A Practical Scoring System For Air to Air Rockets

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A PRACTICAL SCORING SYSTEM FOR AIR-TO-AIR ROCKETS

The advent of development of successful air-to-air rockets revolutionized concepts, equipment and tactics of aerial interception. A host of new problems accompanied this revolution including training of air 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 of these systems. Previously a towed target had been used for evaluation of aerial gunnery and though this method left much to be desired, it was considered adequate. It was also assumed some sort of similar method would suffice for these new weapons.

An "E" system interceptor during its firing phase, can be ~~roughly~~ clearly divided into two distinct, interdependent parts or sub-systems, which ~~much~~ must be evaluated separately. One is composed of plane, radar, computer, and missiles all of which, when combined with a servo system to translate error signals into control movement, will place these missiles in a position to destroy another aircraft. The second, of course, is the servo system or pilot in the present "E" systems. Though his contribution during firing runs is being largely eliminated on ~~later~~ some future "E" ~~models~~ systems, a pilot's function at present during firing is supposed to be nothing more or less than flying his plane in such a manner that the steering dot is centered. How well this is accomplished can be determined by examination of a photographic record of steering presentations during simulated attacks. Scope photography has become ~~more~~

2 efficency during firing

or less standard procedure thus evaluating pilot proficiency.

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

Evaluation of hits or, even more important, misses, assumes a vastly more important 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 setting up a system to find a target, lock on this target, give steering information to the pilot, 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 of setting up this system is the impossibility of firing in on the ground. To have any reasonable assurance at all that an interceptor is combat-ready, it must be fired and by one method or another be determined capable of striking this target. Even the most careful of practical ground checks cannot assure that the plane is accurate just by the number of components involved. Calling an

This complexity makes each plane and system an individual different to some extent from every other A/C + system of its type -

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"E" system equipped ~~plane~~ A/C ready for combat without aerial firing ~~would be~~ is the equivalent of merely boresighting a gun without firing in. ~~These planes are no longer alike as peas in a pod but are now, even in spite of standardized production, individuals each with its own characteristics.~~

This situation would be alleviated to some extent if enough evaluated firings had been made but other than a relatively small number of firings on a few aircraft under somewhat artificial conditions during project 4,5,6. this has not been done. In spite of firings being made every day at Yuma and other points little information is obtained which furthers knowledge of the systems' performance since here no firing error indicator of any kind is used.

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

~~A successful~~ Such scoring system must contain the following elements: Target which gives a radar return large enough for the system to "see" and which is capable of performing flight characteristics of ~~planes~~ A/C to be attacked, some method of determining hits or misses; and a method of determining the accuracy of steering by the pilot.

Most suitable of all targets would be an aircraft as similar as possible to the craft ~~which is~~ to be attacked during combat combined with some method of scoring misses. Drones ~~were~~ seemed a logical choice of realistic targets. During the Operational Suitability Testing of "E" System aircrafthere at APGC, a program of firing was implemented against QB-17's which were realistic as to configuration but left much to be desired in performance, ~~was implemented~~, ~~it~~ (14?) was soon obvious that these targets were much too expensive and vulnerable to be used on any reasonable scale. Since that time a large contract was let for development of small drones with realistic performance. These units, however, would not be suitable targets without auxilliary equipment for determining miss distance because of their greatly reduced area. This development program was apparently unsuccessful. ~~In addition a suitable scoring system was not previously available.~~

Concurrently with testing and later field operation of F-86D's, F-94C'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 rely on familiar methods was strong. Even though towed banner targets were becoming inadequate for 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 "E" system equipped interceptors.

A banner target is far from a suitable scoring method for a number of reasons: The problem of making it radar reflective can be solved by the addition of corner reflectors and/or using reflective material for the banner but In regards to simulating performance of a bomber, it is woefully inadequate. Drag figures are extremely high, and this added to drag and weight from a long cable necessary for safety purposes, seriously limit performance of a plane. This drag, often over 2,000 pounds, is well beyond reliable operating limits of presently available tow reels. To add to the problem, first line aircraft are not available for tow purposes. B-29's are admittedly, relics of a bygone era and when harnessed with the additional drag of a banner, it is barely capable with full climb power of operating within the minimum speed limits for Phase III firing of the F-86D. B-45's are slightly better but they too lack realistic performance as tow craft for they are limited to about 30,000 feet and speeds of 230 TAS which again places the computers near the minimum speed limit for Phase III firing with F-86-D's.

A banner is nothing more than a rudimentary form of firing error indicator ~~. For~~ which for scoring of rockets, ~~it~~ is totally inadequate.

~~First of all,~~ In its most common configuration with one or more radar reflectors attached to the lower end of a tow bar, ~~the~~ aim point is no longer target center. In this case a banner ~~Instead it~~ covers only a quadrant above and behind ~~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' target and 9' x 45' target respectively present 180 square feet and 405 square feet as against ________ of a B-50 type aircraft. Most serious ~~of all~~ though, is the inability to determine magnitude or direction of a miss. If a plane is improperly set up it should miss ~~the~~ targets consistently and since there is no way of determining what corrective action for maintenance to take, the only resort is to check and recheck previous work and finally in desperation 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. On a recent rocket meet, we had scoring equipment along on three passes which hit. Two of these hits were scored by wild rockets with the centroid missing completely. It is obviously impossible to determine an A/C's ~~a plane's~~ performance from towed targets without some form of auxilliary FEI (Firing Error Indicator).

The need for FEI was early recognized and a great deal of money and effort was expended in attempts ~~an effort~~ to develop a suitable system. Much of this work has been centered around various photographic procedures. Photographic records of flight path of projectile and 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 dimensions are recorded. By knowing necessary angles of attack, rockets fired against fixed ground targets can be scored easily by single camera, for the rocket's impact is in or very close to the target plane. With air-to-air rockets an entirely different situation exists. Here, when photographed from firing craft, the rockets appear to become relatively fixed a short time after firing with the target apparently moving across the projectile's path. Without a hit it is impossible to select the proper frame, i.e., when the rockets are in the target plane. ~~See Figure 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~~ miss distance can be computed by comparing apparent miss distance to the known target length. The only real problem then in rocket scoring by photographic means is choosing the photographs exposed at the correct time. This is reducing the problem to its most ~~elementary~~ basic elements. Some of the details will be treated later.

Fig I strike Photo

~~This~~ Photography 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, cameras mounted on the target, and detecting devices on the target for quantitative measurement of a standard radiation or field from the missile itself.

When operational suitability tests were started on F-86D's, F-94C's and F-89D's here ___date___ at APGC, neither this nor any other installation had any means of scoring. So efforts were started to develop some suitable scoring device. One early attempt was quite interesting. Sonne S7A continuously moving film cameras were mounted in nose and tail of a QB-17. These cameras were pointed upward with overlapping fields of view covering 60° vertical plane on the longitudinal axes of the aircraft. Prior to firing, a fixed bias was introduced into the fire control system of ~~the~~ an interceptor causing the fighter to fire high but correctly in azimuth, ~~This~~ which placed the missiles above the drone where they were photographed. In addition, the rockets were Aeromites which left ~~a~~ dense ~~trail of smoke~~ smoke trails. By knowing base line and film speed of the cameras, rockets' miss could be calculated from the angle of the smoke trail image on the film. Once total miss distance was known it could ~~This distance~~ could then be compared with the deliberately introduced system error, and actual miss computed. The scheme worked well but it was considered unrealistic to introduce errors and for this reason was discarded.

Months passed with other unsuccessful attempts being made to use stereo pairs of cameras as FEI. During this time ~~and~~ some of the projects were completed without evaluation of ~~the~~ a fire control systems' most important function, its ability to hit a target. In June 1953 a concentrated program was started under Project APG/ADA/54-A and continued under Project APG/ADA/49-A-4 to develop ~~a method for~~ an evaluation method for ~~of~~ "E" systems' firing accuracy here at APGC, a method which if possible ~~could be used in the field~~ would be satisfactory for field use 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. ~~Amount some of the ones discarded are~~ Some of the methods discarded are listed below along with ~~the~~ [illegible] reasons for not being considered:

Note

A large development program ~~is under way using~~ is being conducted in an effort to develop this method into a workable F.E.I. Great things seem to be expected of this radar planar scoring method~~s~~ but it has many inherent limitations such as being unable to handle large numbers of rockets unless scoring range is drastically reduced. ~~It is extremely complex and sensitive~~ ~~Rec~~ Transmitting and receiving gear on the target is delicate and imposes many target limitations. Ground reduction gear is complex and this and associated gear would neccessitate a large maintenance and operating force. Expense seems to be ~~no~~ generally be no object, if it were this system would be immediately abandoned. For these reasons it was not considered feasible ~~as~~ for engineering of field use here.

1. Acoustic ranging by measurement of shock wave amplitude - Inherent inaccuracies in measurement place overall accuracies outside of acceptable limits.

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

3. Ranging from magnetic field in missile - Magnetic fields decrease too rapidly with distance.

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

5. Ranging by measurement of field strength of a radio transmitter mounted in rocket head - Number of transmitters required were considered excessive.

6. Photographing 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 lengths of tow cable used, unless some auxilliary device such as a flash head is used. Even in this case a large amount of auxilliary gear would be necessary as would prodigi uus amounts of data reduction and assessment.

7. Ranging by doppler radar - Can handle only small numbers of single rockets; elaborate accessory gear involved. [← add Note]

The above are just a few 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~~ out 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 are chosen the rockets' misses are ranged stadiametrically.

Fig 2 - Stad. Range

* this crossing of target plane ~~by~~ projectiles has acquired the misleading term 'crossover' ~~and it~~. For brevity it will be used.

the four methods ~~choses~~ chosen ~~are described in the order in which they are listed below~~ are listed below and described in the order given.

~~C~~ 1. Stereoscopic ranging as function of time

2. Sonic detection of ~~of~~ rocket crossover and stadiametric measurement of miss ~~for~~

3. Recording of rocket crossover by a strip camera mounted on the target and ~~sta~~ stadimetric measurement of miss

4. ~~Roc~~ Ranging of rockets & target by pulsed radar on a plane following the rockets path and ranging of miss by stadiametric means

Stereoscopic means of adding ~~the~~ depth to the other two dimensions ~~is~~ arises from the fact that objects distances appear different in each photograph taken by paralell but separated cameras ~~is~~ unless ~~the distances~~ distances are in a common plane parallell to the plane through the base line of the two cameras.

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

Messrs. Prince and Rush of our Data Reduction Branch predicted this and in order to verify this fact empirically, set up a stereo pair and simulated very accurately a firing pass using point sources of light as target and missiles. Results showed that it was impossible to choose the intersection of the almost parallel lines. Attempts to use this method at several bases have also resulted in inability to determine moment of missiles' cutting the target plane as the curves become parallel lines.

One use of stereo ranging which showed promise was plotting apparent distance of missiles from aim point against time. Curves from two cameras were then superimposed on a common scale, the point of intersection being moment of missiles' cutting the target plane. Frames corresponding to this time are chosen and miss distance determined stadiametrically. A pair or synchronous 35mm cameras with 4-inch lens were mounted in modified tip tanks of a F-94C and boresighted such that rockets 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 became apparent that with only a 40-foot baseline, combined with high angular velocity of targets on beam attacks, the point of intersection, i.e., moment of missile piercing target plane, could not be determined with necessary accuracies to make this a ~~suitable~~ feasible 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.~~ A 2.75" NOTS rocket generates a shock wave of very large magnitude which may be detected considerable distances away by a suitable tranducer ~~which usually is~~ quite similar to a microphone. A magnetic transducer was ~~used~~ coupled to an AM transmitter and attached to the harness of a tow target. This transmitter's signal was received in the tow craft and recorded on an oscillograph. A number of flights were made in September of 1953 with this gear in order to test and perfect ~~gear to record the shock waves.~~ it. During some missions shock waves were recorded but results were inconsistent. ~~A good deal of effort was expended~~ Development work was continued

Fig 4 Pickup

during the winter in an effort to refine system components. A very promising setup was devised with excellent response and low signal to wind noise ratio with pickup and FM transmitter 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 9-inch film moved continuously past eight lenses which through a system of mirrors covered a 360° plane normal to the longitudinal axis of the S-27 glider on which the camera was mounted. This camera will be turned on by a radio link, the transmitter of which is located in firing or chase plane. A rocket passing through the field of view of the camera will be recorded and the quadrant through which it passed and a rough estimation of its miss can be readily determined. By means of a common code recorded on both this camera and a strike camera on firing or chase aircraft, time of missiles' crossing target's plane may be related to strike film and miss 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 but its chief drawback is the complexity and large amount of accessory gear. Data recovery is also a problem. While this method might be useful in testing phases of a system, it obviously could not be used in field operations.

The fourth method to be tried consisted of recording the relative range of rockets and target from a radar A scope presentation and relating the instant of range coincidence to proper frames of a strike camera. This is perfectly straight forward with recording of rockets by radar being the only unique feature. Possibility of this at first seemed 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 sufficient return to be recorded by a radar set. Several people with a 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 ~~as~~ was built and installed in an F-94C to determine ability of a set to "see" rockets. This was completed in October 1953 but was not tested until April 1954 when a salvo of six free-fired rockets were easily recorded. Further tests were immediately made against targets with complete success. In an effort to prove feasibility of this system as a method suitable for field use, a complete system including radar, cameras, and A Scope was assembled. The R.T. unit of a G-30 was housed in a 120 gallon M-116 napalm tank along with an A Scope presentation which was photographed by a 35 mm camera whose shutter openings were synchronized with those of another 35 mm strike camera equipped with a 4" lens. This unit was hurriedly assembled suspended from an 86F and without preliminary tests taken to Yuma AFB where a large number of firings were being made. During the week, 8 firings were chased by this 86 with all 8 being successfully recorded. This instrumentation, in spite of its hurried design and construction and unnecessary complexity, required no maintenance. Several hits were recorded, thus affording a check against instrumentation accuracy which proved to be excellent. This was the first instance of a firing error indicator functioning successfully under operational conditions ~~in the field~~. Several conferences were held with members of Air Defense and Training Commands as to the most satisfactory configuration of this system and it was decided that a chase plane equipped with this F.E.I. offered more advantages than any others. A unit was then designed using, with one exception, AF stock items which is simple enough to be reproduced by any Air Force installation equipped with machine shops and facilities for maintaining an "E" system. A prototype of the unit was assembled and tested here and will be given to Yuma for further tests. Complete details of construction and operation of this FEI are given in the attached appendix.

Since the concept of tracking missiles with pulsed radar is relatively new and opens a realm of possibilities in the missile field in general, its specific application as a practical F.E.I. for E system scoring will be described in some detail. ~~This scoring metho~~

This scoring method is extremely versatile, requiring basically only two sources of data, radar video information and photographic data from a strike camera. We have built a series of these Radar-Optic F.E.I.'s using various configurations. They have fallen into roughly two classes--units mounted on the firing craft and using system's radar for video, and those mounted on a chase plane with its own radar. The system described in the following is the Model 2b which was designed for field use. It consists of an unmodified G-30 Radar feeding a 5 tube sweep and ~~wide~~ video chassis whose output is an "A" presentation on a 3JP11 Cathode Ray Tube. A modified lens combines the C.R. tube image ~~along one edge of tx 35 mm film~~ with strike photographs on 35 mm film. A 40 frames per second camera is used. Housing for the unit is an M-116 Napalm Tank with necessary changes. Weight is approximately 125 pounds and drag is only slightly higher than a normal tank. The chase plane flies a fairly tight formation with firing craft and during the last few seconds of a firing run, * foot note (radar voltage is applied to the magnetron only during this period to eliminate possibility of interference), radar and cameras are turned on for ten or fifteen seconds.

Restating the problem of photographic scoring: Ranging of rockets miss by motion picture photography is easily accomplished by stadiametric techniques if and only if a rocket is in ~~perpendicular plane normal to the longitudinal axis of the strike camer; i.e.,~~ a plane through the target parallel to the camera's film plane. First order accuracies are determined solely by the errors in detecting the cutting of target plane by rockets and relation of this to the strike camera film. Positional errors thus become a function of time errors as the target is in continuous linear motion. An example will illustrate: Assume that a single rocket crosses a target plane at some given time, missing the target aim point by 50 ft lead in azimuth. A photograph is taken 1/20 of a second later and miss-distance is assessed from this photograph. Elevation errors are negligible since vertical target velocity is zero and vertical rocket velocity relative to the firing aircraft arises only from gravity acceleration, which is on the order of 70 ft/sec at this point. Errors in azimuth will now vary directly as target speed. In this case, the missile will appear to have passed closer to the target by distance of target travel in 1/20 second. With a target speed of 300 ft/sec this error in azimuth would be 15 feet against an elevation error of 3.5 ft. It is obvious that the following relation holds for this specific case. Error in assessing miss-distance in azimuth (ft) equals target velocity (ft/sec) times error in determining time of crossing rocket plane (sec). Other much smaller errors are present in ranging technique but this time function error predominates. This of course leads to another problem. Since rockets are fired during a relatively long period of time* the rocket pairs must be followed separately and crossover time recorded for each pair, or one pair must be chosen and the time of only that pair's crossover be recorded. The first procedure is necessary for extremely accurate work in engineering tests. For field evaluation of system accuracy, it is enough to know where the so-called strike rocket or pattern centroid goes, for it is this rocket which is theoretically designed to hit target aim point. Since neither missiles nor fire control system is perfect, it is necessary to add rockets fired before and after the strike rockets to bring kill probability to a reasonable figure. It is the centroid which is scored with the system being described, although it is possible to score other rockets by interpolation. The Radar set used to determine range coincidence is an AN/APG-30, an airborne, low power, X band set commonly used for range data on A series sights. It would be desireable to have a set with more power and/or an antenna of smaller beam angle, but this is more than offset by such factors as small size, light weight, simplicity and ease of maintenance.

(*Approximately 1.25 seconds for an 89D; .084 seconds for 86D; and .168 seconds for an F-94 for full salvos.)

Range information is displayed on 3" scope in an "A" presentation. In this presentation, the scope beam is started coincident with transmitter output pulse at one edge of the tube and is swept linearly along X axis. Return pulse information is displayed along Y axis resulting in a scale on which distance of objects from the set may be determined. Relative, not absolute range is of primary interest here.

Since extremely short ranges are necessary ~~here,~~ some complications arise since the sets are designed for much longer ranges. Radar range factor is approximately 490 per micro-second, thus the .4 micro-sec pulse of a G-30 covers 196 feet in space. Objects closer together than this cannot be separated on a presentation. Ideally, pulse length would approach zero with position of each scanned object appearing as a single, narrow line. Unfortunately, practical limitations prevent this. A salvo of rockets appears as a single lengthened pulse, and the target as another relatively wide pulse. After a little experience, however, time of crossover for the centroid can be determined by inspection to within one frame of film run at 40 frames per second, even though pulse width occupies a relatively large amount of trace width.

At forty frames per second, the maximum azimuth time error is less than 1/40 second times tow speed. With present tow speed, this is on the order of 7 ft. Elevation error is negligible. Once the instant of crossover of the centroid is found, it is necessary only to select the centroid of the pattern from strike photographs and determine magnitude of miss stadiametrically. For ~~use with present targets~~ this evaluation, a slide projector capable of handling roll film would be desirable but not necessary. Experience here has shown that pattern centroid is extremely close to the center of a circle which encloses all but obviously wild rockets. Choosing this point becomes simple after observing several strike films. Once this point is chosen, magnitude of miss ~~is determined by comparison of image distance of centroid from aimpoint* to~~ ~~(See Page 16 for footnote.)~~

is determined by comparison of image distance of centroid from aimpoint* to image distance of target.

This sytem has much to recommend it. Indeed it is difficult to conceive of another system with the advantages of no target limitations, simple data reductions, a record of firing passes realistic enough to offer incentive to a pilot to study his performance and one which may be built maintained and operated by existing personell. To accurately evaluate a pass with any form of FEI it is necessary to have a record of pilots' performance to determine errors introduced from steering.

As mentioned before, the use of radar to obtain range data from missiles has many applications. It should be an extremely valuable tool in ballistics studies of velocity, acceleration, and pair dispersion. As an FEI system, its value is obvious. Many possibilities exist for its immediate utilization. There is no reason why the Model 2b FEI, as described in the appendix, should not be immediately reproduced for use at bases where firing programs are being conducted. At present, it seems impractical to equip individual fighters with this system, even though it would involve only s simple "black box" and a camera. Such an installation would be far simpler, and of vastly more use than the Nadar? equipment which is presently scheduled for installation. ~~It would be of vastly more use.~~ Value of an FEI system needs no further justification.

Use of this sytem should have far reaching effect on targets. Now instead of having to use banners as a crude attempt at scoring, the only function of a target need be provision of a radar target with realistic performance. A logical target configuration would be a radar reflector enclosed in a streamlined structure offering small drag. Once drag is reduced to a low figure, it is possible to reduce cable size, weight and drag as well as reduce tow reel size, weight and complexity. With this reduction in size, weight and drag, the

(*Aimpoint on a non-reflective banner with corner reflectors attached is of course the reflector. It will vary with reflective targets.)

next logical step is use of fighter craft to obtain realistic performance. Work has been done toward developing small low drag radar reflective targets by at least two companies, one of whose targets has the added feature of frangibility which should be extremely attractive for training use. A protype of a high speed target was recently constructed here and preliminary tests of it are under way. Drag of such targets are approximately 50 lbs at 300 knots T.A.S., while weight is 20 lbs or less. Radar reflector area is equivalent to a 3 ft diameter conventional round reflector. These are commercially available nylon fishing lines which have adequate strength to tow these targets. With small cable, reel sizes can be cut to reasonable figures. It is a relatively minor problem to design a reel such that it could be carried under the wing of a fighter in a nacelle which could also partially house the target for takeoff. Probably most practical of all, would be a target and small reel which could be attached to a conventional bomb or tank rack of a fighter. Once airborne, the target could be released and after completion of mission, both target and cable be detached from aircraft. This is an entirely feasible system even from an economic standpoint, since cable and target should cost less than $40. 00. At present, a marquisette target and reflector cost almost $300.00. Seven of the smaller targets, discarded after every mission, would provide much longer time in the air than a single banner plus ~~These targets would provide performances~~ performance which banners never can. If cost of maintenance of a present bomber type tow plane are compared to those of a fighter using smaller targets, target price becomes insignificant. Fighter type tow craft would provide individual squadron with presently lacking tow facilities. There are many squadrons which, if tow facilities were provided, could carry on firing programs rather than "shadow boxing" which is what the present training amounts to.

The radar optic scoring system described is a presently available for immediate application to scoring of "E" systems equipped interceptors. New, and presently unique, methods are involved but this is necessary if we are to close the ten year lag that presently exists in tow target facilities.

This F.E.I. system ~~coupled~~ will is ~~provide~~ an immediate, practical solution to the scoring of 'E' system equipped interceptors. Coupled with targets described ~~and a continuous~~ it ~~will~~ can bring ~~us up to date~~ the archaic ~~tow capabilities~~ target capabilities ~~up~~ up to date.