C05-0989
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SPECIAL HANDLING

PROPOSAL: A CONVERGENT STEREOSCOPIC CAMERA SYSTEM

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I. SCOPE AND OBJECTIVES

It is proposed that stereoscopic coverage be incorporated into the Corona reconnaissance subsystem as an aid to photo interpretation. This may be accomplished by mounting two panoramic cameras on converging planes within a lengthened fairing, each camera feeding its film onto a separate spool in a modified cassette. Continuous coverage will be obtained over target.

Since it is the purpose of this proposal to aid photo interpretation, design parameters should be chosen to provide additional coverage where it is needed most. These areas of emphasis are determined by the special tasks of interpretation and by the specific weaknesses of monocular photography.

The targets of most interest to the intelligence community are man-made structures and objects and their immediate topographical environment. Often, and especially in military areas, the shape of such structures and their detectability is subject to rapid change with time as may be exemplified by missile launching sites being constructed and then camouflaged, and the movement of military aircraft and ships from base to base, or dispersion among civilian facilities. Previous experience has shown that detectability and interpretation are aided by the ability to view such objects in stereoscopic photography where their third dimension of height is apparent.

The greatest weakness of single picture information is found where the objects in question appear so small on the photograph that their significant distinguishing features are near the limit of resolution.

Another weakness is the loss of information when a three dimensional structure is shown in flat projection. In this case, confusion of actual structural details and their shadows often leads to misinterpretation.

It is also known from previous experience that the smallest stereoscopically recognizable ground parallax is a factor of about 1/2 to 3/4 smaller than the smallest monocularly resolved distance. Mathematically, this may be stated:

$$\Delta P\,min = \left(\frac{1}{2} \cdots \frac{1}{4}\right) \frac{1}{R_g}$$

where ΔP = difference in parallax

and R_g = ground resolution in feet.

Applying this to the existing Corona system, which has a monocular ground resolution capability of approximately 25 feet, resolution could be improved to the range of 6.25 to 12.5 feet. This should permit identification of ground objects 15 to 30 feet on a side as compared to approximately 60 feet for monocular photography.

In order to obtain stereoscopic photography, it is proposed to use two C Prime or C Triple Prime cameras mounted as convergent obliques. The technique to be employed should meet the following requirements:

(1) Time lapse between two pictures of a stereo pair should be minimized; i.e., stereo coverage should be obtained by a fore and aft look as the vehicle passes over the target (see Figure 1).

(2) The stereo effect which depends upon the base/height ratio should be maximized as far as compatible with good viewing conditions. Base/height ratios of well over 1:1 have actually been used with several types of wide angle photography and

have proved satisfactory. It should be noted, however, that large stereo angles in excess of 30° - 40° increase the photographic scale at the expense of ground resolution, while yielding very little additional height discrimination.

Base/height ratio, H, can be expressed in terms of angle of convergence as:

$$H = 2 \tan \frac{a}{2}$$

since

$$\Delta h = \frac{\Delta P_{min}}{H}$$

then

$$\frac{\Delta h}{R_g} = \frac{1}{K} \cdot \frac{1}{\tan} \cdot \frac{a}{2}$$

Where k is a subjective constant between 2 and 4, R_g is the value of a ground resolution element, a is the angle of convergence, and Δh is the detectable difference in height of object.

Figure 2, attached, denotes the stereo angle relationship. An optimum region of 27° to 52° indicated. Vehicle altitude and velocity plus present instrument capability and exposure requirements suggest about 30° as a suitable angle of convergence falling within the optimum region. This angle of convergence can be obtained with minimum modification to our fairing design and camera supporting structures.

If requirement (1) above is met, the usual conditions of stereoscopy will always be closely approximated for a small area to be viewed. Consequently, in any stereo pair, corresponding domains will have very nearly the same scale. This means that satisfactory stereoscopic fusion can be obtained with any conventional stereoscope without rectifying the photographs. For the stereoscopic examination of extended areas and particularly for the correct interpretation of topography, rectification is recommended in order to avoid gross deformation of the stereoscopic terrain model.

II. DESIGN

A. Engineering Prototype

Two (2) Corona cameras are presently available at our facility. An engineering prototype can be established in the earliest possible time by mounting these instruments on the proper planes in a modified fairing.

The cassette for this unit can be built in Boston. The recovery vehicle can be modified from the present Mk 5 vehicle if one of these units can be made available to us.

With much of the hardware usable, "as is" or with little modification, it is conservatively estimated that the engineering prototype can be assembled and in readiness for a systems functional and environmental test program within 24 weeks from design start.

B. Operational Units

There is nothing radical or new in this proposal outside of the basic concept; much of the hardware has been proven in successful operation. The C Triple Prime instrument and the recovery system closely follow and continue the line of development established in the Corona programs. Because of this, concept-to-operation time can be drastically reduced. We estimate that a first launch could be accomplished within nine (9) months from design start.

The complete operational unit would consist of two (2) C''' instruments, a modified fairing, a modified recovery capsule and cassette for the Mark V recovery vehicle, and the Agena/Thor combination.

The Agena vehicle is designed for second stage orbital boost with

with any of several first stage boosters. The Agena-Thor combination is recommended since it is operational and has proved its dependability in the Discoverer project. It is readily adaptable to the stereoscopic subsystem. The ability of the combination to carry weights imposed by the stereoscopic subsystem and recovery vehicle are discussed below.

C. Agena-Thor Propulsion Capability

The Agena-Thor propulsion system capability for placing the estimated operational satellite system weight on orbit is indicated in Figure 3. The circled point represents nominal 4-day mission operational parameters for an orbit having a 93.8 minute period, approximately 0.033 eccentricity, and a perigee altitude of 130 statute miles, assuming the present VAFB launch configuration, with 172 degree launch azimuth. As shown, the 1960 current propulsion systems (3-sigma minimum) capability can provide the energy necessary to boost the estimated 2450 pounds of satellite stage hardware into the design orbit, including an allowable total payload system weight of 670 lbs. This "empty" weight is different from total "burn-out" weight by the amount of residual propellants, control fluids, etc.

The performance is derived from current LMSD propulsion systems "planning" capability for Thor DM-21 (165,000 lb. thrust) booster and Agena 8096 engine (specific impulse, 289.5 seconds) with the integrated subsystems weights for the proposed operation.

As suggested above, this performance should be somewhat conservative since it is based on (minus) three times the standard deviations expected in system parameters. Such conservatism is deemed necessary at this point in the proposed system development to allow for usual final "empty" weight growth and a practical degradation in estimated propulsion performance derived from experience.

D. Weights

Weight estimates for the camera system are given in fig. 4. It will be observed that with sixty pounds of payload and using the C instruments, total weight will be 661 lbs., or 9 lbs. below the conservative limit noted above. Since it is expected that C Triple Prime instruments will be 5 to 10 lbs. lighter than C instruments, 80 lbs. of payload appears to be feasible.

With this weight carrying capability, the real constraints on film footage are the present configurations of the Mark IV or Mark V recovery vehicles. Primarily this is a space and balance problem. Sixty pounds, spooled on two 16" diameter spools, can be handled with relatively minor changes to existing designs. For 80 pound payloads, redesign of the recovery vehicle and analysis of the re-entry mechanics and heat shield requirements for the increased weight will be necessary. It is interesting to note that 30 pounds of payload of the J-16 type currently used is approximately 5500 feet in length as compared to 7200 feet for the 40 pound weight.

E. In-Flight Operation of Instrument Subsystem

It is proposed that the two cameras be turned on simultaneously and operated continuously as the vehicle passes over the target area, with no attempt to obtain precise synchronism. This means that a portion of the target may not be covered by stereoscopic photography or that some payload must be expended over non-target areas. From predicted orbit parameters and instrument cycling time, it is estimated that approximately 10 frames (25 feet) of non-stereoscopic coverage would be obtained each pass. It is considered that this is an acceptable trade-off compared to resulting weight, complexity, and reliability problems of synchronizing devices to result in timed photography by one camera or other. It should also be pointed out that the non-stereoscopic coverage should not be considered a total loss as it may still be exploited for intelligence purposes, assuming it is obtained over land areas adjoining the target area.

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III. COVERAGE

Considering 4-day operations projected toward the nominal orbit, having a 93.85 minute period and a perigee altitude of about 130 statute miles, it might be noted that a single mission could obtain complete coverage at latitudes above 63-degrees north latitude over an area of interest limited by the amount of film available. The control of orbit parameters anticipated for the proposed operational period -- dependent upon the satellite guidance and control systems as well as on propulsion impulse control limitations -- would indicate that actual operational periods would fall within ± 0.5 minutes of prescribed conditions. Considering coverage then, for a normal variation of operational parameters, it might be noted that complete coverage of desired areas below the aforementioned 63-degrees north latitude would require combination of the results of at least two properly related missions. That is, complete coverage of areas north of 60° N. latitude could be obtained from the complementary results from a 93.8 minute orbit operation and that from a 94.05 minute orbit, above 50 degrees north covered by the results from 93.7 and 94.35 minute period operations and so on.* Capability for complete coverage of all areas above 30-degrees north latitude could be obtained from two missions, one on an orbit period between 94.6 and 95.0 minutes coupled with a properly chosen period near 90.2 minutes.

* NOTE: These combinations are not precisely prescribed since exact complements require consideration of shifts in combination patterns around the globe for multiple operations.

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Similarly, looking at the general operational coverage capability, still assuming (conservatively) that all operations be continued on orbits having relatively low perigee altitudes of the order of 130 statute miles, it could be assumed that excellent coverage of the entire area of interest could be obtained from 3 to 5 missions having periods with normal distribution about the nominal 93.85 minutes, coupled with the results from 3 or more missions having periods distributed about a properly chosen (lower) second period.

This estimated coverage assumes a total camera view angle of 70-degrees, orbits having an initial perigee near 22-degrees north latitude, shifting northward 3 to 4 degrees per day and an earth-shape approximated by the Hough ellipsoid.

IV. GROUND SUPPORT EQUIPMENT

Costs of ground support equipment can be held at surprisingly low figures. The reason for this is the fact that most of the equipment has already been designed and has been put into use in connection with the existing programs. With some modification this equipment can not only be adapted to the stereoscopic camera system but in some cases can be used for the simultaneous checkout of two different systems.

A large proportion of the costs shown, therefore, reflect the need for the new handling fixtures that will be required.

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V. AREAS OF RESPONSIBILITY

It is proposed that the existing relationship between IMSD and Itek for the C Triple Prime be retained for this project. IMSD will be the systems manager and will be responsible for production of the Agena B, integration of the instrument system and REC system with the vehicle, and launch operations at Vandenberg Air Force Base. IMSD will also be responsible for procuring the Mark V recovery vehicle from General Electric MSVD. It is planned that IMSD will be totally responsible for preparing the recovery vehicle for flight. Itek Corporation will be responsible for the design and fabrication of the camera and cassette, which constitute the instrument subsystem. Itek will be expected to provide technical support for the checkout and flight preparation of the instrument subsystem.

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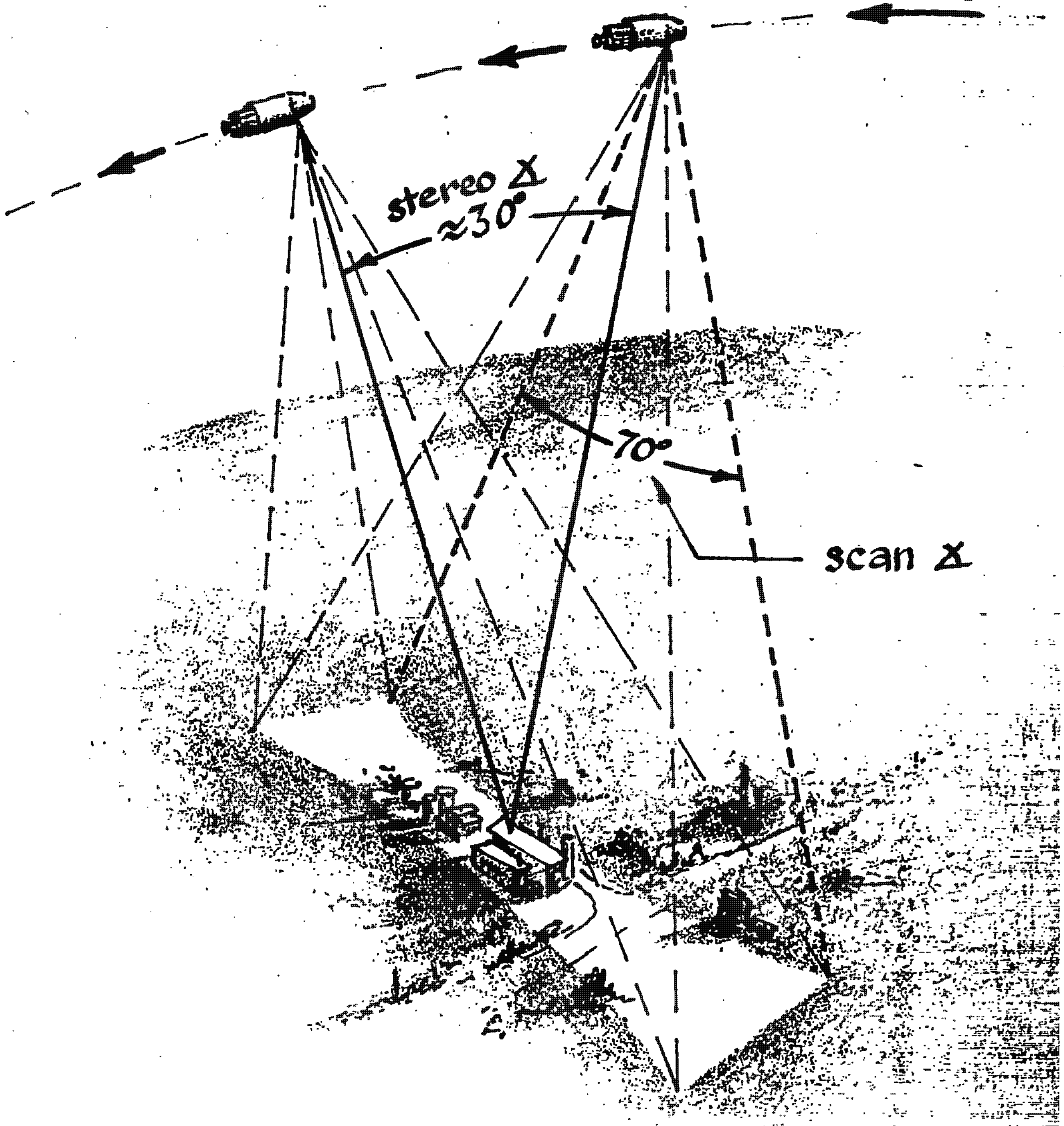

CONVERGENT STEREO CONCEPT
fig. 1

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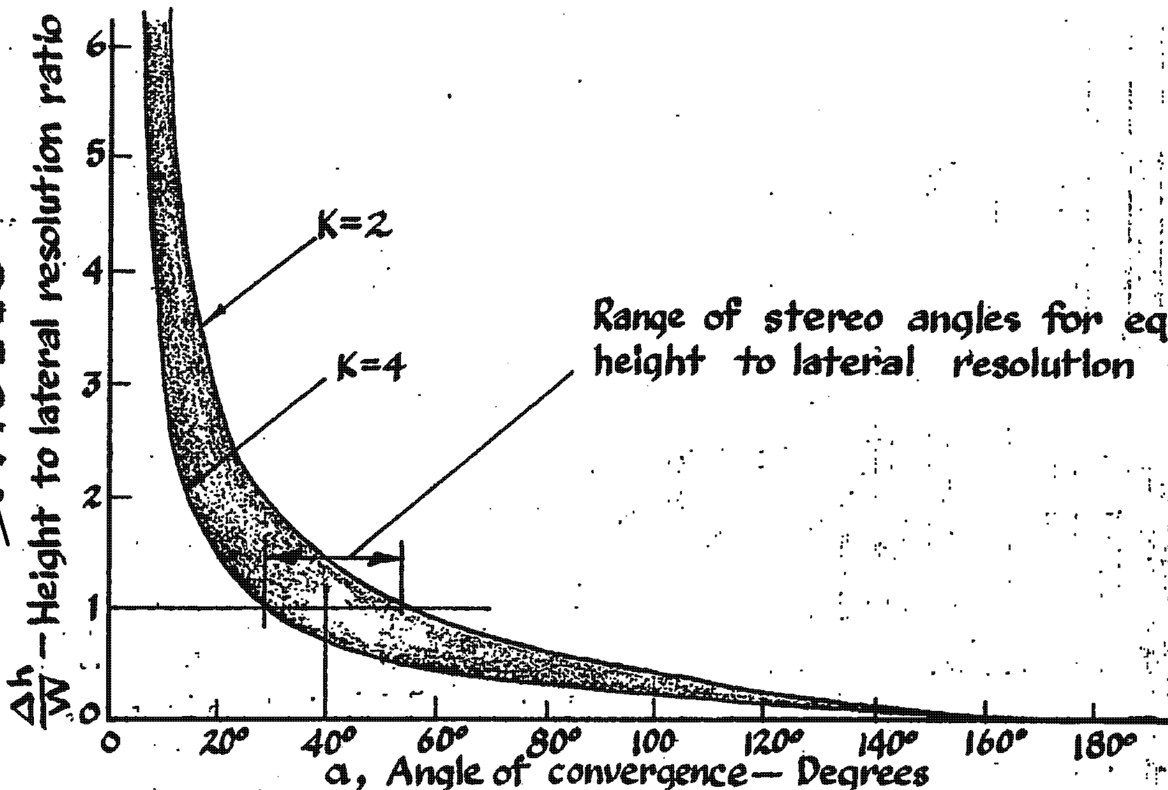

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fig. 2 STEREO ANGLE RELATIONSHIP

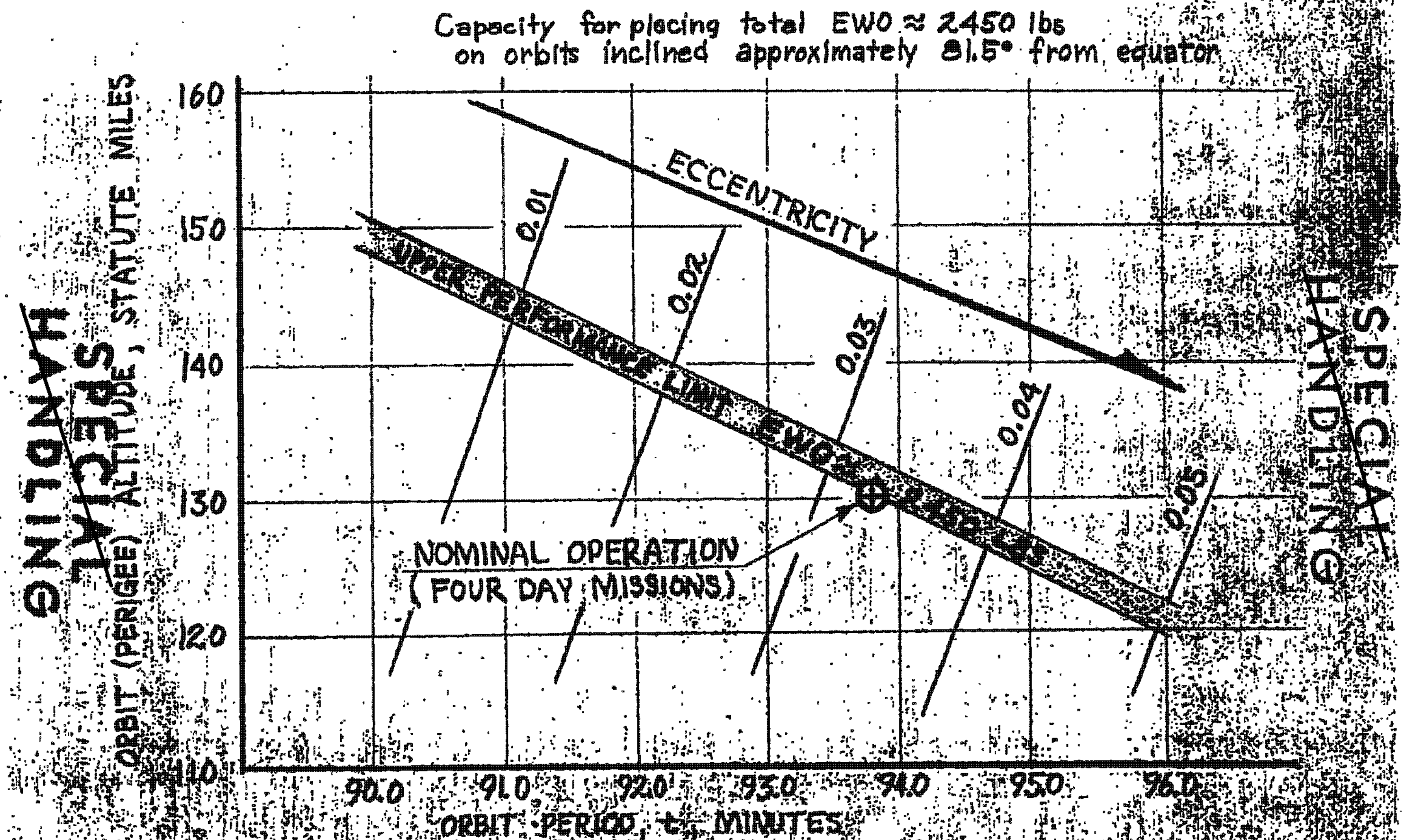

Fig. 3 AGENA-THOR PERFORMANCE CAPABILITY

FIG. 4 WEIGHT ESTIMATE

The estimated weights of the compete payload system is outlined below:

	With C	With C'''
I. FAIRING ASSEMBLY		
A. Instrument (2), including the clock	220 lbs.	200 lbs.
B. Forward Fairing, including electrical harness, mounting rings, and accessories	55 lbs.	55 lbs.
C. Aft Fairing (added) including electrical, special mounting structure, etc.	65 lbs.	65 lbs.
Subtotal	340 lbs.	320 lbs.
II. NOSE CONE ASSEMBLY		
A. Nose Cone with Recovery Items, less GFE	240 lbs.	240 lbs.
B. GFE - Cassette	18 lbs.	18 lbs.
Subtotal	258 lbs.	258 lbs.
III. PAYLOAD		
A. Payload	60 lbs.	60 lbs.
B. Leader	3 lbs.	3 lbs.
Subtotal	63 lbs.	63 lbs.
TOTAL WEIGHT	661 lbs.	641 lbs.

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Fig. 5 CONVERGENT STEREOSCOPIC PROPOSAL

Preliminary Cost Review

Two-Flight Program

Cameras -	
2 C's, modified	$ 100,000
2 B's, modified	100,000
Fairings -	
2 Prototypes (1 Qual.)	300,000
1 Flight Model	80,000
Cassettes -	
2 Prototypes (1 Qual.)	60,000
1 Flight	20,000
Recovery Capsules -	
3 Mk V (modified)	900,000
GSE	100,000
Engineering and Labor	600,000
Testing	100,000
Material	150,000
	$ 2,510,000
Fee at 7%	175,700
Sub-total	$ 2,685,700
Seven Additional Flight Units	$ 7,020,000
Fee	491,400
Sub-total	7,511,400
Total for Nine Flights	$10,197,100

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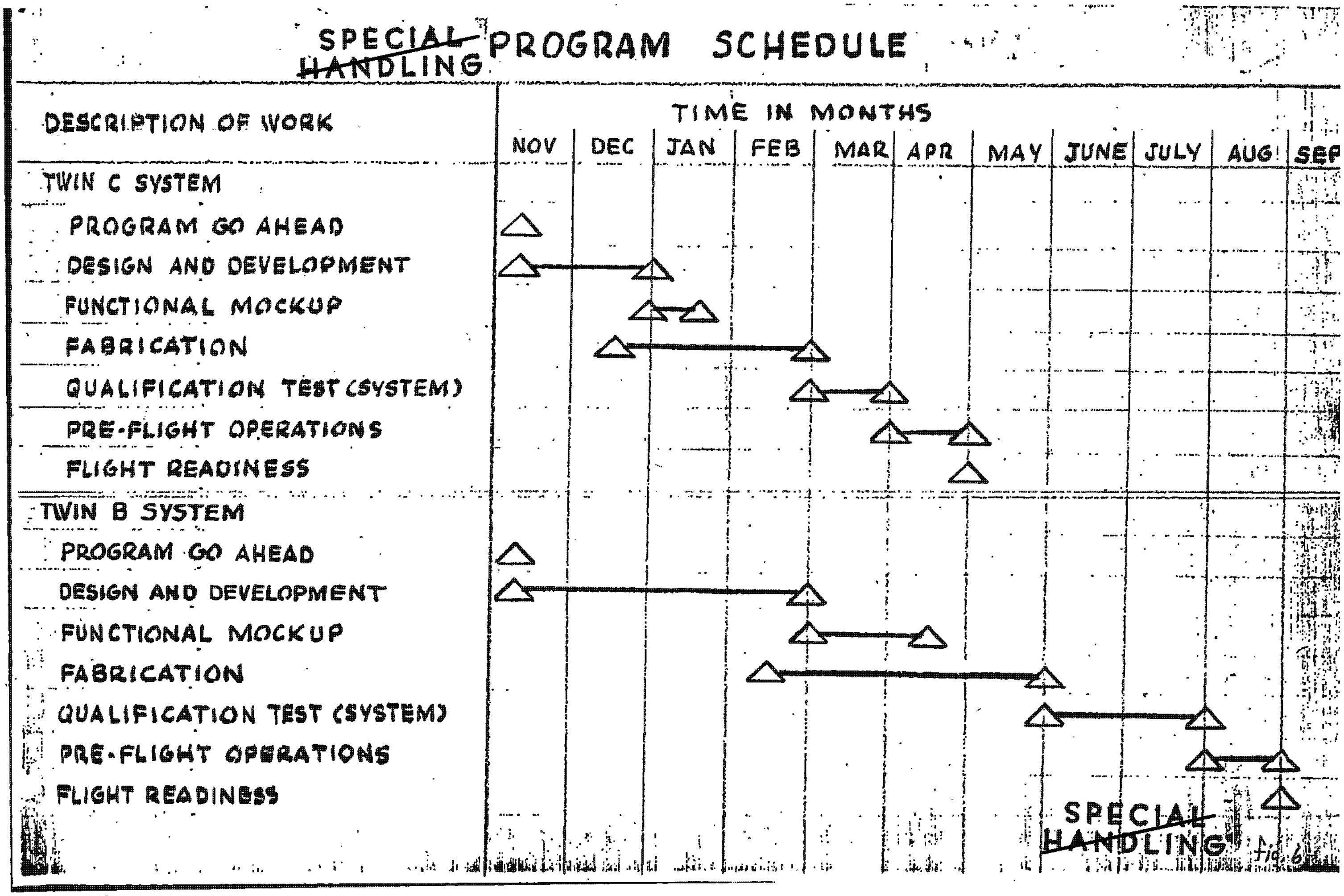
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PROGRAM SCHEDULE
DESCRIPTION OF WORK
TIME IN MONTHS
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
TWIN C SYSTEM
PROGRAM GO AHEAD
DESIGN AND DEVELOPMENT
FUNCTIONAL MOCKUP
FABRICATION
QUALIFICATION TEST (SYSTEM)
PRE-FLIGHT OPERATIONS
FLIGHT READINESS
TWIN B SYSTEM
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Fig. 6