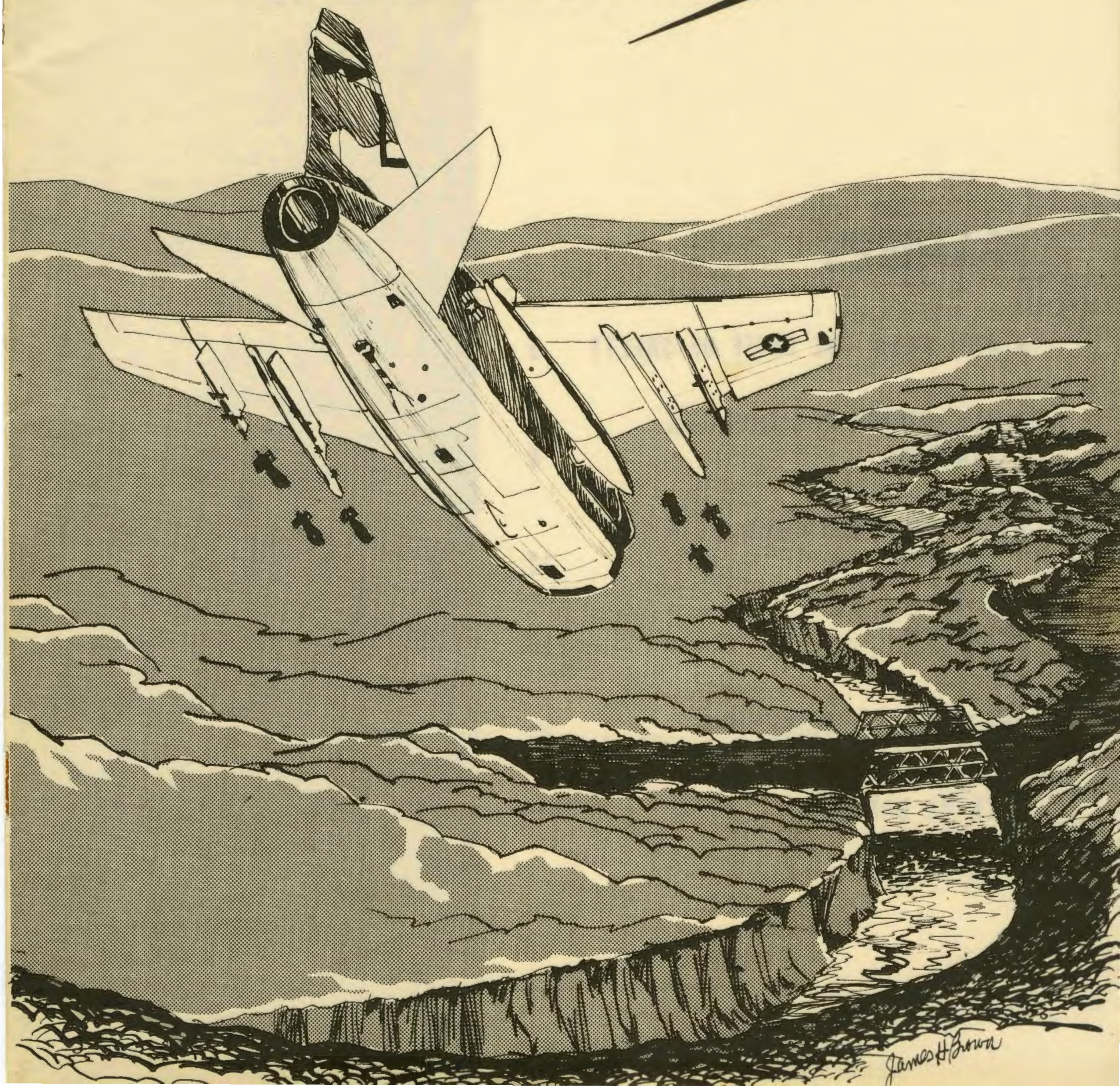
GROUND ATTACK

SPECIAL EDITION



SPECIAL EDITION

GROUND ATTACK

FEATURES

A NOTE FROM THE CHIEF OF SAFETY

During 1976, nine major aircraft accidents occurred during air-to-ground missions which were caused by aircrew error. Nine aircraft were destroyed and eleven TAC aircrewmen lost their lives. This special edition is the first of two covering aspects of ground attack missions. It is published with a specific goal in mind ... to help prevent future accidents during air-to-ground missions.

This issue contains selected articles on air-to-ground delivery reprinted from recent USAF FIGHTER WEAPONS REVIEW and TAC ATTACK magazines. A follow-on issue will contain new articles on air-to-ground delivery techniques written by our highest qualified people throughout the command. It is my hope that these articles will help you ... the fighter pilots and fighter 'gators ... do your job more effectively and efficiently. The only acceptable way to stop ground attack accidents is to make sure every TAC aircrew member knows "how to do it."

George M. Sauls

GEORGE M. SAULS, Colonel, USAF
Chief of Safety

INITIAL PIPPER POSITION AND

By: Captain Alexander H. C. Harwick
32nd Tactical Fighter Squadron
Squadron Weapons Officer

EDITOR'S NOTE: Readers of the Fighter Weapons Review have expressed considerable interest in the manual aspects of dive bombing. The following article covers manual bombing techniques with a fixed depressed sight. Captain Harwick presents possibly the most complete treatment yet of the subject in this article. The techniques discussed can easily be adapted to any tactical squadron's weapons program.

One of the most overlooked, yet most important aspects of manual dive deliveries, is initial pipper placement. There is a very simple and effective method to use pipper position and known tracking points to improve one's scores on a training range and one's bomb damage assessment in combat. In order to demonstrate this technique, a thorough understanding of the fixed sight and "tracking" is essential. It is hoped that a discussion of basics will not insult any fighter pilot egos. For the purpose of this basic discussion, wind will initially be ignored. The initial pipper method can also compensate for wind, which will be discussed later in this article.

In spite of advancing technology, which has produced automatic release systems and terminally guided munitions, modern day fighter pilots must understand how to, and be able to, deliver accurate iron bombs, using a fixed sight. With *desire, an average mind, intense study,* and *adequate practice,* it is relatively easy to drop good bombs.

The manual sight is a simple and reliable device which can be used to drop ordnance much more accurately than it is given credit for. It, like the "dash 34" figures and data, is designed to be used in wings level (no roll) flight. In dive deliveries, it is assumed that the pilot will be able to fly at a "G" loading equal to the cosine of his dive angle. While it is possible to compensate for, and to drop in a bank accurately, "G" is critical. In spite of some popular notions to the contrary, "G" affects what the sight tells you and not the bomb trajectory. A pure mathematical discussion might show a foot or so of bomb range difference; however, it is insignificant unless your CEA happens to be expressed in single figures, in which case you're releasing at the proper "G" loading already.

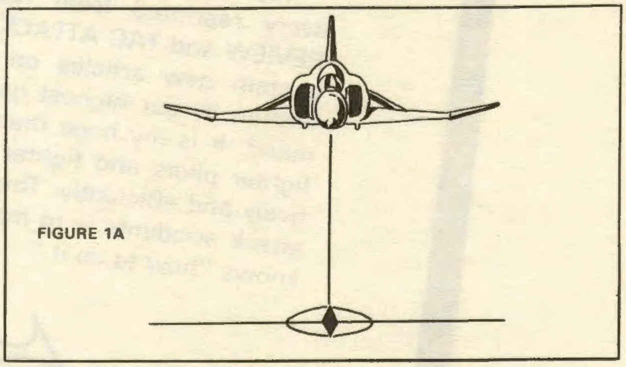


FIGURE 1A

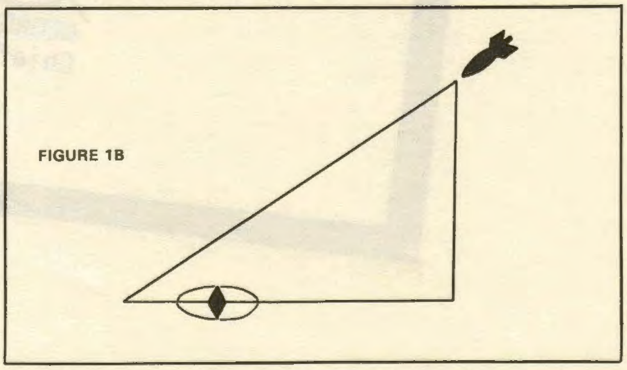
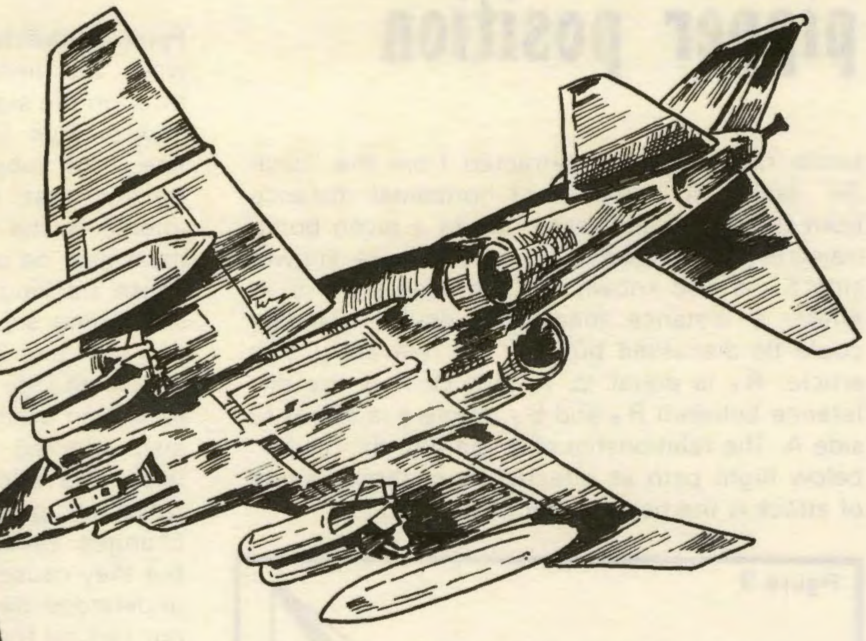
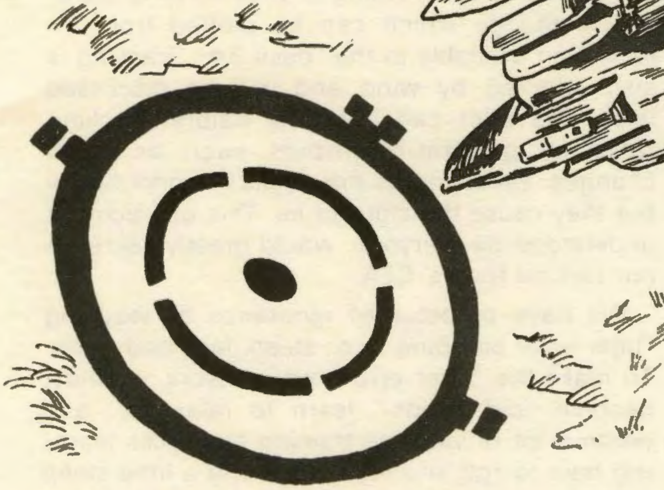


FIGURE 1B

TRACKING





Let us assume that the pilot will deliver ordnance in a dive and fly his aircraft in a plane perpendicular (no roll) to the earth's surface (Figures 1a and 1b). The angle between sides P and R is the flight path angle or dive angle Θ. P is the path the aircraft would describe if it flew a constant "G" loading equal to the cosine of Θ from roll in to impact with the ground. It should be realized that for all cases other than a "zero time of flight projectile" or for ordnance boresighted above side P, the aircraft impact point is beyond the target regardless of wind. This is due to our friend gravity, air resistance, or projectile drag, and ejection forces that provide separation. These variables determine or define a fixed bomb range which is the basis for all ballistic data presented in the tables in the "dash 34." As fighter pilots we are vitally interested in the mils depression below flight path data. This data is really nothing more than an angular solution of a triangle defined by bomb range, release altitude, and dive angle. With the pipper on the release aimpoint, somewhere below side P, except as theoretically noted above, and all parameters met, one should rightfully expect a bullseye. Let us assume angle of attack, α, has been solved for the time being. At release then let us examine Figure 2.

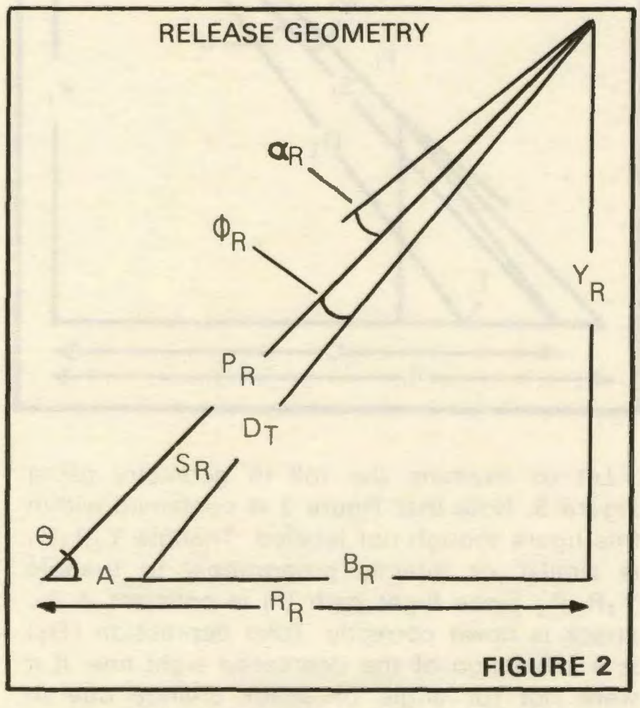


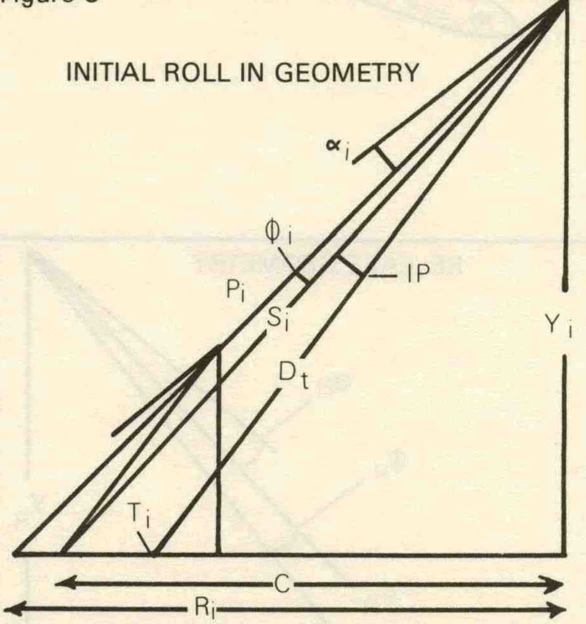
FIGURE 2

Side S_r is a projection of the sight line from the aircraft to the target. S_r equals or coincides with the total depression for any given trajectory at release. Side Y_r is the release altitude. B_r or

initial pipper position

bomb range may be extracted from the "dash 34" tables. It is the exact horizontal distance from the target at release due to a given bomb trajectory. Since sides Y_r and B_r are known, side S_r is also known and the fixed sight is, in effect, a distance measuring device. Parallax could be discussed but it is not relevant to this article. R_r is equal to $Y_r \cot \Theta$. A is the difference between R_r and B_r. Angle ϕ is opposite side A. The relationship of angle ϕ to depression below flight path as effected by changing angle of attack is the basis of our discussion.

Figure 3



Let us examine the roll in geometry using Figure 3. Note that Figure 2 is contained within this figure though not labeled. Triangle $Y_iR_iP_i$ is similar or directly proportional to triangle $Y_rR_rP_r$ since flight path (P) is constant if the attack is flown correctly. Total depression (D_t) is a projection of the depressed sight line. If it were not for angle of attack change due to increasing airspeed in the dive, S_i would be parallel to S_r. As altitude (Y) decreases the projection of D_t, the extended sight line, tends to move toward the target. This phenomenon is known as tracking. The point the pipper intersects the horizontal plane is annotated by T. Point T_i defines point T at roll in. Side S is always the line of sight from the pilot's eye through the sight to the target which is being attacked. Side S_i defines side S at roll in. This line is the subject of this article. It should be apparent that the position where this line intersects the fixed sight can be calculated. It must also be understood that the pilot does not cause tracking; rather, tracking is the result of shortening side Y from condition Y_i (Figure 3) to Y_r (Figure 2). Tracking is affected by angle of attack change which can be plotted from information available in the "dash 34." Tracking is also affected by wind and will be discussed later. The pilot can alter the natural tracking rates by generating inputs such as pitch changes. These inputs may make the pilot happy but they cause the sight to lie. This one point, if understood by everyone, would greatly decrease our tactical forces' CEA.

We have perpetuated ignorance by teaching "tiger error bombing," i.e., steep, fast, and press. To make the "tiger error" system work, we must become "old heads," learn to relax "G," and waste a lot of valuable training resources learning how to roll in a little close and a little steep with the pipper shorter than it should be so we can "track," i.e., pull the pipper up, then unload to the proper "G," and pickle. This whole process is wrong, but we can then spend great effort debriefing so we can learn how to fudge the whole pass to make it finally look right. The "G" releasing routine gets great emphasis in some circles but at this point it should be apparent that the only thing accomplished is a happy crew. Eventually we even get pretty good at the "tiger error" system as unit bomb records portray. Why not fly a constant dive angle, constant release "G," and do it the easy way?

Let us return to sides S and D_t. On a practice range with concentric circles, we can put the pipper a certain distance short at position T or T_i at roll in. In combat, judging this **exact** distance or point is a bit more difficult without a thorough knowledge of the fixed sight. Initial pipper position techniques will work on all fixed sights. For the purpose of this discussion, let's use the F-4 sight for illustration.

The F-4 sight has a pipper 2 mils in diameter, an outside reticle radius of 25 mils, 12½ mil indexes, and tabs at the top 6 mils above the top of the reticle or 31 mils above the pipper center (Figure 4).

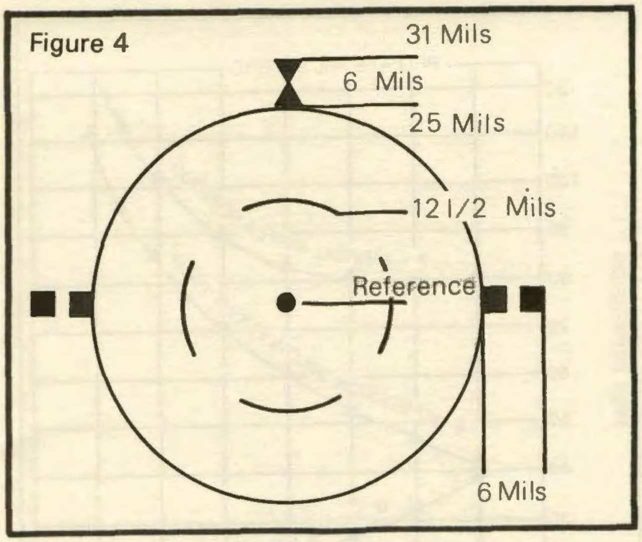


Figure 4

It should be realized that an infinite number of sight settings are available in both the vertical and the horizontal axes of the sight. Let us look at the vertical axis initially in a no wind condition and compute the initial pipper position at roll in under a given set of conditions. Assume you are flying an F-4E weighing 40,000 pounds and you are planning to release a BDU-33A/B from a SUU-21/A dispenser in a 45° dive at 440 knots TAS and 4000 feet AGL. The target elevation is sea level and the surface temperature is 10°C. The roll in point is planned for 300 KCAS at 10,000 feet AGL.

The steps required to compute the initial pipper position at roll in are as follows:

1. R_r

Range from dive angle vs distance chart using selected dive angle and release altitude or using the formula $R_r = Y_r \cot \Theta$ where Y_r is release altitude and Θ is dive angle.

2. B_r

Bomb range from ballistic table using selected release parameters.

3. $A = R_r - B_r$

4. R_i

Range from dive angle vs distance chart using selected dive angle and initial altitude or computed using the formula $R_i = Y_i \cot \Theta$ where Y_i is initial altitude and Θ is dive angle.

5. $C = R_i - A$

6. ϕ

Mil depression angle to target from altitude using slight depression chart for the selected dive angle, altitude, and range C. Mil depression may be computed using the formula:

$$\phi = [\tan^{-1}(\frac{Y}{C}) - \Theta]\ 17.45$$

$\tan^{-1}(\frac{Y}{C})$ means the angle whose tangent is equal to Y divided by C. To compute ϕ_i, use Y_i and C_i.

7. α

Angle of attack from the angle of attack chart for the selected airspeed, gross weight, and dive angle.

8. $\phi + \alpha$

Sight setting at given altitude with pipper on the target. For the initial pipper position solve the above equations using initial parameters.

9. $IP = (\phi + \alpha) - D_t$

Initial pipper position for parameters as related to mil setting or total depression.

For the given example the solutions are:

R_r = 4,000 feet,
B_r = 3,202 feet,
A = 798 feet,
R_i = 10,000 feet,
C = 9,202 feet,
ϕ_i = 41 mils,
$_i$ = 39 mils,
$\phi_i + \alpha_i$ = 80 mils, and
IP = -45 mils.

It has previously been noted that there are an infinite number of sight settings in the vertical. Since we do not possess a second adjustable pipper, let us use our knowledge of various indices to good advantage. The actual release setting required under the given conditions is 125 mils and is set into the depression window. The initial depression required for pipper on the target is 80 mils, which is 45 mils above the

initial pipper position

release setting. At roll in with our example F-4E, if "G" is equal to .707 and if in no bank flight, the target should be 20 mils above the reticle. The pipper will "track" of its own accord from that point to the target at release. Or, conversely, the target will move from the initial position 20 mils above the reticle to the pipper.

From flight tests it can be shown that at idle power in the normal delivery airspeed range for dive bombing, the F-4 will accelerate at an almost constant increment under stabilized dive conditions. In a 45° dive at a normal release parameters the F-4 accelerates 20-25 knots calibrated airspeed per thousand feet of altitude loss. The actual rate is a function of temperature and pressure. As a result, the angle of attack change is relatively constant (Figure 5). The angle of attack change tends to cause the pipper to go to six o'clock or to be slowed. Overall, the tracking rate will tend to accelerate since the airspeed increase results in an increasing vertical velocity and the ratio of the distance between point T and the target to side Y decreases at an accelerated rate until T is at the target or the distance difference equals zero. After that point the difference is negative, an impossible solution for bombing under the planned conditions.

If one graphs initial pipper position in mils at various altitudes in the dive from roll in to release, he will find that there is very little tracking motion during the first three thousand feet of altitude loss or the first half of the dive (Figure 5). Practically, then, it is possible to roll in at the proper airspeed for the given altitude and place the target at a known position and be able to deliver accurately. Figure 6 depicts target motion on the fixed sight during an ideal pass under no wind conditions.

By being able to predict pipper tracking, two things are possible. For example, it is possible to roll in at 8,000 feet AGL at 341 KCAS, put the target at 80 mils or 45 mils above the reticle, the same position as at 10,000 feet and 300 KCAS, retard power to idle, and arrive on schedule at the proper release parameters with the pipper on the aimpoint. "Tracking" time is lost; however, good results can be achieved.

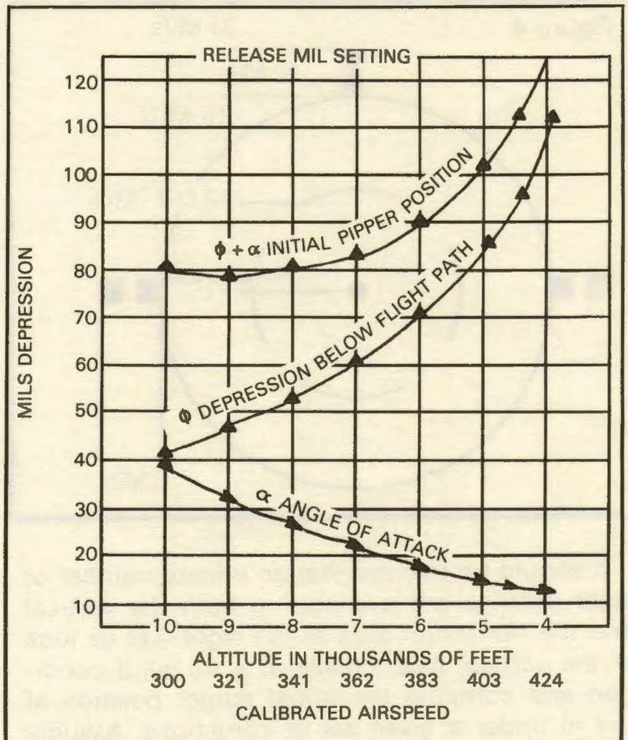


FIGURE 5

This technique can be used in low ceiling conditions to keep dive angle steep. Another application is to minimize "down the chute" time in combat. In certain combat situations one might be higher than planned at roll in. If this occurs, merely use a tight curvalinear approach to keep speed down until you pass through a known altitude/airspeed combination. At that time relax the spiral or jink to achieve the scheduled acceleration and place the target at the correct sight position. Dive angle should not be changed since a properly executed attack profile will be very similar to sliding down the inside of a paper drinking cone.

While the first application allows for other than standard entries, the second provides instant error analysis prior to actual release. This statement is based on several assumptions, and a fighter pilot, as opposed to the pilot of a fighter, can achieve them all. It is assumed that the release altitude can be recognized, that airspeed error can be kept very minimal, and that it is possible to achieve the planned dive angle. If at roll in the target is at 76 mils rather than 80 mils, and all other parameters met, then one must assume at release the target will be at 121 mils with a correspondingly short bomb. In actual fact the aircraft is flying parallel to and

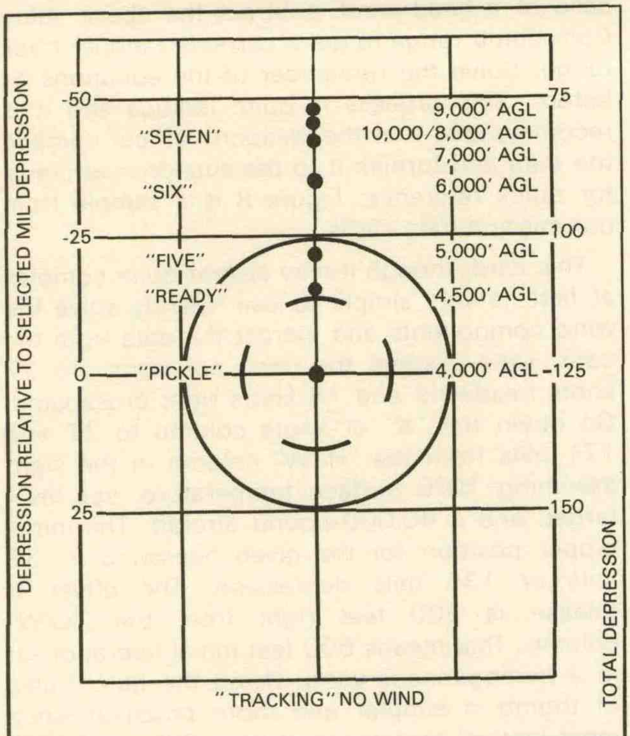


FIGURE 6

below the desired flight path. The exact distance short is the length of the horizontal line cutting the parallel flight paths. This distance is also viewed in mils on the sight as the distance between the known and desired pipper position. If one elected to continue the dive until the pipper was on target, the additional altitude loss would be about 200 feet. Then, under these conditions, the bomb would be long since 125 mils is not the correct setting for the new parameters - lower and slightly faster release. Ideally, the error can be corrected at roll in by floating the roll or by pulling up to the proper flight path, bunting to intersect the path, then flying proper "G" to release. If this is not possible, try not to change dive angle unless a new mil setting is known. Explaining this technique of changing dive angles and mil settings and/or release parameters is complex and will be discussed in a future article. The best technique for small errors is to use half the recognized error, or two mils in this case, and drop when the sight is two mils short. The release will be at approximately 3,900 feet AGL, which still allows adequate recovery altitude. A detailed discussion of this technique requires a lengthy discussion and will be accomplished at a later time.

During the actual pass, monitor the desired position versus actual target position in relation to the sight. Any deviation from the desired or known position will indicate a corresponding impact error. For small errors use half the error for correction. Continually compute a new half the error point by comparing actual with desired pipper position until release.

Let us now turn to the real world of winds and discuss initial pipper placement. It can be shown both mathematically and from flight tests that the time from stabilized roll in to release for all current parameters and deliveries of low drag munitions is very nearly double the projectile time of fall or T_C . This fact is the reason for the adage, "Triple the offset for initial cross wind off set." (This is not true for either short time of flight munitions like rockets or 20mm or for newer high drag items such as Rockeye or most varieties of CBU.) Tripling the offset will work for initial cross wind offset for "traditional" bombs only. Merely triple KR_3 as found in the "dash 34" and multiply the cross wind component by that factor for initial lateral pipper placement in feet. It should be apparent that in a homogeneous wind that double the offset will be required at 7,000 feet AGL for the example used in this article.

The fixed sight also has an infinite number of offsets in the horizontal as depicted in Figure 7.

In a homogeneous wind the lateral pipper drift is relatively slow. This is due to the fact that as slant range decreases, the distance measured by a constant mil setting in the lateral axis decreases. This rate tends to approximate the total wind effect versus time remaining. The difference is related to cross trail. For example, with about 13 knots of left cross wind, one would have a final aim point of 144 feet left for our example BDU-33A/B. This offset would be 25 mils offset or on the 3 o'clock portion of the outer reticle. Initial position at 10,000 feet AGL is 432 feet or 31 mils initial offset at roll in. The total drift is 288 feet but only 6 mils due to decreasing slant range. It should be noted that this drift is linear when plotted versus altitude loss. It can be shown for every 4 mils of lateral offset required at release, that initially 5 mils must be offset at roll in for our example. Other similar relationships can be arrived at for ordnance you may be responsible for if you will take the time to sit down with a paper and pencil and work them out. The example relationship is basically true for standard parameters for

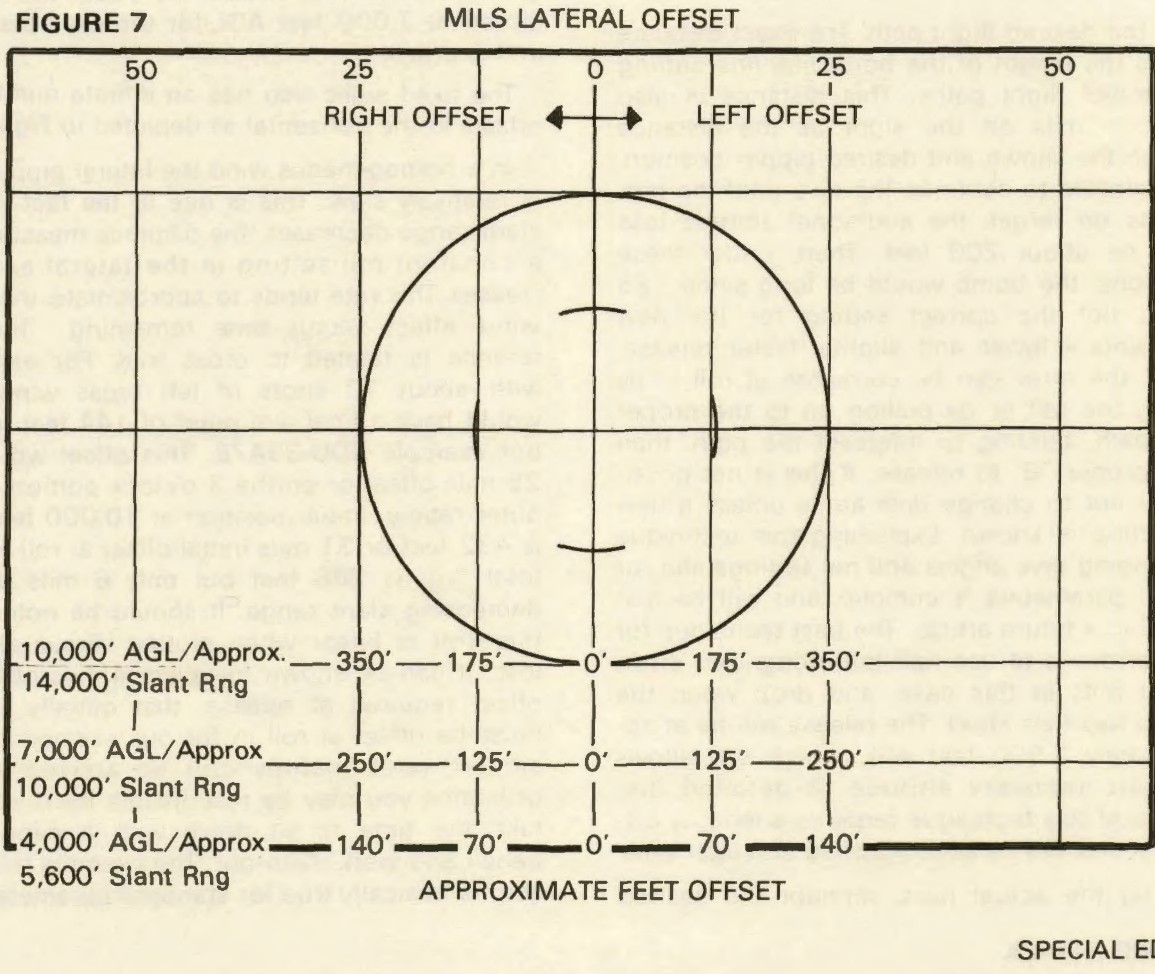
initial pipper position

slick munitions. From the above observations, two easy and almost exact rules of thumb may be stated. *The final offset expressed in mils is equal to twice the cross wind component expressed in knots. The initial lateral offset expressed in mils is equal to 1.25 times the final offset expressed in mils.* These rules of thumb are valid for the example in this article and close for dive bomb parameters in general. It is recommended that you learn to understand the ballistics of any particular munitions and parameters you may be responsible for.

Let us now solve the headwind/tailwind initial pipper placement position. The no wind solution has been discussed. The steps are the same except that during step number two when solving for bomb range, wind must be applied. The wind affects the delivery aircraft from roll in to release and the bomb until impact. Therefore, multiply the head or tail wind component expressed in knots times the total time from roll in to impact - 21 seconds, in our example, times 1.69. In the case of a head wind, subtract the above value from bomb range to get a corrected pipper track range. Solve the remainder of the equations as before. This process is quite tedious and it is recommended that the weapons officer compile the data and furnish it to the squadron aircrews for quick reference. Figure 8 is a sample from our mission data cards.

This card, though it may appear quite complex at first, is very simple to use. Merely solve the wind components and extract the data from the card. Let's assume the wind solutions are 27 knots headwind and 18 knots right cross wind. Go down the "K" or knots column to 27 and 171 mils from the "H/W" column in the sight assuming 10°C surface temperature, sea level target, and a 40,000-pound aircraft. The initial pipper position for the given headwind is -36 mils or 135 mils depression. The offset at release is 200 feet right from the "X/W" column. That means 600 feet initial lateral offset in a homogeneous wing. Using the quick rules of thumb is simpler and more practical since most tactical targets won't have 200- and 600-

FIGURE 7



45° MANUAL DIVE

BDU-33A/B, SUU-21/A, 4,000' RELEASE, 4G in 2 SECONDS 40M GROSS WEIGHT (7M FUEL), 440 KTAS, STANDARD DAY

CORRECTIONS: ADD .7 MIL/1M WEIGHT, ADD 1 MIL/10° C

SURFACE TEMP	-10° C	0° C	10° C	20° C	30° C
RELEASE TEMP	-20° C	-10° C	0° C	10° C	20° C
BASIC MILS*	123	124	125	126	127
RELEASE KCAS	442	433	424	416	408

*FOR EACH 1,000' TARGET ELEVATION, ADD 1 MIL AND SUBTRACT 6 KCAS DELIVERY SPEED! RETARD THROTTLES TO IDLE AT 9,000' AGL and 320 KCAS AND DELIVERY SPEED WILL BE ACHIEVED.

K	H/W	I.P.	T/W	I.P.	X/W	K	H/W	I.P.	T/W	I.P.	X/W
0	125	-45	125	-45	0	25	168	-37	83	-48	278
1	127	-45	123	-45	11	26	170	-37	82	-48	289
2	128	-44	122	-45	22	27	171	-36	80	-48	300
3	130	-44	120	-45	33	28	173	-36	78	-48	311
4	132	-44	118	-45	44	29	175	-35	77	-48	322
5	134	-44	117	-46	56	30	177	-35	75	-48	333
6	135	-43	115	-46	67	31	178	-34	73	-48	344
7	137	-43	113	-46	78	32	180	-34	72	-48	356
8	139	-43	112	-46	89	33	182	-34	70	-48	367
9	140	-42	110	-46	100	34	183	-33	68	-48	378
10	142	-41	108	-46	111	35	185	-33	67	-49	389
11	144	-41	107	-47	122	36	187	-33	65	-49	400
12	146	-41	105	-47	133	37	189	-33	63	-49	411
13	147	-40	103	-47	144	38	190	-32	62	-49	422
14	149	-40	102	-47	156	39	192	-32	60	-49	433
15	151	-40	100	-47	167	40	194	-31	58	-49	444
16	153	-40	98	-47	178	41	196	-31	57	-49	456
17	154	-39	97	-47	189	42	197	-30	55	-49	467
18	156	-39	95	-47	200	43	199	-30	53	-49	478
19	158	-39	93	-47	211	44	201	-30	52	-49	489
20	159	-38	92	-47	222	45	202	-29	50	-48	500
21	161	-38	90	-47	233	46	204	-28	48	-48	511
22	163	-38	88	-47	244	47	206	-28	47	-48	522
23	165	-38	86	-47	256	48	208	-28	45	-48	533
24	166	-37	85	-48	267	49	209	-27	43	-48	544

H/W, T/W, and I.P. (Initial Pipper Position) are expressed in Mils. X/W is expressed in feet of offset. K is in Kts. Triple X/W in feet for initial lateral offset or double cross wind in knots for final Mill offset. Lateral drift is relative slow. 1.25 times final lateral offset in Mils equals initial lateral offset in Mils.

FIGURE 8

initial pipper position

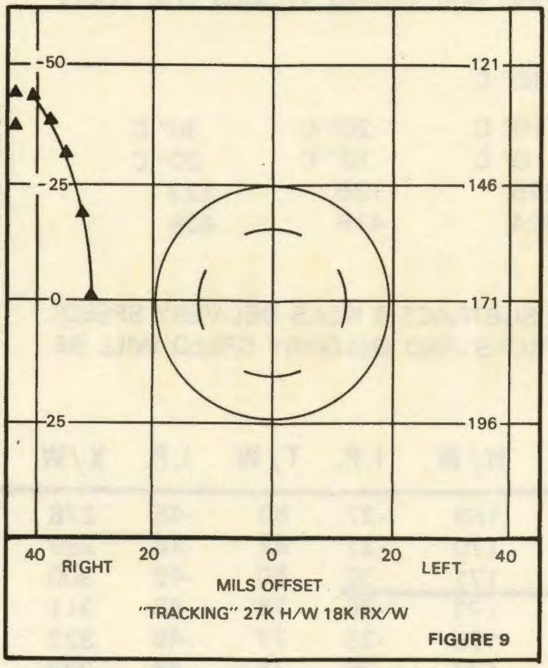
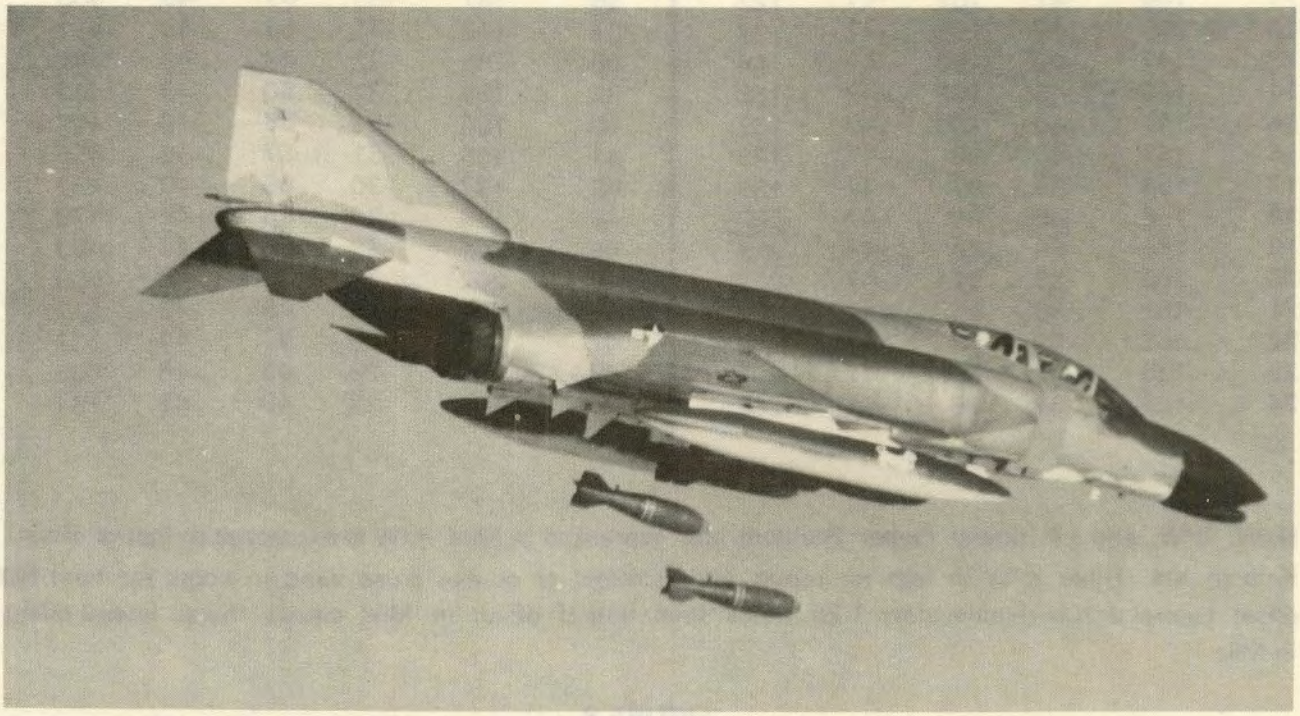


FIGURE 9

foot circles around them. The final offset is 36 mils and the initial offset is roughly 1.25 times that - or 45 mils. Figure 9 shows the initial pipper placement in relation to the target. "Tracking" until release is also depicted.

Initial pipper prediction is a precise method of explaining and separating the sequential elements of the dive delivery pass. It can be presented in a manner similar to the example mission data card, Figure 8, and can be used quite successfully by airborne aircrews. Knowledge of desired versus actual pipper position can be used to make intelligent error corrections during actual deliveries. One caution must be noted. Until one becomes familiar with ballistics, there may be a tendency to try to fly the pipper and become a victim of pendulum effect. Proper delivery techniques should not change in any way. Now that we are finally getting gun cameras, weapons officers should be able to have a good tool to improve squadron accuracies by being able to critique "tracking." Initial pipper positioning as explained in this article eliminates the need to guess where 500-800 feet or any other nebulous point is on the ground. Most importantly this method can be used in combat. Give it a try. The results may surprise you.



Courtesy FIGHTER WEAPONS REVIEW
Reprinted from FIGHTER WEAPONS REVIEW, Summer 74

KEEP THE SHARP END POINTED FORWARD

stability and control from a commander's viewpoint

QUOTE: "When excessive AOA causes the fuselage to wash out airflow over the vertical stabilizer, directional instability causes the blunt end to precede the sharp end. We call this phenomenon nose slice. At this point, departure from controlled flight has occurred. The next event is poststall gyration, which may be followed by one of two final events - the rolling departure or the spin. Smooth and positive application of recovery controls will invariably initiate the recovery sequence which is indicated by a healthy unloading to zero or negative G, and is normally followed by a series of one to three recovery rolls. The only remaining event is that of dive recovery. Now, let's form a mental image of this entire loss of control and recovery sequence. Let's talk about how to keep the sharp end pointed forward. First, stall warning. There are two types of stall warnings: natural and artificial ...." UNQUOTE. -F-4 Stability and Control Briefings, 1973/1974.

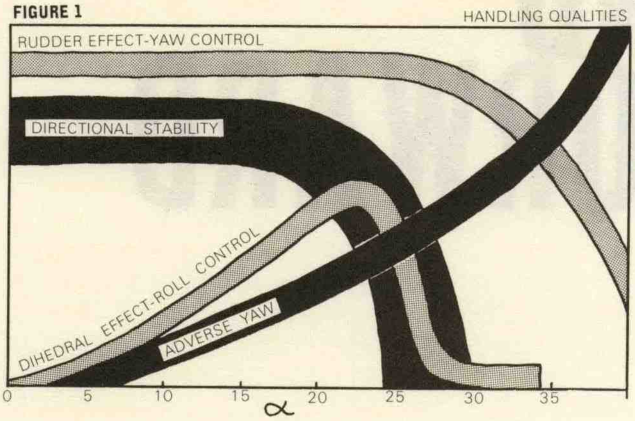
By Major General Gordon F. Blood
Commander, USAFTFWC
Nellis AFB, NV

During the past year, over 3,300 fighter jocks have heard the words of the F-4 stability and control briefing team. I would like to supplement those briefings with a challenge to all F-4 aircrews and all command echelons to join in the TRI-COMMAND crusade to keep the sharp end pointed forward.

During the past decade, the United States Air Force has lost over 60 F-4 aircraft due to loss of control. These losses exclude complicating circumstances such as aircraft malfunctions, weather phenomena, and combat losses. TWO HUNDRED MILLION DOLLARS down the drain because our pilots inadvertently flew the F-4 beyond maximum performance. An austere defense budget, limited combat resources, and spiraling weapons system procurement cost will not permit a *similar record* during the next decade. Positive action is required at all levels to check this unnecessary drain on combat potential.

Extensive efforts have been expended in the area of aircraft modification; among these were downspring removal, stab aug, fuel system,

FIGURE 1



continuous AOA indexer, AOA indicator rear cockpit, 3-pound bob weight, aural stall warning, 16-pound overbalance, and leading edge slats. The Rivet Gyro program has investigated the F-4 system, seeking to eliminate uncommanded flight control inputs and related problem areas. These programs have proved beneficial; however, losses continue.

During 1969-1970, a "stall/near-stall investigation" was conducted by the Air Force Flight Test Center at Edwards AFB. As a result, we know a lot more about the flight characteristics of the F-4. During fiscal 1974 at the request of PACAF, USAFE, and TAC, a stability and control briefing team representing TAC, AFSC, and AFLC visited all F-4 units in an effort to reeducate aircrews in this vital area. Examinations administered during this effort, experience in the Fighter Weapons School, and evidence gathered through extensive unit visits point to several problem areas contributing to our loss-of-control record. Elimination of these factors is necessary to check the spin-crash-burn trend.

MAINTENANCE. I challenge commanders to bring our basic riggers and STAB AUB/AFCS personnel up to speed on T.O. procedures and proper maintenance practices. If flight control malfunctions elude T.O. procedures, ask for depot assistance. The ALC and/or MACAIR will inevitably provide a solution.

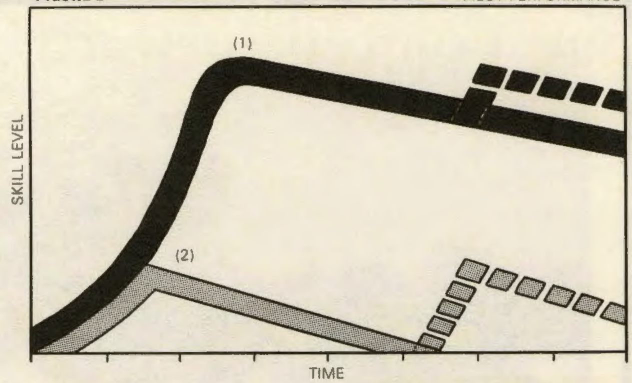
QC. I challenge commanders to limit the number of FCF aircrews. Three to five "professional FCF aircrews" are adequate to service a wing. These test personnel must understand Dash Six procedures thoroughly, and should always perform a complete test profile. I recommend an "FCF school" for aircrews. Too often, incomplete testing or misunderstanding of test procedures produces marginal flight control systems.

OPERATIONS. I challenge operations to educate our pilots in proper execution of ground/airborne flight control check procedures. Marginal/malfunctioning systems should be aborted immediately with a complete and accurate debriefing by the most highly qualified specialists available. Always write up the systems completely, regardless of anticipated impact on the daily flying schedule. It's better to MND than to end up in a critical emergency.

ACADEMIC TRAINING. I challenge all F-4 aircrews to thoroughly educate themselves in stability and control. Begin with an in-depth study of Section VI of the Dash One. The "stall/near-stall investigation" final report, produced by AFFTC, is an excellent expansion of the out-of-control characteristics of the aircraft. The movie, "Unload for Control," filmed during that test, is a superb capsulization of loss-of-control characteristics. This film is required in the RTU; however, I recommend several viewings by all F-4 aircrews to gain an adequate, in-depth understanding of both out-of-control characteristics and recover techniques. The 58 TFTW ISDT, in cooperaton with TAC, AFSC, AFLC, and AAVS, has produced a sound/slide training presentation on the subject. I recommend several viewings by each F-4 aircrew. Thorough academic training is the essential foundation; however, this first step must be followed by an equally intensive flying training program.

FLYING TRAINING. I challenge the RTU/CCT and CIS to conduct a thorough aircraft handling program. Marginal performance cannot be condoned. Loss of directional stability at high angle of attack causes departure from controlled flight. Conversely, proper control of AOA will eliminate departure, or loss-of-control. I direct your attention to Figure 1, a simplistic, unscaled quantitative graph displaying the deterioration in aircraft handling qualities with increasing angle of attack. At 20 units note that, while rudder effect and dihedral effect are quite high, adverse yaw is rising and directional stability is decreasing. This matrix of handling qualities is easily controlled by the relatively unskilled pilot. Moving toward 30 units in the hard wing F-4, note that rudder effect is the only positive characteristic remaining. Adverse yaw is high, while dihedral effect and directional stability are minimal. Only the highly skilled pilot is capable of positive directional control in this high lift region, warding off nose slice with judicious rudder control, thereby avoiding departure. As aircraft handling qualities deteriorate in this high alpha region, positive aircraft control is directly proportional to the skill level, or aircraft handling expertise, of the pilot. Psychological conditioning can best be accomplished through direct experience with warning cues at both positive and negative angles of attack and the associated preventive and/or recovery procedures. More often than not, loss of control occurs when least expected. The aircrew, preoccupied with mission accomplishment, inadvertently allows the AOA to become excessive; excessive meaning the angle of attack at which the pilot's personal skill level will no longer permit positive aircraft control. Operation at high lift/reduced handling quality levels is often dictated during last ditch maneuvers such as multiple SAM or AAM breaks in combat. Proficiency in this alpha region results in positive aircraft control in the event of inadvertent or intentional entry into that region. Control of AOA (recognizing the natural and artificial stall warnings with smooth application of proper controls) is the hammer. Alpha control is learned, either correctly or incorrectly, in the aircraft handling phase. Note Figure 2, a pilot performance curve based on initial learning level and the associated effects of time. We have learned, through extensive experience, that a pilot, once trained to a high level of proficiency (Curve (1)), loses proficiency slowly and is easily retrained to the original level (Dotted Line). This pilot is capable of operating at relatively high angles of attack safely (above 25 units). In Curve (2), the initial level of proficiency is low, and the same amount of continuation training (Dotted Line) as was administered in Curve (1) produces a rather unskilled pilot. The pilot in Curve (2) is incapable of safe operations with even the slightest degree of deterioration in aircraft handling qualities. Let's teach our pilots how to fly correctly from the outset. Once conditioned or trained to a high level of proficiency, the pilot

FIGURE 2 PILOT PERFORMANCE

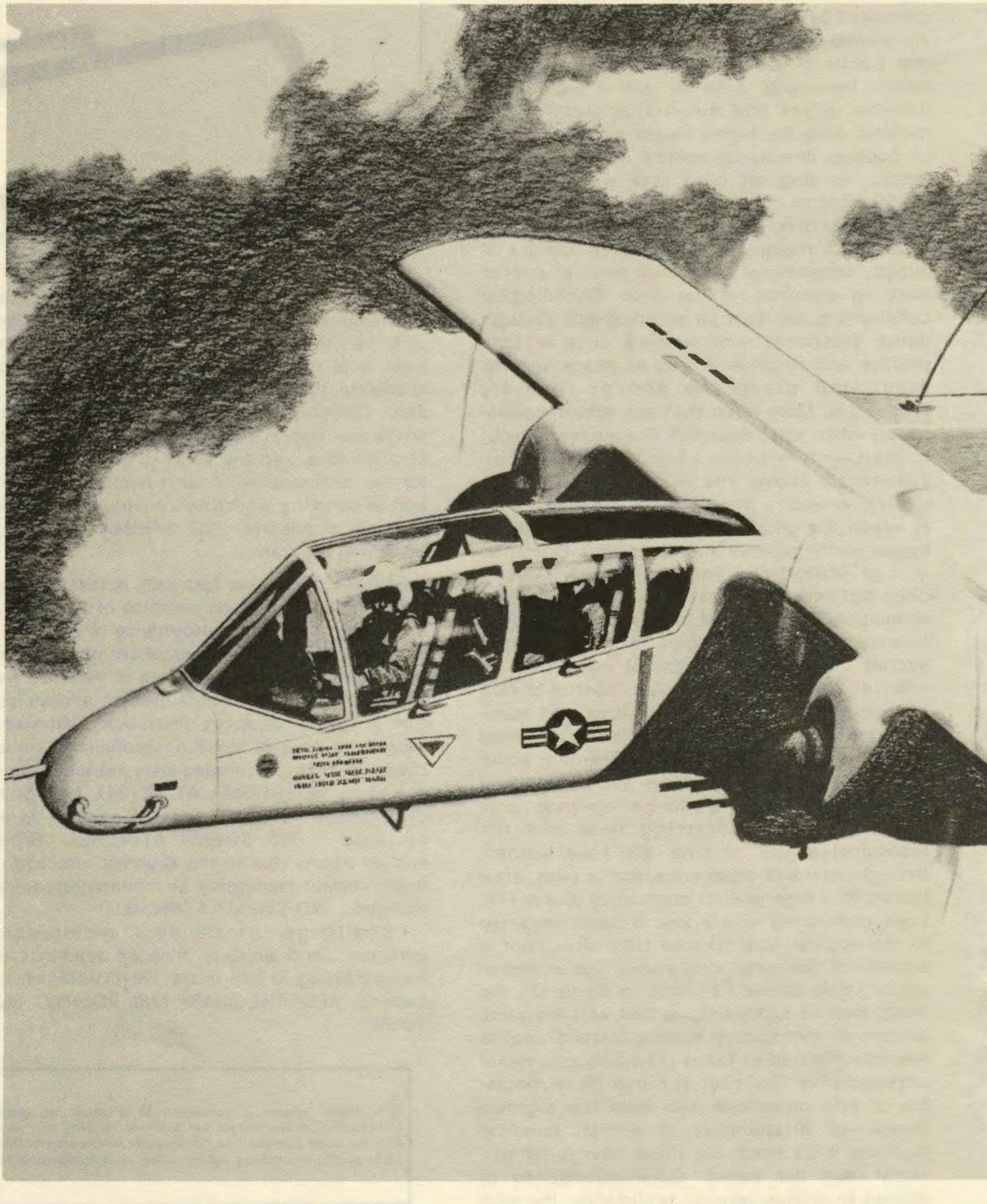


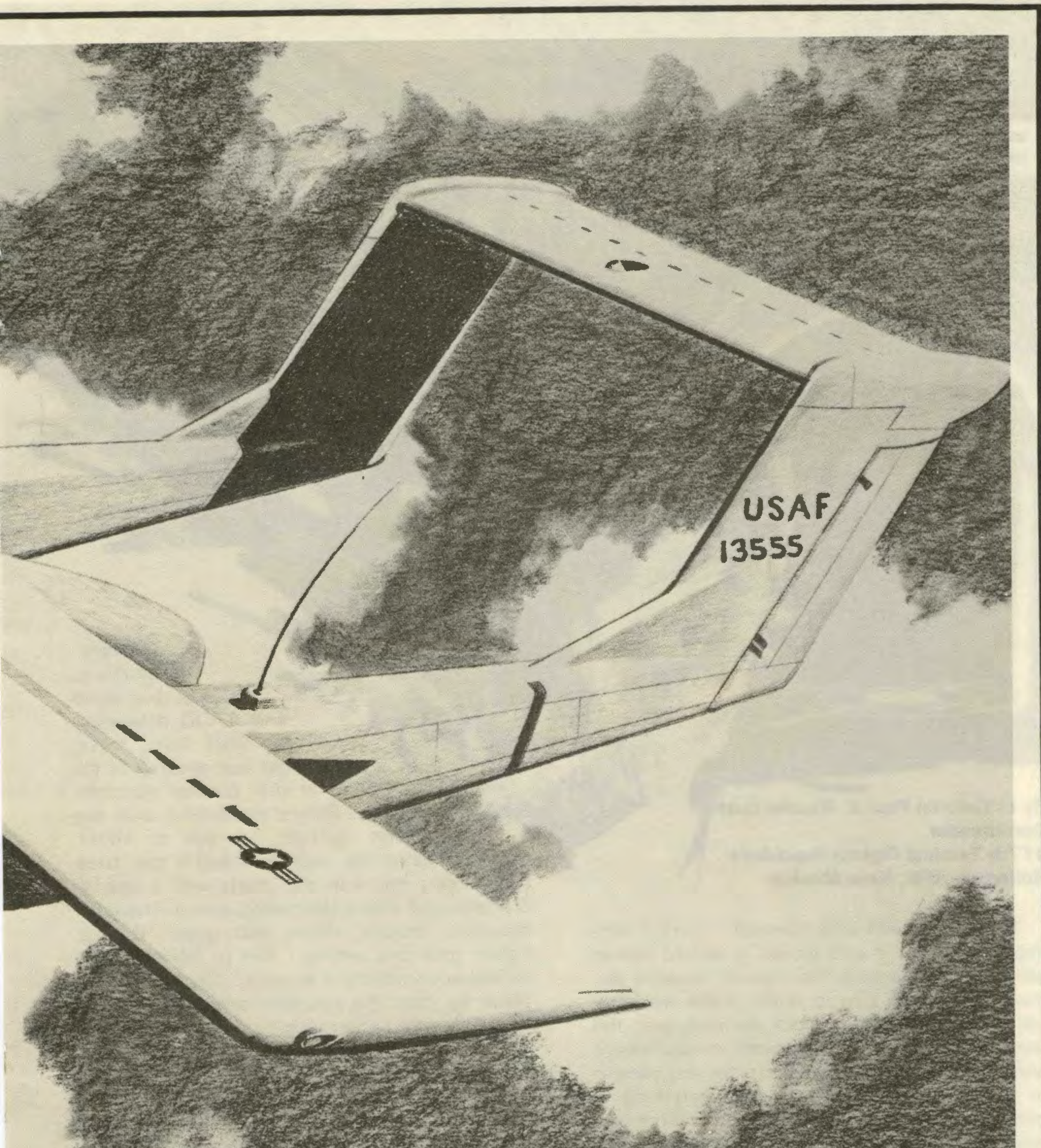
performance curve decreases slowly. Continuation training requirements in the operational unit; i.e., the training necessary to maintain a high level of proficiency are thus minimized. I challenge operational commanders to insist on Zero Defects in the aircraft handling area. I challenge operations officers, ACT IPs, flight commanders, and the WSO to constantly monitor the performance of each pilot. Any degradation in handling performance should be rectified through a positive "NO STIGMA ATTACHED" retraining program.

STIGMA. The Nellis approach is that basic aircraft handling is the cornerstone of tactical aviation. Basic handling performance is essential to the smooth, effective execution of all fighter missions. Therefore, all stigma is removed from all actions taken to insure perfect aircraft control. A fighter weapons instructor observed to decline in aircraft handling proficiency, in any chase of flight, is immediately retrained as required ... NO STIGMA ATTACHED. Use of the drag chute to avoid loss-of-control is encouraged ... NO STIGMA ATTACHED. Ground and air aborts due to the slightest indication of flight control misrigging or malfunction are demanded ... NO STIGMA ATTACHED.

I challenge commanders, maintenance personnel, and aircrews, through academic and flying training, to join in the TRI-COMMAND crusade to "KEEP THE SHARP END POINTED FORWARD."

The above article is produced as a result of detailed discussions General Blood had with the stability and control briefing team and years as Commander or Operations Officer responsible for training fighter pilots to a professional level.





BRUCE H. BOLINGER

EMPIRICAL vs. SCIENTIFIC

By Lt Colonel Paul E. Raudenbush
Commander
417th Tactical Fighter Squadron
Holloman AFB, New Mexico

"Measure it with a micrometer - mark it with chalk - and cut it with an ax" is an old saying which is applicable to the manual weapons delivery problem. I like to think of the weapons officer or other fighter jock pouring over the tech orders as the micrometer measurement and the base leg of a weapons delivery pattern to bomb impact as the ax cut; everything in between is the chalk mark. The micrometer portion of the problem is mostly a science, the chalk mark is part science and part art, while the ax cut is mostly an art. I will emphasize the ax cut portion of weapons delivery.

To study the problem, manual dive bomb and LADD deliveries will be used since these are the most complicated of the conventional and nuclear weapons deliveries. Before dispensing with the micrometer portion, I'd like to affirm that it is extremely important and I, too, have spent many hours in the charts with a pair of dividers, and finely sharpened pencil. There is, however, another saying that goes, "Give a fighter jock any setting - zero to infinity - and he will soon modify it to work." Thus there is a place for both the scientific and the empirical in the life of a fighter jock.

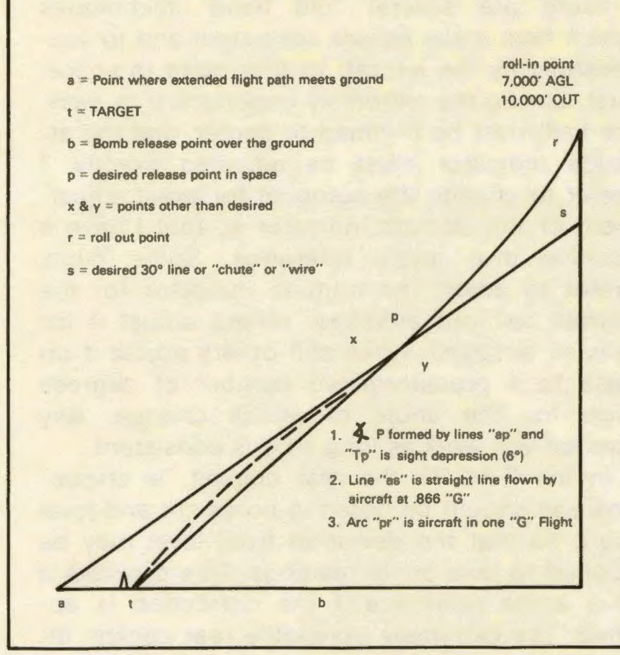
When national policy began changing from "massive retaliation" in the early 1960's, the first approach to conventional weapons deliveries was mostly trial and error or the empirical approach. Over the years, as engineers and other college graduates entered the fighter jock ranks, the approach became more scientific and has shown very favorable results.

There are three *USAF Fighter Weapons Review* articles which I believe are representative of our changing approach. First, an excellent article by Lou Aufdemorte in the March 1963 issue[1] which outlines extremely well the techniques which were developed through trial and error. Second, Keith Hanna's article in the Summer 1972 issue[2] updates the March 1963 article and adds a few more "scientific" thoughts such as more precise initial pipper positioning. The third article by Alexander Harwick in the Spring 1974 issue[3] takes the most "scientific" approach to date and refutes some of the traditional approaches to the problem. It also provides an excellent discussion of the wind problem.

These three articles provide as fine a review of manual weapons delivery techniques as are available. While reading them it is all too easy to fall into the trap of trying to determine who is right or most right since they do not all agree. To quote Dewan Madden in his excellent dive bomb article from the Spring 1972 issue[4], "The question, therefore, is not which is the best technique, but does the pilot understand how the technique he is employing relates to the problem at hand?" There is a tendency among young fighter jocks to change techniques or systems, depending upon which "expert" they talked to most recently.

Another common error is to combine parts of two systems which are not clearly understood. Using ground speed for a nuclear delivery but correcting for winds with true airspeed corrections is one example. A consistent pass from which corrections can be made is the important thing. This is where maintaining bomb plots is essential to the serious fighter jock. Once consistency is achieved, corrections may be made. Most top guns have modified standard settings and have tailored them for their own personal techniques. Thus we develop a consistent ax swing and adjust our foot stance (roll-in and sight settings) so as to consistently hit the same mark. Colonel Hanna says it well, "A dive delivery pattern should consist of a whole lot of constants and a few variables. If you find yourself making variables out of those things that should be constants, you probably need to re-examine your techniques and consciously strive to achieve better mental discipline throughout the pattern."

FIGURE 1



The dive bomb problem involves reaching a predetermined point in space which is determined by considering release vehicle velocity, dive angle, and weapon drag (Figure 1). If an aircraft is at point "Y," and the pipper is pulled up to the target, the bomb will fall short because the parameters have not been met despite the pipper being forced onto the target. If the aircraft is at point "X" and the pipper is forced down, a long bomb will result. If the aircraft is at point "P," the proper point in space, and release conditions are met, the bomb will impact on the target regardless of the pipper position. The sight is only an aid in determining when you have reached that point. An exercise during the trial and error days was to bomb with the sight turned off in order to practice putting the aircraft at the proper point

[1]**Aufdemorte, L. G., "Dive, Skip, Rockets and Strafe,"** ***Fighter Weapons Newsletter,*** **March 1963, P. 11-19.**

[2]**Hanna, Robert K., "Manual Air-Ground,"** ***USAF Fighter Weapons Review,*** **Summer 1973, P. 23-29.**

[3]**Harwick, Alexander H. C., "The Wind Cube and the Tiger Error Fallacy,"** ***USAF Fighter Weapons Review,*** **Spring 1974, P. 7-14.**

[4]**Madden, Dewan, "Dive Deliveries and the Iron Sight,"** ***USAF Fighter Weapons Review,*** **Spring 1973, P. 14.**

in space and not fly the sight to the target.

There are several "old head" techniques which help make passes consistent and to successfully fly the aircraft to that point in space. First, during the extremely important trim pass, the ball must be trimmed to center, and the attitude indicator must be adjusted exactly. I prefer to engage the autopilot for exact adjustment of the attitude indicator so that I have a positive dive angle reference. Some pilots prefer to adjust the attitude indicator for the normal roll out airspeed; others adjust it for release airspeed, while still others adjust it on base to a predetermined number of degrees high for the angle of attack change. Any method will work as long as it is consistent.

In the F-4C/D, the rear cockpit "el strobe" position should be noted in boresight and level flight so that the deviation from level may be applied to dive angle readings. This provides a dive angle reference if the correction is applied. The extremely unreliable rear cockpit attitude indicator should not be used for a reference in weapons delivery except as an emergency procedure, i.e., loss of aircraft control.

At this point it might be appropriate to discuss the crew concept for conventional deliveries in the F-4. A crew which flies together consistently has a big advantage, as procedures may be established. Those who fly with many back seaters may prefer to give the nav a simple task to allow him to be a critic and point out errors. For example, I task the navigator with altitude information only during the pass but expect him to note dive angle, airspeed, altitude, and "G" at release. He makes comments on tracking and predicts bomb impact from the pipper; a good nav can do this. This forces him to understand the delivery problem, gives him a big job in correcting errors on subsequent patterns, and allows the pilot to fly the pass IAW established habit patterns. Between passes, required corrections should be discussed.

The base leg must be flown exactly. For new gunners in particular, position the downwind leg out far enough to allow an exact and stabilized base. Don't let the "old heads" rush your pattern. The comment, "Your pattern was too big," doesn't go into the weapons records, only your scores do. On a training range, flying to a point out ahead is easier than trying to fly over a point by trying to look underneath the aircraft. This is like marching to a point and allows you to maintain a better sense of perspective which will be valuable when bombing away from the home range.

Perspective is achieved by looking at the target over the canopy rail while flying to the point ahead. The roll-in point must be modified upwind so as to arrive at the proper release point in space. This can't be done properly unless all winds from base leg to the release point are thoroughly analyzed. It is very disconcerting to attend a flight briefing and not have all of the latest winds available. A proper briefing can't be conducted without a discussion of the expected winds and their effect upon the patterns that day. A top gunner studies the wind and wind trends thoroughly. Such factors as seasonal patterns, early morning and late afternoon shifts, increasing and decreasing winds at various times of the day, must all be considered. All known winds for the day must be reviewed so as to detect the pattern for that day. Wind, as the biggest factor in the "ax cut" portion, will be discussed in further detail later. One empirical method of determining wind effect has been to roll-in and observe the wind effect without dropping a bomb. This technique is of value, particularly in tricky winds.

Once a consistent roll-in is achieved, airspeed may be made a constant by reducing power to idle at an exact indicated airspeed for each configuration. Any errors are easily adjusted on subsequent passes. Also, the selection of idle is rather simple and exact.

Let's talk about why many "old heads" initially roll-out 3 to 5 degrees steep. First, the aircraft doesn't fly a straight line unless it is flown at less than one "G" (Figure 1). Flying at the .866 "G" required for a straight line in a 30 degree dive for many is more difficult and less exact than one "G" flight. Even with one "G" flight, however, the pipper should be momentarily stopped on the target to track and obtain the .866 "G" condition. There is up to one degree change in angle of attack from a normal roll-out release. The proper number of degrees steep at roll-out for a one "G" pass must be determined through experience. Some "old heads" use extra dive angle to control pipper movement to the target and adjust pickle altitude to compensate for small variations in dive angle.

Let's look at some options where it is necessary to compensate for errors. The "finger off the pickle button" technique is the best for a bad pass but this is not always practical. If the roll-in is too far to one side of the track, consider rotating the run-in slightly and continue to track. The changed run-in heading means obvious error for the "mil cranker" but these errors should be less than those resulting from a "Yahoo" back to track when all tracking is interrupted.

What about correcting for dive angle errors? Computing mil corrections or varying the aim point to correct for dive angle is accurate, but it is also more complicated than correcting with a change in altitude. Take a look at Figure 2 to see what dive angle errors do to place the aircraft at the wrong point in space. A bomb release on the preplanned altitude from a 5 degree steep pass (point "x" in Figure 2) puts the aircraft closer to the target at higher dive angle and results not only in a long bomb but also in a bottom-out altitude of about 400 feet lower than planned - a foul in this case. Steep and close doesn't make sense. Conversely, a 5 degree shallow pass causes a release further from the target (point "y" in Figure 2) which results in a substantial six o'clock error. If the aim point or sight is adjusted, this in effect rotates the extended flight path further beyond the target when the pass is shallow or further short of the target when the pass is steep. In other words, adjusting the aim point changes the dive angle and results in flying to a point in space not along the original path of the aircraft. Releasing the bomb 500 feet high for the 35 degree pass and 500 feet low for the 25 degree pass results in releases from points in space very close to the correct points were the passes planned for 35 degrees and 25 degrees originally. Recovery altitudes are close to preplanned and all are above minimums. Note how close the sight settings are for the three types of passes (Figure 3). Altitude corrections for dive angle error have the added advantage of being simple to apply.

What is the basic difference in the two methods of correcting for dive angle errors in a 30 degree dive pattern? If the aircraft is rolled out 5 degrees steep or shallow and you intend to release at a predetermined 3,000 feet, then a sight setting adjust of about 15-17 mils is necessary. This also further increases or decreases your dive angle by about another degree (17.45 mils equal one degree) which then requires another pipper adjustment.

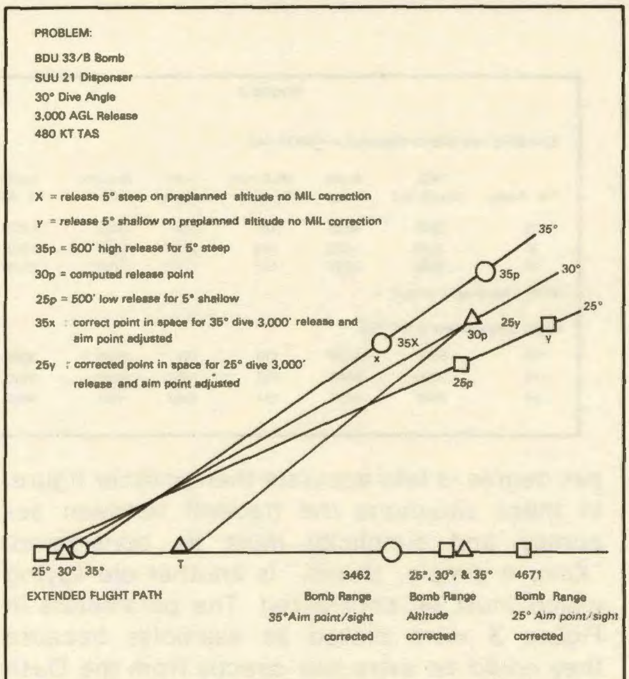


FIGURE 2

It is normally practical to include the angle change in the original correction and start out with about a 20-mil correction. In effect, you select and fly to a point in space not on your original approach path to the target. By correcting with altitude, your flight path to the target remains the same and you merely fly down the established "chute" until reaching the altitude (point in space) which is correct for that pass.

Admittedly it is not normally practical to fly low enough for a complete correction when shallow; however, a compensation for all but 30-50 feet is possible. This is pretty good for a pass as grossly bad as five degrees shallow.

Applying this technique to a 45-degree pass delivering a MK-82 in a high threat area, the same principle holds true if 200 feet is used for each degree of dive angle error. Five degrees shallow will put the aircraft below 4,000 feet, thus steep or on dive angle is necessary for safety. If a 45-degree dive angle is a problem in combat, figure a 40-degree setting and go for five degrees steep. This will work fine from 45 degrees to five degrees shallow and still keep the aircraft out of ground fire. Don't hesitate to modify your settings as long as you know what you are doing and have had them checked by a weapons officer.

There are cases where 100 feet or 200 feet

FIGURE 3

BDU-33/B from SUU-21 Dispenser at 480KTS TAS

Dive Angle	AGL Release ALT	Bomb Range	MILS from Flt Path	Sight Setting	Recovery Alt	Bottom Alt AGL
25	2500	4032	121	147	1000	1750
30	3000	4020	119	143.5	1350	1650
35	3500	3945	117	139.5	1750	1500

NOTE: 4 MILS equal 33 feet

MK-82 Single release at 520 TAS

Dive Angle	AGL Release ALT	Bomb Range	MILS from Flt Path	Sight Setting	Recovery Alt	Bottom Alt AGL
40	6000	5639	119	137	2500	3500
45	7000	5549	116	131.5	3100	3900
50	8000	5338	111	1243	700	4300

per degree is less accurate than another figure. In these situations the tradeoff between accuracy and simplicity must be considered; "Keep it simple, stupid," is another old saying which must be considered. The parameters in Figure 3 were picked as examples because they could be extracted directly from the Dash 34 without interpolating. In practice, it is unusual to change one parameter without effecting another. Releasing above/below preplanned altitude will probably result in a lower/higher airspeed than planned. The resulting bomb range and AOA errors are additive, which means the full altitude correction would not be necessary. How much less than the full correction should you make? "Cut it with an ax!"

Another fact which is not apparent from this discussion is that in practice this technique really works well only in dive angles above 28 degrees, so it pays to keep steeper than 28 degrees.

At this point it is worth noting why the 30-degree dive pattern has been selected for discussion rather than the 45-degree delivery. Everyone knows that a given error is less critical in a 45-degree dive than in a 30-degree dive. What doesn't show in the charts is that 30-degree parameters are easier to achieve so that errors, especially dive angle, are less. Empirically speaking, squadrons switching from 45- to 30- degree patterns improve unit CEPs. The closest thing to proof occurred in the mid 1960s when virtually all USAFE Wings converted from 45-degree to 30-degree deliveries. Overall, CEPs improved approximately 20 feet across the board. Does this prepare fighter jocks for combat? In 1972 the 49TFW deployed four squadrons to SEA which had been practicing 30-degree dive patterns almost exclusively. The switch to 45-degree patterns in combat proved no problem and accuracy was generally the best most FACs had seen to that time.

Now the real "biggie" in the "ax cut" portion of weapons delivery - wind. Bombing in a wind is the art portion, and the part which, as Alexander Harwick says, "... is nature's way of separating the fighter pilots from the pilots of fighters during manual air-to-ground deliveries." Let's take a look at what wind really does.

First, let's examine the effect the wind has on a bomb alone by dropping a BDU-33 low drag bomb and an MK-106 high drag bomb from a 3000-foot high railroad bridge in a 20 knot wind (See Figure 4). The BDU-33 accepts so little of the wind that it "blows" an insignificant distance of 13.6 feet downwind during 13.86 seconds time of fall.[5] The MK-106, on the other hand, accepts more of the wind for a longer period of time and "blows" 388.4 feet downwind during 20.23 seconds time of fall. Many weapons officers believe that bomb displacement will always be 1.69 feet per knot of wind for each second time of fall. This is only true after the bomb accepts the full influence of the wind. A theoretical bomb with no drag will not be influenced at all by wind alone, whereas a parachute drifts at the velocity of the wind almost immediately. Now let's drop these two bombs from a train going 20 knots in the same direction as the wind (Figure 5). The time of fall for each bomb does not change but the BDU-33 hits 368 feet downwind while the MK-106 impacts 683 feet downwind. This is the crux of the wind problem. For a low drag bomb we correct only for the movement or velocity of the release vehicle. For a high drag bomb, we correct for vehicle velocity and wind effect upon the bomb. (This simplified explanation does not take into account mach effect which alters the effective drag at high speeds, but this doesn't alter the principle.)

By applying this principle to the dive bomb problems it is apparent that the aircraft drift at release will primarily determine wind effect. A

[5]**Young, Bill, Chief Munitions Ballistics and Delivery Data Analysis Branch, Eglin AFB, Florida.**

FIGURE 4

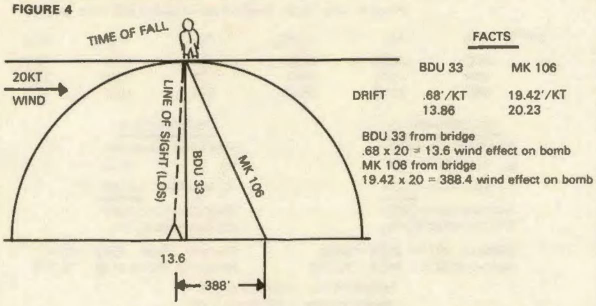
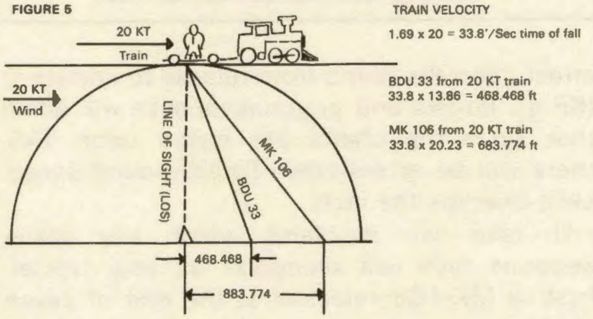


FIGURE 5



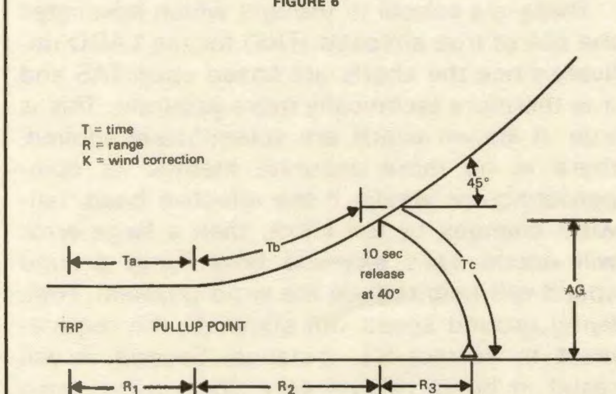
NOTES
1. In Figure 4, the low drag bomb (BDU 33) doesn't accept the full wind effect during the time of fall; it would eventually if it fell long enough.
2. In Figure 5, the release vehicle is going in the same direction and at the same velocity as the wind; similar to a fully drifting aircraft. In this case, the time of fall determines offset.
3. In releasing from an aircraft, the result is the same but is arrived at after considering bomb trail, K-crab, mach effect and other factors.

constant 20-knot tailwind will obviously impart 20 knots to the bomb, but a 30-knot tailwind at roll-in which slacks off to 10 knots at release must be carefully analyzed for its effect on release. A rule of thumb is that it takes two seconds for the aircraft to accept the full drift of the wind as it descends at about 500 feet per second. Do the crosswind and head/tailwind components affect the aircraft equally? The answer is yes if you use the fully drifting technique. The answer is no if, as most fighter jocks, you kill some of the crosswind drift. A technique used by some "old heads" in a strong crosswind, is to control drift through a prolonged roll-in and then roll out shortly before the release point. This greatly reduces crosswind effect but takes considerable judgement to arrive at the proper point in space. Few, if any, "mil crankers" use the full offset, but most use the full head/tailwind corrections.

As stated by Alex Harwick, the wind will not steepen or shallow the dive angle if you compute the aircraft drift and move the base leg in or out the appropriate distance. This is absolutely correct. A less than perfect pilot will find, however, that this criteria is difficult to meet, and dive angles will often be steeper to some extent with a tailwind, and vice versa. Being one of those less than perfect types, my bomb plots show that I need to crank out more than the computed mils for a tailwind and add more for a headwind. To determine this value, it was necessary for me to enter wind information into my personal bomb plots.

Many refer to the offset aim point method of bombing as "combat offset" and recommend it as the most realistic method. This is true for a high threat interdiction target and was certainly used extensively in North Vietnam. In low threat areas, such as South Vietnam, where offsets were difficult to determine, mil corrections proved very effective. By orbiting a target at release altitude, it was possible to determine wind velocity and direction in this low threat area. Attacks upwind and downwind may utilize "mil cranking" techniques. For a crosswind delivery in the F-4 there are excellent references at 12½ mils (inner reticle), 25 mils (outer reticle) and references out to 31 mils using the tabs. Talk to the best manual dive bombers you know and see how many of them crank mils. The Fighter Weapons School technique of us-

FIGURE 6



ing mils rather than linear offset also solves the problem of bombing targets where linear off-sets are difficult to determine, and attacks from any heading are possible.

Now let's apply the wind problem to the LADD delivery as depicted in Figure 6. Wind and the pickle point are the really big factors in the LADD problem. Range wind effect varies from as little as 45 feet per knot for a typical training range delivery to around 95 feet per knot for a typical target. Determining actual winds and accurately applying them is a major problem. Winds may be obtained from a forecaster, a pibal, or by using aircraft computers. There is an excellent article by George Sherman in the June 1967 *Fighter Weapons Newsletter* on wind computations with doppler or INS.[6] Basically, one degree of drift equals one knot of wind for each 60 knots of TAS. For example, one degree of drift equals six knots of crosswind at 360 knots, and seven knots of crosswind at 420 knots. For fighter jocks - multiply degrees of drift by miles per minute to get crosswind.

In most LADD maneuvers, the crosswind effect from the IP to release will be corrected for by a crab which kills the vehicle drift. The scientific method of correcting for head/tailwind (range wind) is to correct R_1 for the approach winds, R_2 for the average wind from pull up to release, and R_3 for the wind effect from release to impact. In practice, a "chalk mark" approach is to average the surface to release winds and apply one factor which takes all others into account. This is valid only if the winds are equal or homogeneous from surface to release.

There is a school of thought which advocates the use of true airspeed (TAS) for the LADD delivery since the charts are based upon TAS and it is therefore technically more accurate. This is true. If known winds are scientifically applied, there is no more accurate method of compensating for winds. If the effective head/tailwind changes by ten knots, then a large error will occur. Let's examine how flying ground speed will help reduce the wind problem. First, flying ground speed will eliminate the requirement to correct R_1 distance. Second, it will result in bomb release very close to the same point in space regardless of the wind; thus the only significant correction required is for wind effect upon the bomb from release to impact or (KR_3). Purists and pragmatists alike will admit that since the charts are based upon TAS, there will be errors when flying ground speed. Let's examine the facts.

FIGURE 7

GROUND SPEED ERRORS

PROBLEM No. 1: BDU-12, Delivery speed-540kts, Tgt elevation-Sea level, Release time-10sec, Winds-40kt headwind and 40 kt tailwind

FACTS: TAS	AG	R_2+R_3	R_3	KR_2	KR_3
500	3004	8166	750	16.9	77.0
540	3075	8911	786	16.9	78.8
580	3119	9627	821	16.9	79.9

TAS Calculations	GS Calculations
40kt Wind Correction	40kt Wind Correction
R_2 40 x 16.9 = 676	R_2 None
R_3 40 x 78.8 = 3152	R_3 40 x 78.8 = 3152
Total Correction 3828	Total Correction 3152
TAS Corrected R_2+R_3	GS Corrected R_2+R_3
Tailwind 8911 - 3828 = 5083	Tailwind 8166 - 3152 = 5014
Headwind 8911 + 3828 = 12,739	Headwind 9627 + 3152 = 12,779

Tailwind error = 69 feet or 1.5'/KT
Headwind error = 40 feet or 1'/KT

NOTE: KR_3 for 540kt was intentionally used for all corrections.

I'll take two problems which any active weapons type will recognize as very typical. First, a MK-106 released at the end of seven seconds; and second, a BDU-12 released at the end of ten seconds. In order to read directly from the charts, a 40-knot wind will be assumed to illustrate the errors. If the exact winds are known, and a steady 40-knot wind is present from surface to release, use of TAS will result in no error. Use of GS, on the other hand, will result in an error as great as 119 feet for a 40-knot tailwind when dropping a BDU-8, to as little as a 40-foot error for the MK-106 with a 40-knot tailwind. These represent 1.77% and .3% errors for a 40-knot wind and insignificant .44% and .07% errors for a 10-knot wind. Calculations for these figures are shown in Figures 7 and 8. If exact winds are not known, one or two knots of wind difference will cause the TAS advocate a larger error than the GS advocate. The difference becomes more spectacular as the distance between R_1 and R_2 increases. Use of GS will be close enough to destroy actual targets, whereas the use of TAS may easily result in a gross error. Advantages of GS or TAS are:

1. The route to a target is flown using ground speed and no change in speed is required for the delivery portion. A change in speed for delivery makes dead reckoning more difficult.

[6] **Sherman, George, "Doppler Winds for Dive Bombing,"** *Fighter Weapons Newsletter,* **June 1967, P. 8.**

FIGURE 8

GROUND SPEED ERRORS

PROBLEM No. 2: MK 106, Delivery speed-540kts, Tgt elevation-Sea level, Release time-7 sec, Winds- 40kt headwind and 40kt tailwind

FACTS: TAS	AG	R_2+R_3	R_3	KR_2	KR_3
500	1454	7980	2374	11.8	34.8
540	1460	8571	2470	11.8	34.4
580	1462	9115	2541	11.8	33.9

TAS Calculations	GS Calculations
40kt Wind Correction	40kt Wind Correction
R_2 40 x 11.8 = 472	R_2 None
R_3 40 x 34.4 = 1376	R_3 40 x 34.4 = 1376
Total Correction 1848	Total Correction 1376
TAS Corrected $R_2 + R_3$	GS corrected $R_2 + R_3$
Tailwind 8571 - 1848 = 6723	Tailwind 7980 - 1376 = 6604
Headwind 8571 + 1848 = 10,419	Headwind 9115 + 1376 = 10,491

Tailwind error = 119 feet or 3'/KT
Headwind error = 72 feet or 2'/KT

NOTE: KR_3 for 540kts was intentionally used for all corrections.

2. Wind effect from pickle to release is virtually eliminated. Wind effect is greatly simplified as only the effect from release to impact (KR_3) need be considered.

3. Errors in using ground speed are minimal as shown in Figures 7 and 8. This has also been confirmed by Young. He agrees that a high drag or LADD delivery in the 10-second timer regime using ground speed is an acceptable concept. He does warn, however, that low drag toss and LABS deliveries are a different story, but these are no longer practiced to any extent.

4. Wind corrections may be applied to within a few seconds of the pickle point. This is particularly significant on the desert ranges where spiraling wind patterns may vary greatly within a short distance of the target. In practice the TAS indicator will be primary for airspeed control with an adjustment for wind based upon the ground speed indicator, pibal, forecast wind, or plain old "Kentucky windage." An accurate in-flight ground speed check will take some of the suspense out of a training range mission.

Ground speed may also be used for laydown deliveries but the angle of attack change must be taken into account for a fixed sight. By using a pitch stabilized sight as outlined by Steve Dingman in the Summer 1973 *USAF Fighter Weapons Review,*[7] only KR_3 or wind effect after release need be considered.

CONCLUSIONS

The increasingly scientific approach to weapons delivery by an increasingly educated corps of fighter jocks has improved accuracy. There are, however, certain empirically derived techniques which still have a place in our scientific world. Although all phases of delivering a weapon are important, emphasis should be placed upon those producing the greatest errors. Don't change techniques everytime you hear a new one. Study the problem; select a technique you like and understand; and then stick with it long enough to give it a chance. When possible, pick the simple procedure over the complex, even in some cases where there is an accuracy tradeoff.

Some of the ideas in this article are not in agreement with current Fighter Weapons School philosophy, but that doesn't mean one of us is wrong. There are several intelligent approaches to the problem, and you must know the one you select.

Once your patterns are consistent, consider changing one thing at a time (including your settings) in order to zero in on the target.

In dive-bombing, go for a point in space and use the sight to let you know when you're there. Don't fly the sight to the target; fly the aircraft to a proper point in space. At Holloman it is possible to put your sight on the target right after takeoff.

TRIM! You won't have a valid dive angle reference if your attitude indicator is not adjusted the same everytime. In the F-4 back seat, only the "el strobe" should be used for dive angle evaluation and only if it is checked during the trim pass for a "zero" reference.

A good gunner must study and know the winds and then know how to apply this knowledge.

Consider:

1. The effect of a one "G" pass in dive bomb.
2. Changing run-in heading for aircraft azimuth errors in dive bomb.
3. Correcting for dive angle errors by changing the release altitude.
4. "Cranking Mils" rather than using the offset aim point technique.
5. Ground speed for nuclear weapons delivery.

[7]**Dingman, Steve, "F-4 Stabilized Sight in Direct,"** *USAF Fighter Weapons Review*, **Summer 1973, P. 4.**

BACK TO BASICS:

PLANNING & EXECUTION OF POP-UP PATTERNS

Tactical Air Command's fighter community over the past two years has been conducting some of the world's finest and most realistic training imaginable - training that demands an orderly progression of difficulty to be successful. Ground attack training now includes ingress navigation and tactical formation flying at very low altitudes and 500+ KTS, execution of pop-up patterns for achievement of precise delivery parameters, and egressing the target area with lots of calibrated airspeed at low level. At the same time, aircrews are required to evade and/or negate the sophisticated threats posed by SAMs, AAA, and MIGs. Elements of the air-to-ground and air superiority communities, as well as heavies, choppers, and SAR elements are being employed in concert to penetrate and destroy targets that are defended by a vast variety of surface-to-air weapon systems. To accomplish this, TAC fighter aircrews have devised some of the most sophisticated tactics in aviation history. Making them work requires extensive planning on the part of all the players, coordination between the players, and precise execution. However, while planning and executing these advanced tactics, some fighter pilots have made serious errors: THEY FORGOT ABOUT THE BASICS. This article goes back to the basics, discusses the mechanics of planning and executing pop-up maneuvers, gives a reference that deals extensively with pop-ups, and offers clues to help the tactical aircrews determine if a weapons delivery pass can be successfully completed or if it should be aborted.

Tactical fighter ground attack operations are focused on destruction of targets through use of a wide spectrum of weapons and delivery profiles. One such profile is the pop-up. The applicability of pop-ups in any given situation is not within the purview of this article, but the mechanics of planning and execution are. In discussing pop-up maneuvers, it is assumed that prior to aircrews progressing to pop-up maneuvers, they are thoroughly familiar with and have demonstrated proficiency in basic and curvilinear deliveries from a box pattern. Further, before these pop-up maneuvers can be applied to the tactical scenario, the crew must master low-level navigation techniques and tactical formations. The first consideration when transitioning to pop-up maneuvers is planning. This requires a thorough knowledge of Chapter 6, NNWD-F4-PT-1, Fighter Weapons School Instructional Text. Note: Rules of thumb in that text typically allow four to seven seconds on final and, as a result, provide some time for error analysis and subsequent corrections.

The place to start pop-up training is on a controlled range. These pop-up profiles must be designed to ensure valid learning situations exist, and they must meet the following criteria: (1) Parameters associated with the various phases of the profiles are thoroughly and accurately planned; (2) Profiles must provide the aircrews opportunity to vary the parameters on successive passes so they can learn what variances in parameters are acceptable; and, (3) geographic references for critical points in the profile must be easily identified from the cockpit.

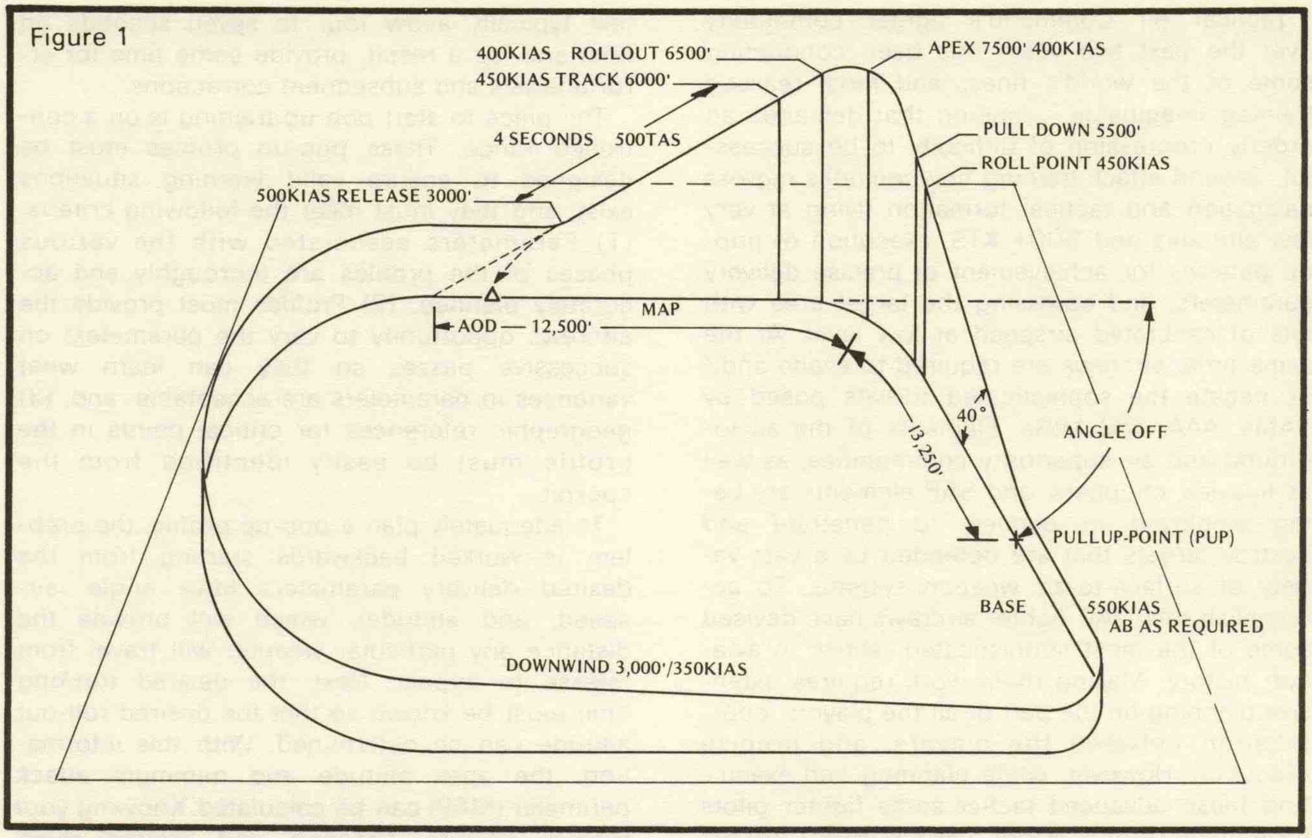
To adequately plan a pop-up profile, the problem is worked backwards starting from the desired delivery parameters (dive angle, airspeed, and altitude), which will provide the distance any particular weapon will travel from release to impact. Next, the desired tracking time must be known so that the desired roll-out altitude can be determined. With this information, the apex altitude and minimum attack perimeter (MAP) can be calculated. Knowing your ingress altitude, airspeed, and desired climb angle during the pull-up, the pull-up to MAP distance can be determined; also, the roll-in and pull-down altitudes are definable. Now all of the variables except angle-off are known, and the mechanics of planning are nearly completed. With the definition of angle-off, the check points on the range or in the area of a tactical target can be identified.

A typical F-4E (LES) range training pattern is depicted in Figure 1 : 30 degrees of dive and a 3,000' AGL release altitude. density altitude is sea level.

Using the typical pattern shown in Figure 1, let's talk ourselves through a pop-up training pattern, starting on downwind. Downwind should be flown at some fuel conserving combination of altitude/airspeed and far enough away from the target to allow for adjustment of pattern spacing. (A popular downwind airspeed for the F-4 is 350 KCAS). The turn from downwind to base should be designed so that once rolled out on base and tracking toward the pull-up point, is adequate room to accomplish an unloaded acceleration to the desired pull-up airspeed and descend to the desired approach altitude. To do this, make a 4-G turn to the desired heading, lowering the nose only enough

back to basics:

Figure 1



to maintain your base airspeed at full military power, roll out, and unload to "O"-G, accelerating to 500-550 KCAS, and descend to the desired approach altitude. Initiate level-off on base early enough so that you don't have to "reef" in 4-Gs and bleed off airspeed unnecessarily. At the pull-up point, a wing's-level 4- to 5-G pull to the desired climb angle is initiated. In the case of a low thrust-to-weight ratio, or if a significant climb to reach the desired apex altitude is required, it may be necessary to have the afterburner(s) going prior to "G" onset at the pull-up point. Be sure you are aware of your aircraft's low altitude handling characteristics. As an example: The first time you F-4 drivers plug in the burners at 500-550 KCAS below 1,000 feet AGL, the pitch-down will get your attention if you are not anticipating it. Upon reaching the desired climb angle, unload the aircraft to establish a stabilized climb to the roll point. During this climb, some pilots will have a tendency to roll and look for the target and may even roll in as soon as they acquire the target; both errors could have serious consequences. In the first case, you may end up inside the MAP with an unacceptably steep dive angle. In the second case, most pilots will initiate the pull-down well below the proper altitude which will result in an excessively shallow dive angle. This normally means the weapon will be released below the minimum altitude for fuze arming time and/or safe separation. Moral to the story: Pull-up at the proper point and start the pull-down at the proper altitude by referencing ye ole altimeter. At the roll altitude, roll to acquire the target and initiate the pull-down to the aim-off point at the pull-down altitude. Transitioning from the climb phase to the roll and pull-down phases to achieve the desired dive angle requires that the aircrew be aware of airspeed, "G" available, and the flying characteristics of the aircraft. Airspeed at the roll point and pattern apex should be 20 to 50 and 50 to 100 knots respectively below delivery airspeed. These parameters may seem quite wide, but they allow for variations in the magnitude of the maneuver, individual pilot technique for "G" onset at pull-up, climb angle, aircraft thrust-to-weight ratio, and roll-in techniques.

Initially, the pilot may feel that the canopy clues available during a pop-up attack are much different than from a box pattern. However, he will notice that as he transitions during a properly executed pop-up maneuver, from the roll, pull-down, and apex phases to establishing the desired dive angle, he should be relatively close to the same point over the ground that he used as a "crutch" during his training in the box pattern and that the same canopy clues should appear. It is at this point that error analysis is accomplished and where no surprises should occur. For example: If the aircrew is 50 to 100 knots off the planned airspeed at the pull-up point, he knows he isn't going to have the planned airspeed on top and, indeed, he will not be able to make the planned apex altitude at his planned airspeed, or maybe not at all. Likewise, if he overflies the pull-up point, or drops a wing toward the target, he must realize right then that he will be flying toward the MAP. The result being, if he doesn't do something immediately, he will be steep. This problem of being inside the MAP will be confirmed if he starts the roll-in. He will see that he is, in fact, inside his geographic "crutch." From roll-out to release through recovery - the pop-up pattern is no different than that of the box pattern except that most likely there will be time for only one azimuth and dive angle correction before reaching the release point. In these conditions, the pilot's error analysis must be instinctive, and the correction applied rapidly. This requires the aircrew be intimately familiar with the basics of dive deliveries. If the pilot cannot assimilate these conditions - he is not sufficiently familiar with the dynamics of the box pattern and has no business attempting pop-ups.

A successful attack from a pop-up maneuver depends on the aircrew's ability to maneuver to a precise position in space relative to the target. This position is determined by the type of ordnance carried, the desired delivery parameters, and maneuvering capabilities of the aircraft. In combination, these factors define an imaginary circle around the target within which the desired delivery parameters cannot be attained with a roll-in turn of 90 degrees or less. This circle is the MAP previously mentioned. If the attacking aircraft is within the MAP during the initial phase of the pop-up, pull-up to pull-down, the aircrew must be trained to realize that he cannot safely accomplish the desired attack without repositioning the aircraft outside the MAP. During pop-up training on a controlled range, the point at which the aircrew realizes he is inside the MAP (prior to rolling out pointed at the upwind aim point) is where he should abort the pass. If he has failed to recognize this, and rolls out on final in excess of five degrees steep, an immediate recovery should be initiated.

During initial pop-up training, repositioning maneuvers should not be permitted: Normally they would be prohibited due to the presence of other aircraft in the same weapons delivery pattern. However, when MC/MR aircrews progress to pop-up training on a tactical range, repositioning maneuvers must be part of any orderly training program. This article will not discuss specific repositioning maneuvers exept to note that: (1) There are several methods of completing repositioning maneuvers that have been tested on controlled as well as tactical ranges, and (2) The primary considerations of impact accuracy, weapon arming time, safe escape from weapons effect, visual contact with the target throughout the maneuver, survivability (exposure time), and safe recovery must never be compromised. It must also be realized that in actual combat, some of the methods of repositioning may be too difficult or not tactically sound. Therefore, the variety maneuvers available must be considered as basic additions to the aircrew's weapon delivery capability. In actuality, it all boils down to being able to judge the amount of turning room required for the given situation. This is something that must be learned in air-to-air training and applied to the air-to-ground arena, just like aircraft handling characteristics.

Up to this point, nothing has been mentioned about minimum airspeed in relation to aborting a pass. It must be realized all aircraft have a minimum turning radius. Being excessively slow over the top won't decrease the turning radius but does decrease the "G" available; therefore, turn rate decreases and, accordingly, the time from pull-down to roll-out is increased significantly. Consequences of increased exposure time during training in itself are not catastrophic in actual combat, they may be. Because of the adverse handling characteristics of modern day fighters at slow airspeeds and high angles of attack, and the fact that the apex of most pop-up maneuvers is well below the altitude required for recovery of an out-of-control condition, minimum airspeeds in the pop-up pattern must be considered. Just like flying inside the MAP and being steep by more than five degrees means gross errors have been committed, failure to meet prescribed minimum airspeeds means gross errors have also occurred, and that

back to basics:

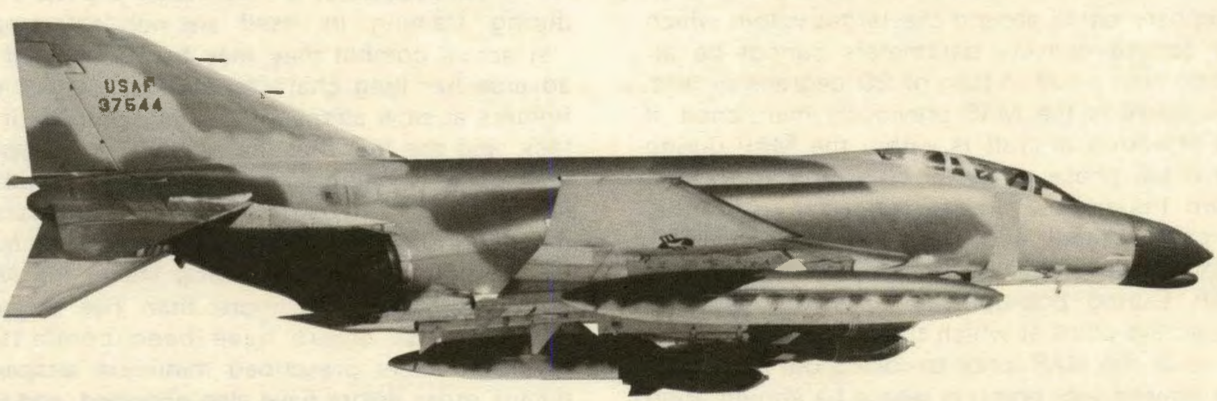
particular delivery pass should not be continued.

Finally, prior to proceeding on to pop-up training on a controlled range, a positive demonstration of proficiency in basic fighter maneuvers and situation awareness must be combined with the ability to consistently qualify in a basic gunnery pattern. Also, proficiency in pop-up maneuvers on a controlled range must be demonstrated before progressing to deliveries against tactical targets.

Let's now transition from the controlled range to tactical scenarios. Once the defensive scenario has been set, the target identified, and the sorties allocated, get everyone in the mission involved. This planning session is not to be confused with a political convention - but many good ideas for ingress, target area tactics and egress will evolve from a short, well-led tactics planning seminar. Remember the old adage, plan your flight, and fly your plan. Most of us do an adequate job of the first part of that verse - but when things start going down hill - playing the situation by ear most often puts somebody in an untenable situation. These "surprises" can most often be eliminated by a short session of "what-ifing" the plan, looking for weak points and areas of vulnerability. In planning, don't slight fuel requirements and switchology or brush them off as "standard." Nothing is more disconcerting (and deadly) than getting to the target area well below planned fuel or not having enough to properly evade or negate unknown threats, and then, making a dry pass due to an error in switchology. Set a point short of the target and establish a go/no-go fuel status. This point may or may not coincide with a point where weapons switchology may be accomplished without undue sacrifice to other tasks. One technique is to select a "fence check" point on the enroute map and write an abbreviated checklist for the weapons switches, then check that everything is, in fact, set at that point.

Target area maneuvering must also be carefully planned. Selection of an easily-identifiable IP, and pop-up point, either through visual or radar acquisition, will make or break a minimum exposure attack. Experience has shown that this task should be kept as simple as possible. Big mountains, towns, etc, have the disadvantage of not being precise enough navigation points, but a small isolated two acre plateau is also easily misidentified. So the technique of using gross navigation features to point you at a precise IP is easily applied. Fly the leg from the IP to the pull point in the same way you practiced on the range, and you won't be surprised when you reach the pull-up point.

Techniques used for target acquisition may be the same as noted in the IP selection. That is, find the big target area features, then move to the smaller pointing cues, finally arriving at your specific aim point. By using these navigation and pop-up techniques, you will be able to avoid those deadly square corners which plague the pop-up pattern. However, if you do have to reposition during the attack, make your decision early and get some maneuvering room just as you would when executing any basic fighter maneuver. What has been learned about maintaining separation between you and an air-to-air target applies in the same way to gaining turning room for the final phase of an air-to-ground attack from a pop-up maneuver. An important fact to realize is that you can put the ordnance on target out of a curvilinear approach using the planned delivery parameters by using a reposi-



F-4E: GW 44,000 Lbs., KTAS 500, KCAS 500			
	25°/3,000 ft	30°/3,000 ft	35°/3,000 ft
O Mils	13	12	11
DFP Mils	110	95	83
Total Depression	123	107	94
Altitude Lost 5Gs in 2 Sec	950	1250	1625
Time of Flight	6.38 sec	5.41 sec	5.15 sec
Achieve Safe Escape Minimum Altitude	yes	yes	yes
Fuze Arming Criteria Met (4 Sec)	yes	yes	yes
Mil/Differential from Planned Parameter	+16	Basic 107	-13

tioning maneuver, much the same as in air-to-air, but it is going to cost you something. That something is increased exposure to defensive reactions. Whether you can live with the increased exposure depends on the situation at the time. Many variables must be considered; too many to be discussed in this article. However, it is an area to consider during mission planning.

The final subject in mission planning to be discussed is that of planned variances in weapons delivery parameters. Specified singular parameters are satisfactory for the "standard" range mission, but combat experience has proven a known parameter variance is a must. One technique is to use a five degree variation in dive angle. In planning this, define a minimum and maximum dive angle and release altitude combination that is consistent with fuse arming and fragmentation clearance. Determine a central sight setting and apply the known variances for the maximum and minimum dive angle. As an example, let's look at a 30° dive delivery of a MK-82 LDGP bomb with a desired release altitude and airspeed of 3,000 feet (AGL) and 500 KCAS respectively, and construct the above table.

You now have a reference point for making corrections within a known delivery window and can use a new aiming index which is slightly below the bottom eyebrow of the sight reticle if you roll out shallow, lower edge (25° dive), or the upper eyebrow if steep (35° dive). For those of you not familiar with the F-4E sight, the eyebrow is the 25 mil segmented circle that is inside a solid 50 mil circle that together with the pipper make up the sight reticle.

In the final analysis, the fighter pilot must be able to destroy the target where he finds it, employing the tactical and delivery techniques dictated by the nature and environment of the target. From the controlled range to the combat arena, aircrews must be taught to adapt to the situation they face at the time. Allowing them to walk before they run and providing them with a training program that incorporates specified paths by which they can progress to scenarios that place more demands on their abilities, will save lives, airframes, and ultimately result in aircrews that are "no sierra" combat ready. Don't unnecessarily constrain for the sake of safety. Safety is bred by proper, logical, and orderly training - training that is real world and not unrealistically constrained out of fear. ➤

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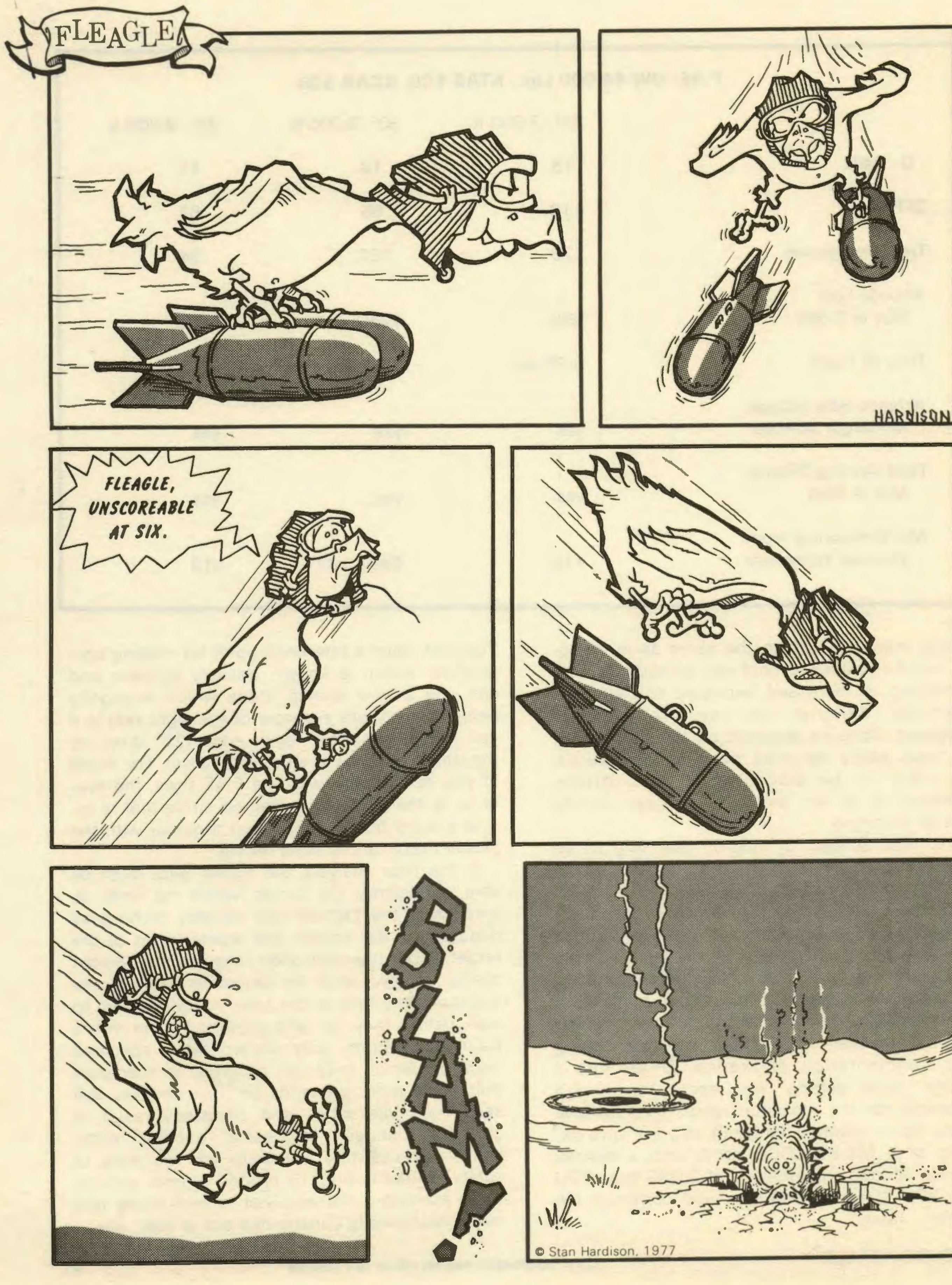
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