingo, so that the "wind" to be accounted for in the "pickup axis" is really about 45 MPH. That is what the guy holding the anemometer in the back feels and it's real in that frame of reference. You created a simulation and worked the problem but didn't transfer the correct "relative Wind" to the pickup truck. This *relative wind* is exactly how the Navy handles winds with respect to carriers landing fixed wing aircraft and destroyers landing helos.

Regards, Herman Kolwey

(Fax sent. Kari asked if he could have done the turns about the truck at night.)

Herman,

Thanks for your latest fax. I've never tried turns around a point at night so I'm not sure how well they would work. The available visual cues would be a factor, well-lighted city pattern versus a ship in the middle of nowhere.

Regards,

Kari Seppanen

Kari,

I will send you a package including the 1991 SFTE paper and some of the *crop-duster* responses if you send me your mailing address. Let me know also if there are any other references *from the paper* that you want. One of the references is a response (with commentary by Dr. J. Barlow at Univ. of Md.) that appeared in the AOPA Pilot Forum (AOPA Pilot - May 86 - ref G in the paper). My opinion is that, in general, academia doesn't have a clue.

Another thing. I talked, just today, to a CH-46 pilot now a FT Engineer for Boeing here at Pax. with the V-22. He said that when he was in Alaska with 60 Kt. winds when he turned downwind he slowed down. He did a test by trimming the aircraft *automatic flight control system (AFCS)* to fly at airspeed and then flew the turns with the "beeper-trim" *(trimming the AFCS in roll)*. If he flew it that way he maintained airspeed. If he tried to fly it manually he was biased towards ground speed, even by his peripheral vision of the outside world.

Regards,
Herman Kolwey

Herman,

I've read all of the material you recently sent me. It's very interesting to see some of the "arguments" people make. Unfortunately someone else has "discovered" the key to my "unified" theory, so I'm turning over my ace in the hole. It is buried in Reference G (The Downwind Turn Revisited, by Barlow) but <u>may have gotten lost to many people amongst all of the other pseudo-science from other readers</u>. Dr. Lawton, in the last letter, very clearly explains the increase in kinetic energy in the earth reference. *He does so* by pointing out that the tilted lift vector (which is perpendicular to airspeed and does <u>no</u> work in the air mass reference) has a component parallel to the ground speed vector which <u>does do some work</u>. This is what drives the acceleration in ground speed and the increase in kinetic energy. I reached this same conclusion in the early '80's while trying to understand some anomalies in our energy height methods at Boeing. If you integrate this force over the turn, the energy "bookkeeping" works out just right. I didn't think it worthwhile to do anything at the time about revealing it to the world. This article is the first time I've seen anything in print on this simple concept. I'm surprised that the controversy still continues. The issues of speed management, sideslip and other control issues caused by the illusions still remain as big a problem as ever.

Kari Seppanen

III

ENCLOSURE IV

SUMMARY OF DISCUSSION WITH GARY KLEIN ABOUT 60 KT WIND EXPERIENCE IN THE ALEUTIANS

Data point labeled "Gary" is a CH-46 pilot flying up in the Aleutians, flying in the area of the ship, with 60 Kt. Winds. He found out that, while flying at about 80 knots, when he turned downwind he slowed down and when he turned into the wind he would speed up. Having the time and not an immediate visual ground-based task to perform he decided that: A) he SHOULD be able to fly "needle-ball-airspeed", and B) he would experiment with the problem. What he found was that the visual outside the cockpit cues (groundspeed) were so strong that in spite of his effort to maintain airspeed on the gauges he had difficulty with it. He solved the problem by letting the Automatic Flight Control System (AFCS) control his airspeed and flying flight path corrections using the trim feature of the AFCS. Only in this manner was he able to maintain "needle-ball-airspeed" in this situation. This is the highest WSR that I have gotten feedback on at 0.75 and his visual cues were so strong that, even though he was not flying to a specific point on the ground he had to rely on the AFCS to control his airspeed.