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To: D. E. Whelan

Date: 14 May 1969

Subject: Trip Report to Inspect Alpha System Bench Test

From: D. S. Nicholson

On April 30, 1969 the Alpha System sub-contractor's facility was visited to inspect the bench test assembly of the system. This bench system contained all the optics of the final system with the following exceptions:

1. No window
2. No folding mirror
3. The eyepiece was a preliminary version with radii checked by spherometer and not test plates and with one incorrect glass.

Items (1) and (2), if inserted into the system, would degrade performance somewhat and item (3), if corrected, should improve the performance slightly. The eyepiece as used, however, is probably indicative of axial performance. Any conclusions drawn concerning off-axis performance may not be valid since the glass error would effect field curvature and other off-axis aberrations.

The purpose of the bench assembly was to verify the design and its performance. By introducing arbitrary errors (tilts, spacings, etc.) into the assembly and measuring the emerging wavefront and comparing the results with computer calculations it was possible to verify the prescription and to increase confidence that the final system will perform as predicted.

In testing the bench assembly an off-axis paraboloid was used as a collimator. A parabola has very poor imagery off-axis and the bench setup did not permit the alignment of the collimator and telescope to be changed so that off-axis images could be examined. It was suggested that some indication of the off-axis performance could be obtained by examining an illuminated chart placed at the reticle plane. This test would be useful only if the real differences between the present and final eyepiece configurations were thoroughly understood. The sub-contractor stated that he would explore this possibility, but its utility would be doubtful unless the required analytical study were to be made.

Mr. Steve Robinson presented a table of test results compared with the predicted performance of the system. This table follows:

PARAMETER		PERFORMANCE PREDICTED EYE	TEST EYE	TEST 3X	TEST DIOPTOMETER
On-Axis Resolution	127X	6-1	6-3		7-1
	63X	5-1	5-2		6-4
	32X	4-1	4-2		5-1
	16X	3-1	3-2		4-5
Magnification	High	127X		127X	
	Low	16X		16X	
	Zoom Range	2.2:1		2.1:1	
Real Field	63X	$1^{o}3'$		$1^{o}5'$	
	16X	$4^{o}10'$		$4^{o}15'$	
Apparent Field		60^{o}-63^{o}		62^{o}-65^{o}	
Eye Relief		.77 in.		.70 in.	
Paraxial Exit Pupil Shift					
Due to Power Change		< .001 in.		.001 in.	
Due to Zoom		$< \pm$ .007 in.		.007 in.	
Exit Pupil Diam.	127X	2.0mm		2.0mm	

The numbers indicated for resolution are those for the USAF Standard Resolution Chart. They do not appropriately translate into lines/mm. but the predicted values represent angular resolutions which are better than the spec. values. Since the test results exceed the predicted values it is reasonable to assume that the device, when built, will very likely meet specifications. No additional information has as yet been generated which will improve our ability to predict operational utility as a function of these specifications.

The other items measured show compliance with the design. The larger than predicted apparent field of view results from the eyepiece design (to accommodate peripheral display) and will probably not occur in the final system.

This bench test tends to confirm our belief that the Alpha System design is a good one and that with careful quality control, it will perform to specifications.

The contractor also stated that his tolerance analyses indicated that the tracking mirror must be made to the following specifications in order to meet system specifications:

power	$< \lambda/10$
astigmatism	$< \lambda/20$
surface irregularity	$< \lambda/12$

It is assumed that the surface irregularity is a peak-to-peak value with the RMS value being approximately $\lambda/60$. This point has not been checked with the contractor nor have the specifications been verified. They seem reasonable for such a system, however.

The question of the effect of a thermal gradient between the objective and the reticle was discussed. The contractor stated that his preliminary analysis showed that a 23°F gradient would cause a 1.2 Diopter disparity between the image and the reticle and that a 10°F gradient would cause a .5D disparity. The contractor stressed that these numbers were tentative and that he believed that a shift greater than .6D could not be tolerated. Clearly this is an area which will require further study. Several approaches are possible to solve the problem if it proves troublesome. Thermal control to reduce the gradient to tolerable levels could be used. This will cost weight and power and system failure will result in performance degradation. A projected reticle with focus control can be used. This would entail additional design and might require penetration of a volume now containing equipment. A different reticle design might be used which is more tolerant to focus shift. Such a reticle might not be as effective in normal use as the present design, however.

The contractor intends to use a combination of Cicoil flat cubles and twisted pairs in the cabling passing through the roll axis of the tracking mirror. This cable assembly is required to twist $\pm 60^{\circ}$ over about an 8 in. length. The cable was cycled 300,000 times within a tube of the designed I.D.. After this test continuity checks were made and no open circuits detected. No insulation breakdown test was made and (as far as is known) no continuity checks made during the twisting operation. It is recommended that the adequacy of this test be verified by GE. The Electrical and Optical Department will also make a preliminary evaluation and report.