A practical scoring system for air to air rockets

The advent of ~~the~~ development of successful air to air rockets ~~brought about with it a host of~~ revolutionized ~~interceptors~~ concepts, equipment, & tactics ~~and~~ of aerial interception. A host of new problems accompanied this revolution including training of air ~~or~~ and ground crews, maintenance of gear of previously unheard of complexity, logistics and many others. One apparently innocent problem was a suitable method for evaluating the firing accuracy ~~on who~~ of these systems.

Change

Previously a towed target had been ~~adequate~~ ~~used~~ used for evaluation of aerial gunnery and though ~~it was~~ this method left much to be desired it was considered adequate. It was ~~just~~ also assumed some sort of similar method would suffice for these new weapons.

~~The firing accuracy of the E syst~~

An 'E' system interceptor ~~once it becomes~~

during its firing phase can be roughly divided into two distinct ~~complexes~~ interdependent parts or sub-systems which must be evaluated separately. One is composed of plane, radar, computer, and missiles all of which ~~com~~ when combined with a servo systems to translate error signals into control movement will place these missiles in a position to destroy another ~~acrf~~ ~~acrf~~ aircraft. ~~The~~ ~~Evaluation~~ The ~~other~~ second of course is the ~~previously mentioned~~ servo system or pilot in the ~~earlier~~ present E systems. ~~His contribution~~ ~~He is being~~ though His contribution during the ~~firing run~~ firing runs is being largely eliminated on later E models. ~~A~~ ~~This contribution~~ a pilots function during firing is supposed to be nothing more or less than flying his plane ~~so~~ in such a manner that ~~the~~ the steering dot is centered. How ~~well a pilot~~ well this is accomplished can be determined by examination of a photographic record of ~~attack~~ steering presentations during simulated attacks. Scope photography has become~~s~~ ~~standard in the~~ more or less standard procedure thus ~~bring~~

Insert

Bore 5

Evaluation of hits or even more important misses assumes a vastly more important ~~position~~ function here than in aerial gunnery for where a plane previously could be boresighted and fired in to check this boresight on the ground and then be expected to reasonably maintain this condition this is no longer true. First the corresponding function of boresighting consists of many complex operations of ~~properly~~ setting up ~~the~~ ~~at~~ system to find a target, lock on this target, give steering information to the pilot, ~~compute a series~~ solve a series of equations, and at the proper instant release a salvo of missiles which will strike the target. Many functions previously performed by a pilot are now assumed by the weapons' system. Added to the problem ~~complexity~~ of of setting up this system is the impossibility of firing in ~~on~~ the ground. To have any reasonable assurance at all that an ~~aircraft~~ interceptor is ~~a~~ combat ready it must be fired ~~with the an against a target~~ and by one method or another be determined capable of striking this target. Even the most calling a ~~plat~~ ~~int~~ E system equipped plane ready for combat without aerial firing would be the equivalent of merely boresighting a gun without firing it in careful of practical ground checks cannot assure that the plane is accurate. ~~One~~ Just by the number of components involved these planes are no longer alike as peas ~~in~~ a pod but are now even in spite of standardized production, individuals each with it's own characteristics. this is ~~caused by it's very number of components.~~

~~A For a target to be realistic~~

~~A successful~~

An ~~scor~~ aerial ~~scoring firing~~ target and scoring ~~st~~ system is thus imperative to evaluate and maintain these new interceptors.

¶ A successful scoring system must contain ~~perform~~ the following elements ~~functions~~; ~~Present a~~ a target which gives a radar return large enough for the system to 'see', which is capable of performing ~~following~~ ~~the~~ flight ~~profile~~ characteristics of planes to be attacked, ~~a system of~~ some method of determing hits or misses, and a method of ~~determing~~ determining the accuracy of steering by the pilot

~~a satisfactory solution to the first pro problem.~~
evaluating ~~a pilot profi~~ pilot proficiency.

Evaluation of the mechanical part of the systems ~~second complex~~ ~~In its simplest~~ is a much more complex situation. It involves presenting a suitable target ~~and~~ for attack and after this attack determing if ~~the cor~~ this target would have been destroyed and if not destroyed the magnitude ~~[illegible] of the target~~ of miss. ~~Problems~~ Old scoring concepts applicable to aerial gunnery no longer hold ~~in the~~ here. In aerial gunnery a relatively large number of hits have ~~had~~ to be scored in a small area to be successful but now one projectile in a relatively large area is a ~~success~~ kill.

Insert Paragraph on Page 5. → Most

~~Most obvious direct method of~~ suitable of all targets would be an aircraft as similar as possible to the craft which are to attacked during combat ~~and con~~ combined with some method of scoring misses. Drones were a logical choice of realistic targets. During O.S.T. of E stystem aircraft here at A.P.G.C. a program of firing against QB-17's which were realistic as to configuration but left much to be desired in ~~spe~~ performance was implemented. It was soon obvious that these targets were much too expensive and vulnerable to be used on any ~~kind of extended~~ reasonable scale. Since that time a large contract was let for development of small drones with realistic perfomance. These units however would not be suitable targets, with auxillary equipment for determining miss distance, because of their greatly reduced area. ~~Cont~~ This development program was unsuccessful ~~however~~. In addition a suitable scoring system was not previously available

Concurrently with testing and ~~tat~~ later field operation of F-86-D's, F-94-C's and F-89D's, development programs were started for some sort of suitable method of aerial firing and evaluation. As always the temptation to ~~remain~~ rely on familiar methods was strong. Even though towed banner targets were becoming inadequate for ~~a~~ conventional aerial gunnery they and their associated gear were pushed up to and beyond breaking point in an effort to use them as targets for ~~all weather~~ E system equipped interceptors.

~~A towed banner target is what~~
~~For a target~~

A banner target is far from a suitable scoring method. The problem of making it radar reflective can be solved by the addition of corner reflectors and/or ~~using~~ reflective material for the banner. ~~A banner is woefully inadequate as a realistic target~~ In regards to simulating performance of a bomber it is woefully inadequate. ~~there is a fact~~ Drag figures are extremly high and this added to ~~the~~ drag and weight from a ~~the~~ long cable neccessary for safety purposes seriously limit performance of a plane. This drag is well beyond reliable operating limits of presently available tow reels. To add to ~~make~~ the problem first line ~~use~~ aircraft are not available for tow purposes. B-29's are admittly relics of a bygone era and when harnessed with the additional drag of a banner it is ~~just~~ barely capable with full climb power of operating within the minimum speed limits for phase III firing of the 86-D. B-45's ~~sho~~ are slightly better but they too lack realistic performance as tow craft for they are limited to about 30,000' and speeds of 230 T.A.S. which again places the computers near their ~~lower~~ minimum speed limit for phase III firing.

A banner is nothing more than a rudimentary form of firing error indicator. For scoring of rockets it is totally indequate. First of all in it's most common configuration with one or more radar reflectors ~~tied~~ attached to the tow bar the aim point is no longer target center. Instead it ~~covers ½ of an area~~ covers only a quadrant above and beyond the aim point thus a plane firing late and high would show more hits than one firing correctly. More important though is the fact that the area of ~~even~~ a large banner is much smaller than that of a bomber. A 6'x 30' ~~foot~~ target ~~and~~ 9'x 45' ~~repsec~~ respectively present ~~180 ft.~~ 180 sqt. ft and 405 sq. ft. as against of a ~~[illegible]~~ B-50 type aircraft. Most serious of all though is the inability to determine magnitude or direction of a miss. If a plane ~~[illegible]~~ is improperly set ~~[illegible]~~ up it ~~may~~ should ~~conf~~ miss the target consistently and since there is no way of determining what corrective action for maintenance to take, ~~[illegible]~~ the only resort is to check and recheck previous work and finally in desperation ~~add tat~~ add guessed at corrective measures. The matter becomes even worse than hit or miss for there is the strong possibility of a stray rocket striking. ~~[illegible]~~ On a recently rockets meet we had scoring equipment along on 3 ~~hit~~ passes which hit. Two of these hits were scored by wild rockets with the centroid missing completely. It is obviously impossible to determine a planes performance from towed ~~p~~ targets without ~~scoring~~ some form of auxillary F.E.I. (Firing Error Indicator).

The need for F.E.I. was early recognized and a great deal of ~~time~~ money and effort was expended in an effort to develop a suitable ~~method~~ system. ~~A great deal of effor time was expended on various~~ Much of this work has been centered around various photographic procedures. Photographic records of flight path of projectile and target ~~target~~ seems a most direct and simple procedure and indeed photographic scoring has only one difficult problem. With normal photographic procedures involving a single camera only ~~two~~ two dimensions are recorded. By knowing neccessary angles of attack rockets ~~can be recorded~~ fired against fixed ground targets can be scored ~~with~~ easily for ~~the impact of~~ the rockets' impact are in ~~the~~ or very close to the ~~same plane as~~ target plane. With ~~roc~~ air to air rockets, when photographed ~~by motion pict~~ from ~~the~~ a firing craft an entirely different situation exists. Here, the rockets appear to ~~move only slightly~~ become relatively fixed a short time after firing with the target apparently moving ~~the~~ across the projectiles path. Without a hit it is impossible to select the proper frame ie when the rockets are in the target plane. See Fig I. If it is possible to select the correct frame or frames when the rockets cut the target plane it is possible to score misses by comparing apparent miss distance to ~~the~~ known target ~~distance~~ length. ~~Thus~~ The only real problem then in rocket scoring by photographic means is ~~the~~ choosing the

~~pictures~~ photographs ~~made~~ exposed at the correct time. ~~the~~ This is reducing the problem to its most elementary elemets. Some of the details will be treated later.

This is only one of an almost infinite number of ways of scoring missiles. Just to list a few of the others which have and are being tried are acoustic means, both amplitude and time differential, doppler radar on the target, ~~[illegible]~~ cameras mounted on the target, and ~~some form of it~~ detecting devices on the target for quantitative measurement of a standard radiation or field ~~on the~~ from the missile itself.

When operational suitability tests were started on F-86-D's, F-94-C's, and F-89 D's here (date) at ~~the~~ A.P.G. neither this nor any other installation had any means ~~at~~ of scoring. Efforts were started to develop ~~so~~ some suitable scoring device. ~~[illegible]~~ One early attempt was quite interesting. ~~and~~ ~~A pair of~~ Sonne S7A continously moving film cameras were mounted in nose and tail of ~~[illegible]~~ a QB 17. These cameras were pointed upward with overlapping fields of view covering a vertical plane on the longitudinal axes of the aircraft. ~~Previous~~ Prior to firing a fixed bias was introduced into the fire control systems of the interceptors ~~thus~~ causing the fighter to fire high but correctly in azimuth. This placed the missiles above the drone where they were photographed. In addition the rockets were Aeromites which left a dense trail of smoke. By knowing base line and film speed of the cameras, ~~film speeds~~ rockets miss could be calculated from the ~~images angle~~ angle of ~~their~~ the smoke trail image on the film. This distance could then be compared with the deliberately introduced system error. ~~in the s the scheme~~ Mechanics of thes scheme worked well but it was considered unrealistic to introduce errors and for this reason ~~the system~~ was discarded.

Months passed with other unsuccessful attempts being made to use stereo pairs of cameras and ~~[illegible]~~ some of the projects were completed without ~~know~~ evaluation of the systems most important function, its ability to hit a target. In June of 53 a concentrated program was started under APG project ADA 54A and continued under ADA 49A4 to develop a ~~suitable~~ ~~[illegible]~~ ~~device~~ method for evaluation of ~~rocket an~~ E systems firing accuracy ~~[illegible]~~ here at A.P.G., a method which if possible could be used in the field by operational units.

The first month or so was spent largely in theoretical study of problems involved, selection for testing of the most promising methods, and preliminary testing of methods which showed promise by previous trials. In ~~this period was largely devoted to elimination selection of several promising methods.~~ ~~and~~ Among ~~the~~ some of the ones discarded are listed as follows along with the reasons for not being considered.

Acoustic ranging by measurement of shock wave amplitude – Inherent inaccuracies in measurement ~~render this~~ place overall accuraices outside of accepable limits.

Acoustic ranging ~~by~~ by measurement of time differential of arrival of shock wave at different points – Complicated, data reduction problem; can handle only small number of single rockets.

~~Measurement of to~~

~~Recording time of closest approach t~~

~~Measurent by recording of standard~~

Ranging from magnetic field in missile –

~~field in head varied~~ magnetic fieldss decrease too rapidly with distance.

Ranging by measurement of standard radiation source in missile- radiation strong enough to ~~produce~~ be recorded at a reasonable distance would ~~be~~ require elaborate safety precautions-

Ranging by measurement of ~~radio~~ s field strength of a radio transmitter mounted in ~~a ro~~ rocket head- number of transmitters required were considered excessive ~~in or~~

~~These are~~

Photographing ~~crossover~~ - ~~moment of~~ rocket crossing target plane from a camera mounted in the tail of the tow plane and relating ~~this~~ to the strike camera film in the firing aircraft- Camera cannot record rockets at the ~~range~~ lengths of tow cable used, unless some auxillary device such as a flash head. even in this case a large amount of auxillary gear would be neccessary as would prodigous amounts of data reduction & assessment.

Ranging by doppler radar - can handle only small numbers of single rockets - elaborate accessory gear involved -

The above are just a few of methods which were rejected upon theoretical grounds or upon preliminary testing -

Four methods were chosen as being promising enough to warrant extensive testing. With one exception they used some means to determine time of rockets crossing the target plane and then relating this time to a photographs taken from a strike camera. Once the correct frames or frames are chosen the rockets' miss are ranged stadiametrically.

Inyokern issued a series of reports on a ~~stereo p~~ method of miss distance evaluation ~~involving~~ using stereo pairs ~~in which~~ ~~A~~ GSAP cameras ~~were~~ are mounted under each wing of the firing craft and operated simultaneously during actual firing ~~and until~~. Apparent ~~distance~~ path of missiles ~~from an aim point on the target~~ is progressively plotted ~~against~~ This is done with film from each camera with the targets image being kept as a stationary reference, resulting in a plot of miss distance against elevation. According to their theory these ~~lines~~ curves will intersect at the point the missile cuts the target plane. Miss distance may then be obtained stadiametricly. This method is predicated upon a change in relavite elevation of the cameras. This change in elevation occurs during a roll in or out during a pursuit curve however during ~~an~~ collision course attacks ~~every~~ efforsts are made to prevent or minimize roll with the result that there is negligible relative camera change in elevation. This results in the plotted curves becoming almost parallell ~~the~~ lines ~~on~~ with which it is impossible to determine intersection.

Messrs. Prince and Rush of our data reduction section ~~wer~~ predicted this and in order to ~~check~~ verify this ~~point~~ ~~method~~ fact ~~emper~~ emperically set up a ~~scaled down~~ stereo pair ~~of~~ ~~ca~~ and simulated very accurately a firing pass using points sources of light as target and missiles. ~~This work~~ Results showed that it was impossible to choose the intersection of the almost parallell lines.

Attempts to use this method at several bases have also resulted in ~~a~~ inability to determine moment of missiles cutting the target plane ~~as the lines~~ as the curves become paralell lines.

One use of stereo ranging which showed promise was ~~the~~ plotting ~~aparent~~ apparent ~~miss~~ distance of missiles from aim point against time. ~~Th~~ Curves from two cameras were then superimposed on a common scale ~~with~~ the point of intersection being moment of ~~crossover~~ missiles cutting the target plane. ~~The~~ Frames corresponding to this time are chosen and ~~miss~~ distance determined stadiametrically.

~~St.~~ A pair of ~~MIV can~~ synchronous 35 ~~mm~~. cameras ~~well capable of taking~~ ~~ph~~ with 4" lens were mounted in modified tip tanks of a 94-C and boresighted ~~such~~ that rockets ~~and~~ fired from the ship were common to the field of view of both cameras. These cameras' shutter openings were synchronized to a few milliseconds. After several tests of these were run it become apparent that with only a 40' baseline the point of intersection ~~of~~ ie moment of missile piercing target plane could not be determined with neccessary accuracies to make this a suitable method.

A good deal of effort was expended upon detection of a shock wave from the rockets' approaching the target and taking this as an approximation of ~~time~~ of crossing. Any object traveling faster than mach 1.0 has associated with it a shock wave.

Fig– A 2.75" ~~rock~~ KNOTS rockets generates a shock wave of very large magnitude which may be ~~detected~~ considerable distances away by a suitable transducer which usually is quite similar to a microphone. A ~~suitable~~ ~~a~~ magnetic transducer was used ~~to drive~~ coupled to an AM transmitter and attached to the ~~tow target~~ harness of a tow target. This transmitter's signal was received in the ~~bomber~~ tow craft and recorded on an oscillograph. A number of flights were made in Sept. of of 53 with this gear in order to test ~~gear necessary~~ & perfect gear to record the shock waves. During ~~Some~~ ~~on~~ missions were shock waves ~~recorded~~ recorded but results were inconsistent. ~~Time was~~ A good deal of effort was expend during the winter in an effort to refine ~~the~~ system components. A very promising ~~system~~ set up was devised with excellent response and low signal to wind noise ratio with the pickup & A.T.M. transmitter portion occupying only a few cubic inches in the tow harness. This system was abandoned however when it became obvious that other methods would give superior results.

An elegant approach to this problem was designed and developed by Mr. Bauer of this command. A camera with ~~continuous film movement~~ 7" film moved ~~continually~~ continuously past 8 lens which through a system of mirrors covered ~~a~~ 360° plane normal to the longitudinal axis of the 5-27 glider on which the camera is mounted. This camera will be turned on by a radio link the transmitter of which is located in fighter or chase plane. A rocket passing thru the field of view of the camera ~~can be~~ will be recorded and the quadrant thru which it passed and a rough estimation of its miss can be readily determined. ~~Through the~~ By means of a common code recorded on both ~~strike~~ this camera and a strike camera ~~mounted~~ on ~~the fighter~~ firing or chase aircraft ~~the~~ time of missiles crossing ~~of the rocket~~ target's plane ~~by~~ may be ~~deter~~ related to ~~the~~ strike film and ~~the~~ miss ~~[illegible]~~ determined stadiametrically. This system has been quite successful in ground tests. It is extremely accurate and is capable of handling large numbers of missiles. Data reduction is relatively complex ~~and~~ but its chief draw back is the complexity and ~~at~~ a large amount of accessory gear. Data recovery is also a problem. ~~S~~ While this method might be useful in testing phases of a system it obviously could not be used in ~~the~~ field operations.

The fourth method to be tried ~~merely~~ consisted merely of recording the relative range of rockets and target from a radar A scope presentation and relating the ~~P~~ instant of range coincidence to ~~the~~ proper frames of a strike camera. This is perfectly straight forward with ~~a~~ recording of rockets by radar being the only unique feature. Possibility of this at first seemed ~~doubtful~~ dubious while in reality it is an extremely simple matter as later tests showed. An object with a cross section as small as a rocket is not usually considered large enough to give a ~~return~~ sufficent return to be recorded by a radar set. Several people ~~of~~ with a ~~l~~ great deal of experience in radar considered it impossible. Radar Observers however reported tracking rockets and other projectiles to large distances.

A crude A scope was built and installed in a 94-C ~~set~~ to ~~check return~~ determine ability of a set to ~~tr~~ 'see' rockets. This was completed in Oct 53 but was not tested until April 54 when ~~an~~ a salvo of six free fired rockets were ~~clearly~~ easily recorded. Further tests were immediately made ~~on the method~~ against targets with complete success. In an effort to