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PROPOSAL FOR A PAYLOAD INERTIA BALANCE SUBSYSTEM (PIBS) FOR THE CORONA J-3 SYSTEM

NOVEMBER 7, 1966

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1.0 INTRODUCTION

1.1 Purpose

This proposal describes a Payload Inertia Balance Subsystem hereafter called PIBS. Its basic purpose is to provide momentum balance for the J-3 payload during periods of camera start-up and shut-down so that the J-3 Panoramic cameras may be started and shut down independently of each other. This capability permits delaying start of the aft looking camera for the time interval represented by 6 frames when the J-3 payload is operated in normal stereoscopic mode. It also permits shut-down of the forward looking camera at the time of departure from a target area and shut-down of the aft looking camera later at the time interval represented by 6 frames of camera operation. Incorporation of PIBS into the J-3 Payload will result in the following advantages:

a) Five frames of film (1 frame allowed for start-up and shut-down) are saved for each photographic operation on each camera by avoiding running cameras before and beyond the target area to obtain stereoscopic coverage. For a total mission, the total film saved is 15 percent.

b) While the same advantage might be gained by allowing the Agena attitude control system to correct the roll rates induced by delayed camera starts and shut-down, PIBS is more efficient as its weight is less than the control gas that would be expended. Calculations show that 90 pounds of vehicle gas and bottle weight would be required. PIBS weight is estimated to be 24 pounds.

c) It removes a theoretical degrading image motion from the photography. Due to the nature of smear, the result of removal of this smear may not be physically detectable by the photographic interpreter. However, its effect on precision measurement accuracies may be of noticeable significance.

1.2 Requirements

In its present configuration, i.e., without PIBS, it is planned to begin each photographic operation of the J-3 system by simultaneously starting both panoramic cameras. Each operation is terminated by simultaneously stopping both cameras. It is readily seen that this mode of operation is inefficient as it uses excess film to obtain stereoscopic coverage of a given area. This arises because of the rigid mounting of the two cameras to maintain a fixed angle of convergence. It is also apparent that this mode of operation results in obtaining six frames of non-stereoscopic coverage with the aft-looking camera at the start of an operation and six frames with the forward looking camera at the end of an operation. This non-stereoscopic coverage has limited usefulness for either intelligence or cartographic operations.

For forecast typical missions with the currently used 3.2 mil thick film, the number of starts and stops should be approximately 180. Assuming 1 frame is of marginal value due to camera acceleration and braking characteristics, simultaneous starting and stopping is wasting five frames of photography in non-stereoscopic coverage. This means that 900 more stereoscopic pairs could be obtained which is a 15 per-cent gain per mission. In the case of ultra-thin base film and the recent trends in shortening camera operational bursts, the number of camera starts could be considerably higher. If the design limit of 400 starts stated in the J-3 Pressure Make-up Unit Requirements is used as the upper limit, the resulting saving of film is equivalent to 2000 stereoscopic pairs.

The intrinsic value of this saved film is easily recognizable. It may be devoted to additional intelligence coverage for search or it may be allocated to the cartographic users thereby enabling them to accumulate coverage at a higher rate. The saved film for an 180 start mission represents three times the film presently allocated to the cartographic community.

1.3 Methods of Satisfying Requirements

It is possible to permit delayed starts of the J-3 instruments in the present system. As a result of the momentum unbalance, roll rates as high as 150 degrees per hour are induced. As this exceeds the roll threshold of the Agena attitude control system by a factor of 2.5, the

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roll jets are activated and remain activated until the roll rate and roll attitude again lie within the control deadbands of the system. Calculations shows that for each delayed start and stop operation, 1/4 pound of control gas will be expended. Over the duration of an average forecast J-3 mission on 3.2 mil thick film, there are 180 operations. Therefore, 45 pounds of gas would be required. Current design practice shows that for each pound of gas, one pound must be added for bottle structural weight. Hence, the potential weight requirement is 90 pounds. With ultra thin base film where the maximum number of starts may be as high as 400, 100 pounds of gas would be required and 200 pounds required for gas and bottle. This is sufficiently inefficient in either case to justify seeking other means to overcome the momentum imbalance of delayed starts.

Analysis of the amount of momentum imbalance is shown on Figure 1. Four possible methods of overcoming this unbalance were considered. Each of these methods is briefly discussed below:

1. Increase the roll inertia by weights on extendable booms. Increasing the roll inertia will reduce the roll rates if the boom can be made stiff enough (which would be difficult for the small angle the vehicle rolls through). However, the roll momentum would be unchanged - still equal to the unbalance momentum of the instrument. Since the amount of control gas required is basically a function of the momentum unbalance, increasing the roll inertia would provide

MOMENTUM UNBALANCE
MONO OPERATION

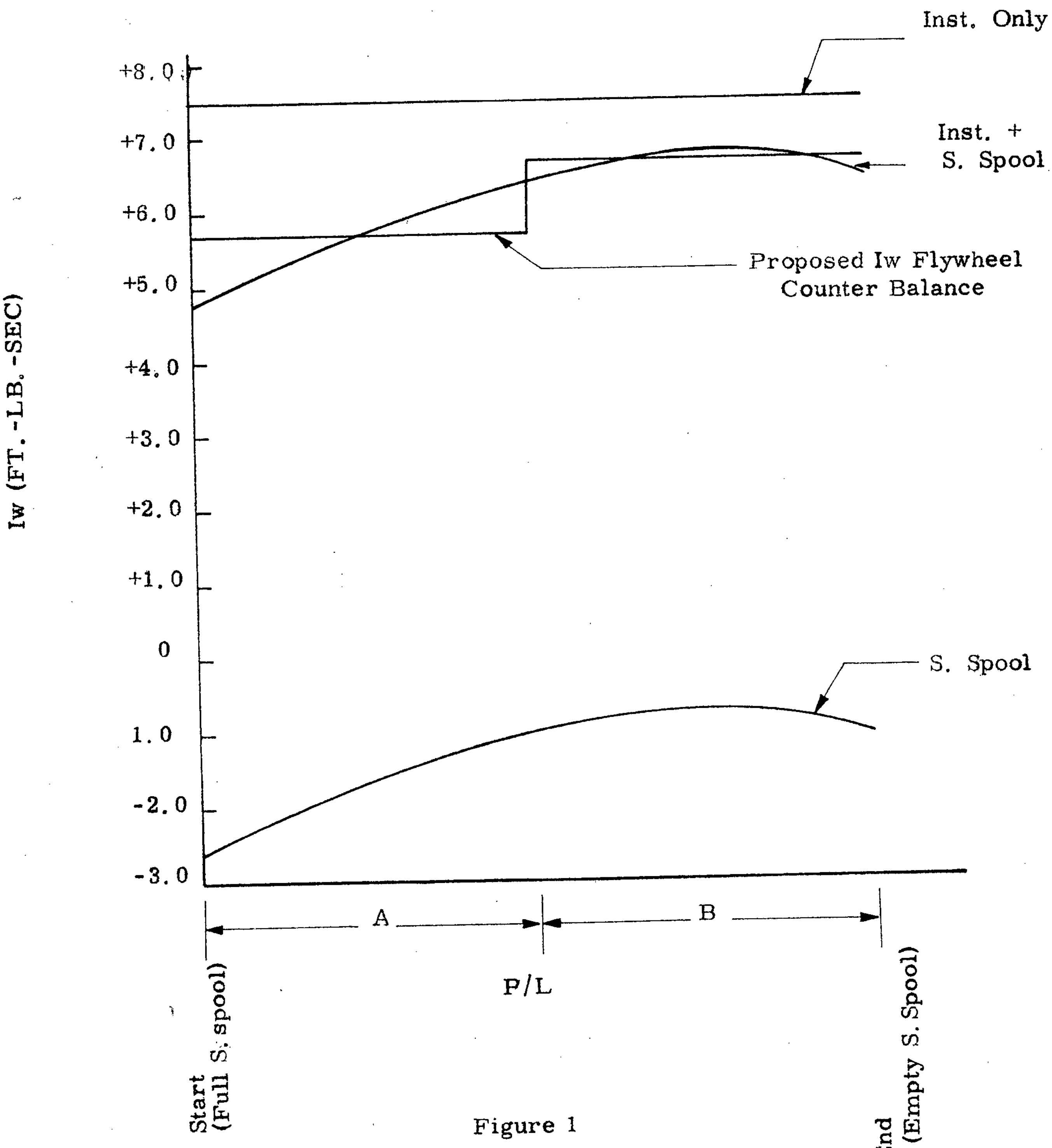


Figure 1

very little help in reducing control gas consumption.

2. Put roll control gas jets out on a boom. These jets need not be the Agena control gas jets, but could be additional jets that start to discharge when the instrument starts and shut off when the instrument is at speed. The boom simply gives the jets a better lever arm and the resulting gas savings will be the ratio of the boom length to the present Agena control gas jet radius. In addition to a reduction in the amount of control gas used, the vehicle roll rates would be reduced. In this case, deflection of the boom is less detrimental since the jet will move in space instead of keeping the mass fixed in space and letting the vehicle roll to produce the required deflection in the boom. (There will be a time lag while the boom tip moves to the deflected position.)

3. Combine methods 1 and 2. No advantages of adding mass to the jets on the end of the boom can be thought of. It would either increase the lag time for the jets to load the cantilever beam or require a very stiff boom.. The added mass would not reduce the amount of control gas required appreciably, and it would increase the weight of the system.

4. Install a momentum wheel. This could be an open loop system installed mechanically and electrically independent of the instruments. The fly wheel would start when the first instrument starts, accelerate approximately with the instrument and come to speed when the instrument comes to speed. It would decelerate when the second instrument starts and come to a stop when the second instrument is at speed. The fly wheel would reverse this procedure on instrument shutdown. This scheme requires but one motor and one fly wheel. No power will be required when both instruments are at speed or when both instruments are off. If it is desirable to have a pick-off to tell instrument speed and acceleration, this could be done with a decoder or tachometer from an idler roller between the supply and the instrument. The overall result would be both a reduction in gas consumption and a reduced roll rate.

It is noted that none of the four systems provides perfect momentum balance. Choice of system is dictated by system complexity, weight and degree of compensation achieved. A brief comparison of these characteristics shows that the inertia or momentum wheel is inherently more efficient than the other three approaches in terms of weight and system complexity.

It is also possible to achieve a high degree of inertia balance during critical periods of starting and stopping the cameras with minimum time lags. For these reasons, the momentum wheel design is selected.

2.0 TECHNICAL DESCRIPTION

The PIBS Subsystem consists of a momentum wheel driven by a reversible DC motor and controlled by a tachometer sensing J-3 camera speed. The momentum wheel is constructed so as to concentrate its mass at its circumference. This gives it a high moment of inertia. The principle of the bicycle wheel employing wire spokes to give the wheel rigidity will probably be followed in construction of the wheel.

The wheel will be driven by a small electric motor similar in type to that used to drive the J-1 camera system.

A tachometer sensing camera speed will control the voltage to the motor and hence its speed, allowing synchronization of the camera and momentum wheel to maximize the inertia balance of the system. The power consumption of the motor and tachometer assembly has been estimated at 3.0 watt-hours per operate period. For the 180 start mission, 540 watt-hours are required. For the 400 starts for missions employing ultra thin base film 1200 watt-hours are required. This is within the power margins for the J-3 mission without additional batteries.

The weight of the momentum balance system is:

Motor	2.5 lbs.
Gearing	1.0 lb.

Flywheel	10.0 lbs.
Tach and Support	.5 lbs.
Support Structure	5.0 lbs.
Electrical boxes and wires	5.0 lbs.
Total System Weight	24.0 lbs.

Installation of the PIBS is shown in Figure 2. Operating principles of the PIBS are illustrated by Figure 3, Operating time is shown in Figure 4.

A proposed electrical design for PIBS is shown in Figure 5. This design will use flight proven components to maximize reliability. Command functions will be accomplished through relays. No new command requirements are imposed by PIBS.

3.0 ENVIRONMENTAL SURVIVAL CAPABILITY

The equipment shall be proven capable of surviving launch and operating use environments. This shall be demonstrated by qualification testing of a production model and unit acceptance and flight systems testing of the flight units.

3.1 Qualification Testing

Qualification testing shall be accomplished to the stress levels specified in subsequent paragraphs.

3.1.1 Sinusoidal Vibration

1/2 inch peak to peak from 5 to 15 cps

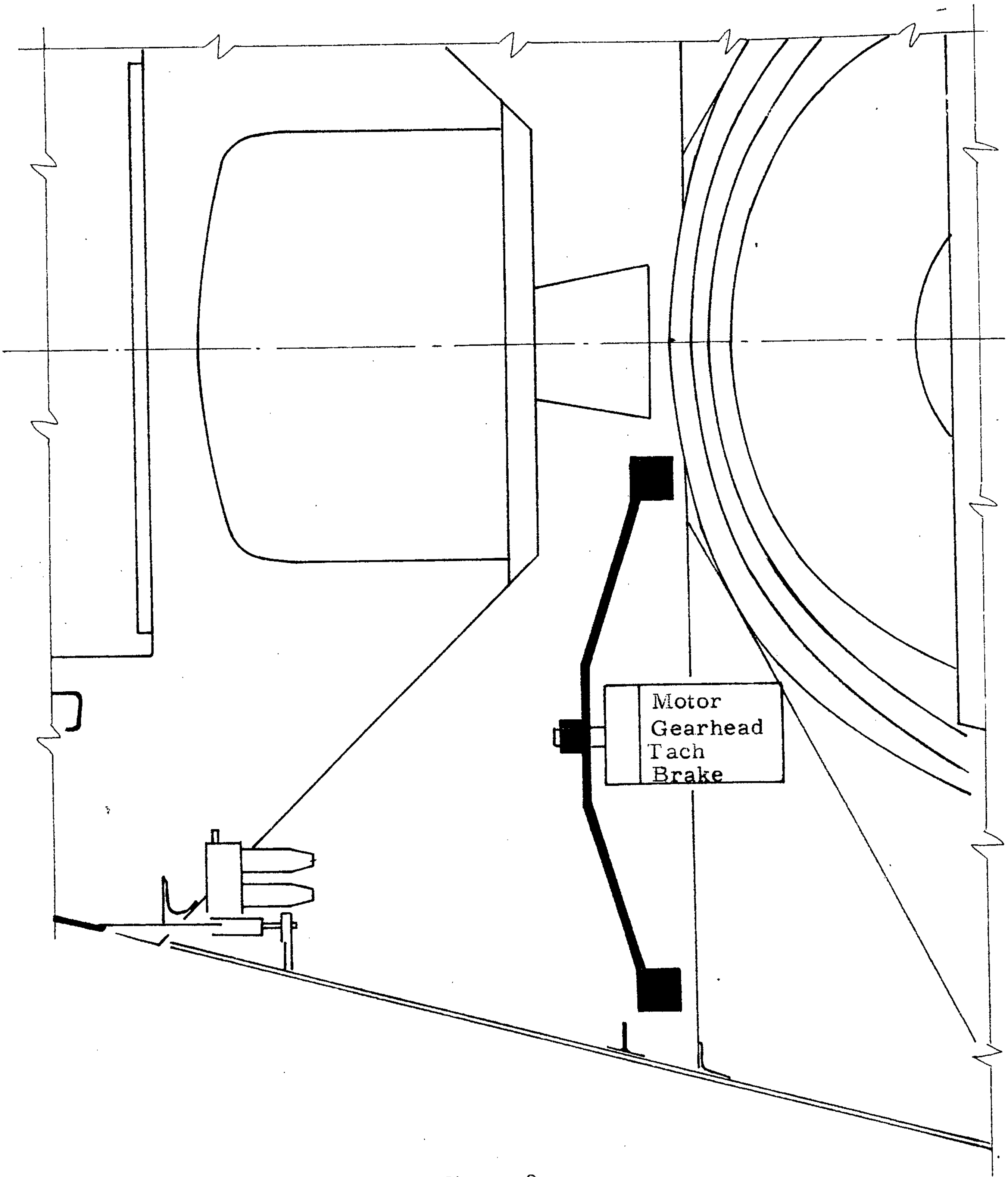
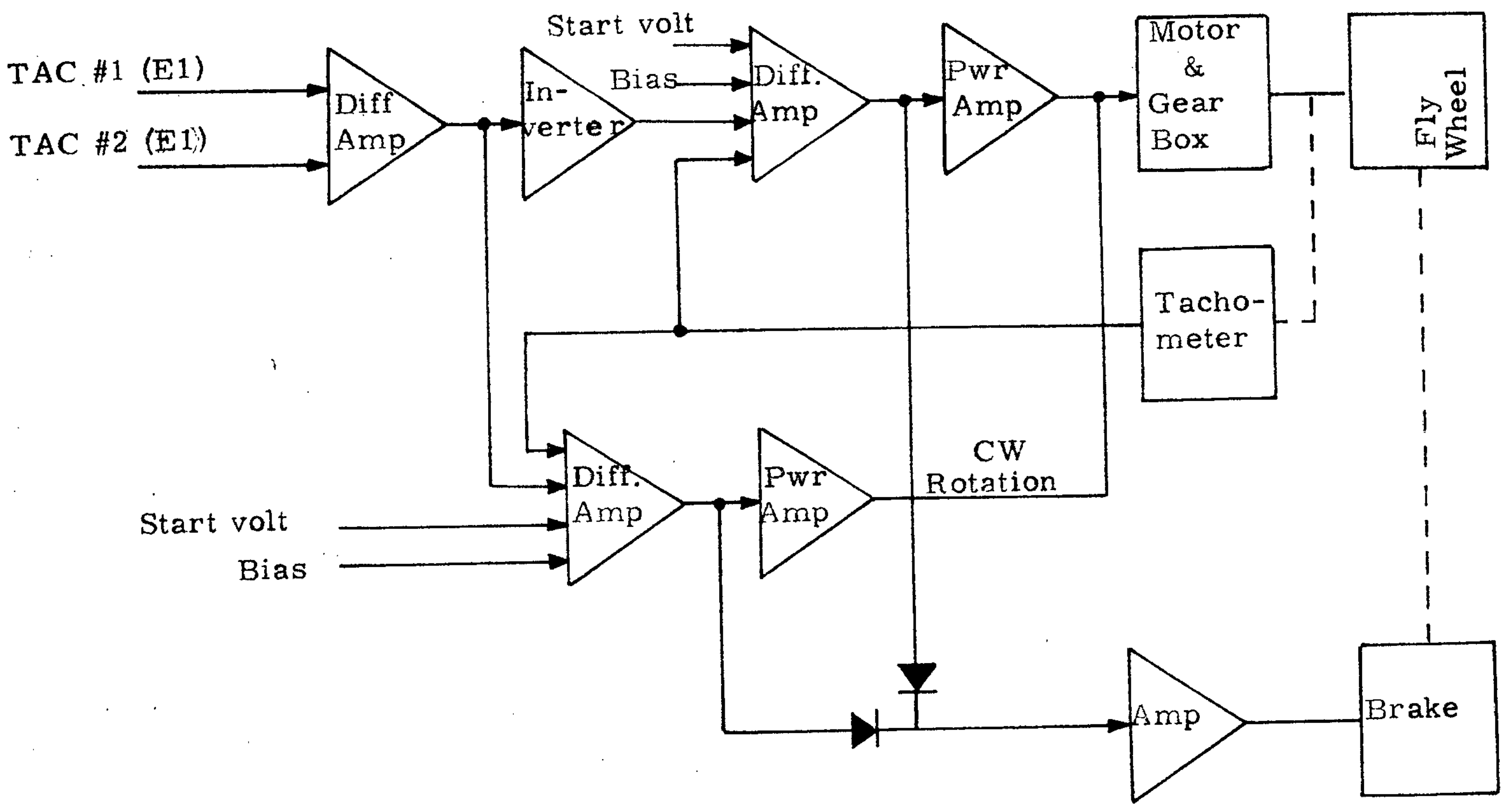


Figure 2

PIBS INSTALLATION IN VEHICLE



PAYLOAD INERTIA BALANCE BLOCK DIAGRAM

Figure 3

FLYWHEEL ROTATION VS. TIME

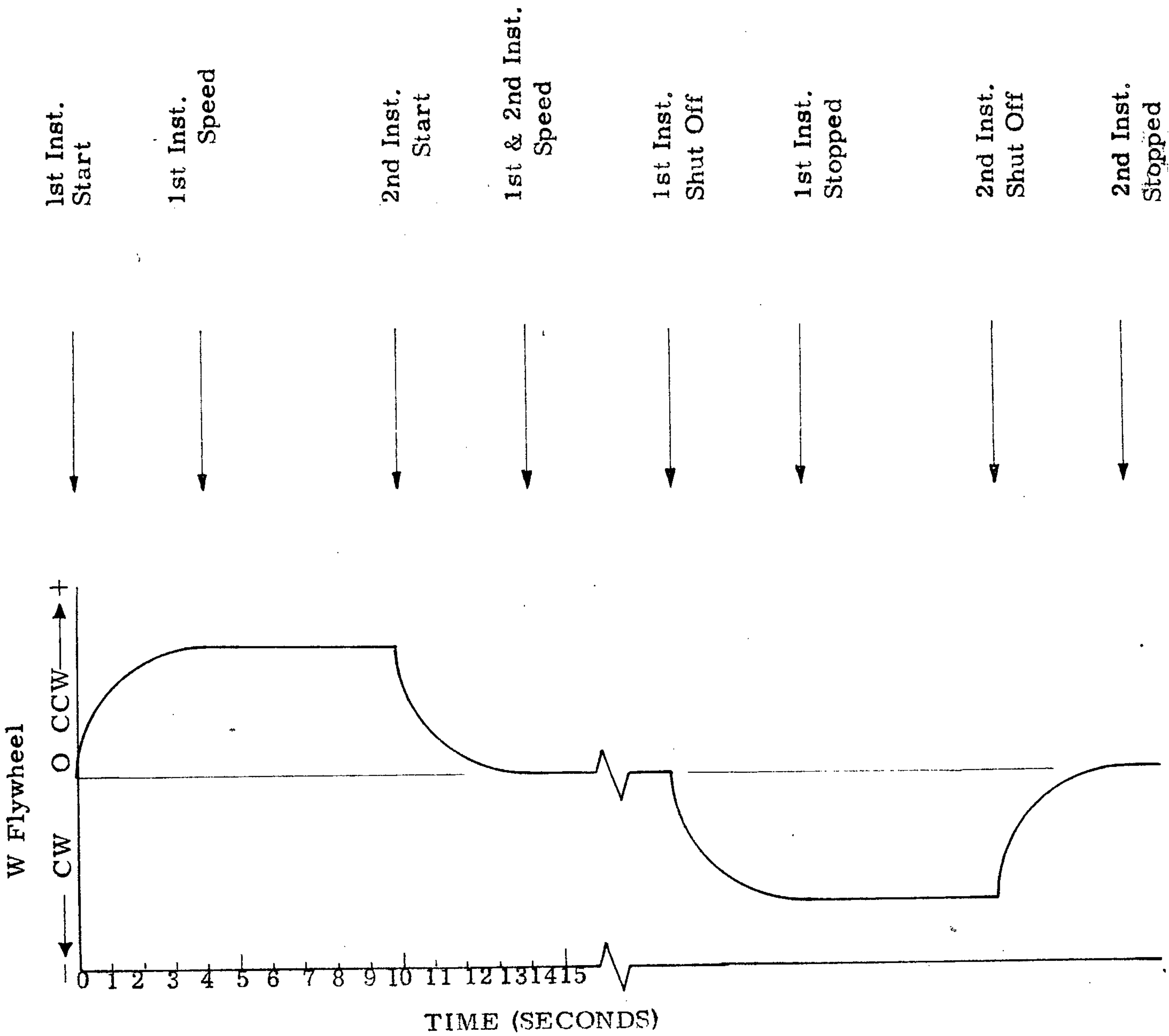
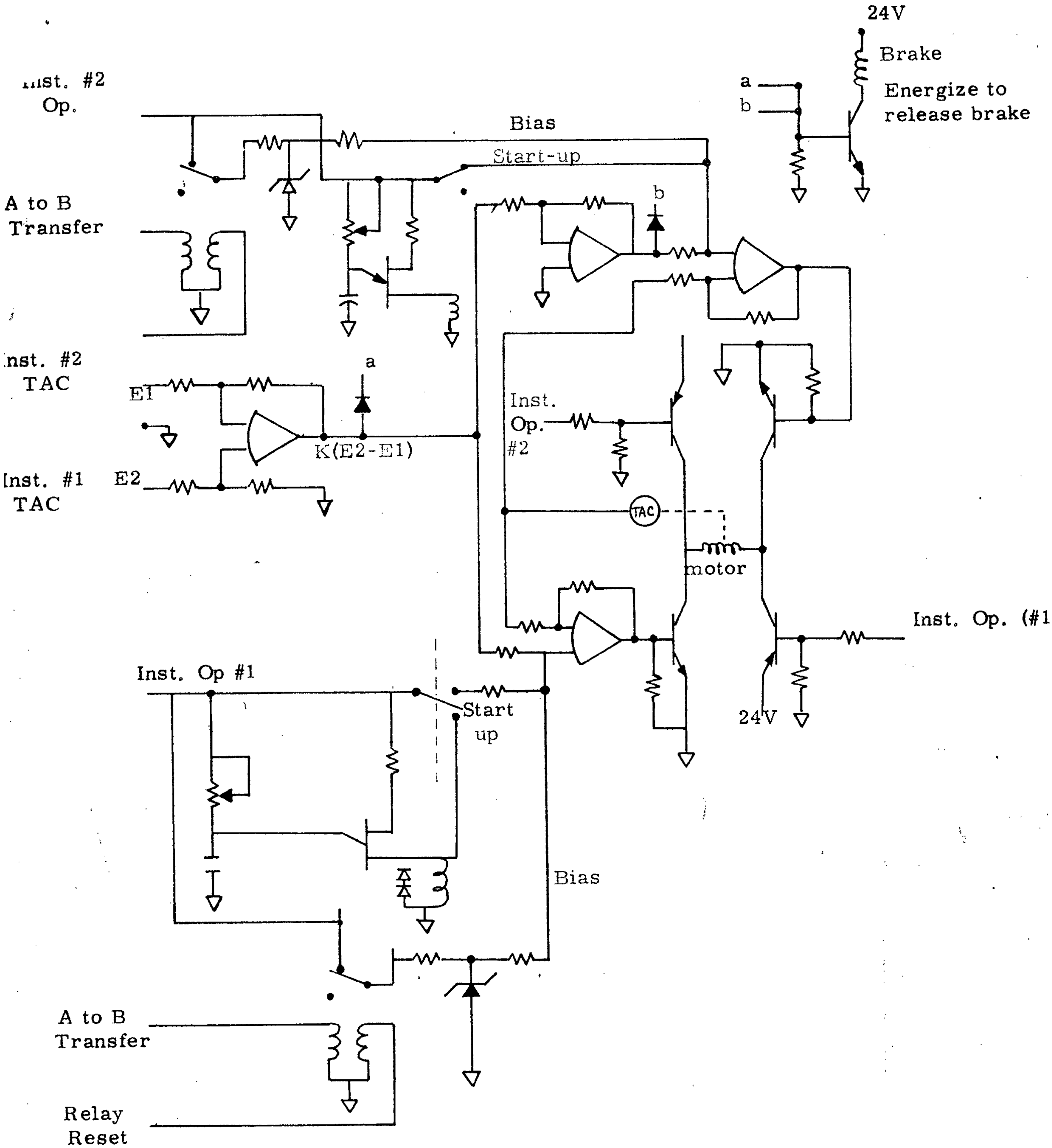


Fig. 4

Figure 4



PAYLOAD INERTIA BALANCE SYSTEM SCHEMATIC

Figure 5

7 g's from 15 to 20 cps (0 to peak)

5 g's from 20 to 400 cps (0 to peak)

7.5 g's from 400 to 2000 cps (0 to peak)

3.1.2 Random Vibration

All three axes

0.05 g^2/cps from 20 to 400 cps

0.12 g^2/cps from 400 to 2000 cps attaining 14.5 g's rms overall acceleration

3.1.3 Acceleration

11.0 g's in the longitudinal axis in the plus direction.

2.0 g's along the lateral axes in both direction (plus and minus)

3.1.4 Shock

20 g's in the longitudinal axes with a pulse duration of 6 milliseconds. Equipment must survive 3 such shocks.

5 g's in the lateral axes with a pulse duration of 6 milliseconds. Equipment must survive 3 such shocks.

3.1.5 Thermal Altitude Test

The PIBS shall be placed in a test chamber and pressure reduced to 10^{-5} mm Hg or lower. While maintaining the reduced pressure, the temperature shall be cycled as follows:

Cycle	Temperature	Time
1	75°F	8 hours
2	105°F	8 hours

Cycle	Temperature	Time
3	110°F	8 hours
4	35°F	8 hours
5	20°F	8 hours.

At the end of each cycle the equipment shall be operated through a maximum duty cycle simulating a camera start-up and a camera shut-down.

After the operation for cycle 5 is completed, the pressure and temperature shall be returned to ambient laboratory levels and the equipment shall be operated through a normal functional test.

3.1.6 Calendar and Operating Life. The PIBS shall be designed to have a calendar life in excess of one year. The useful operating life design goal of the PIBS shall be 650 hours which is equivalent to 99 percent reliability at the 50 percent confidence level.

3.1.7 Electromagnetic Compatibility

The PIBS system shall fulfill the requirement that its electrical and electronic equipment shall operate successfully, not only independently, but also in conjunction with other equipment which may be placed nearby. This requires that the operation of all such equipment shall not be adversely affected by interference voltages and fields reaching it from external sources. It also requires that such equipment shall not in itself be a source of interference which might adversely affect the operation of other equipments. Sufficient EMI testing shall be accomplished to verify that these requirements are met.

4.0 COST ELEMENTS

The cost of the PIBS System is estimated as follows:

a) Non-recurring costs for development, tooling, and AGE modifications [redacted] 50X1

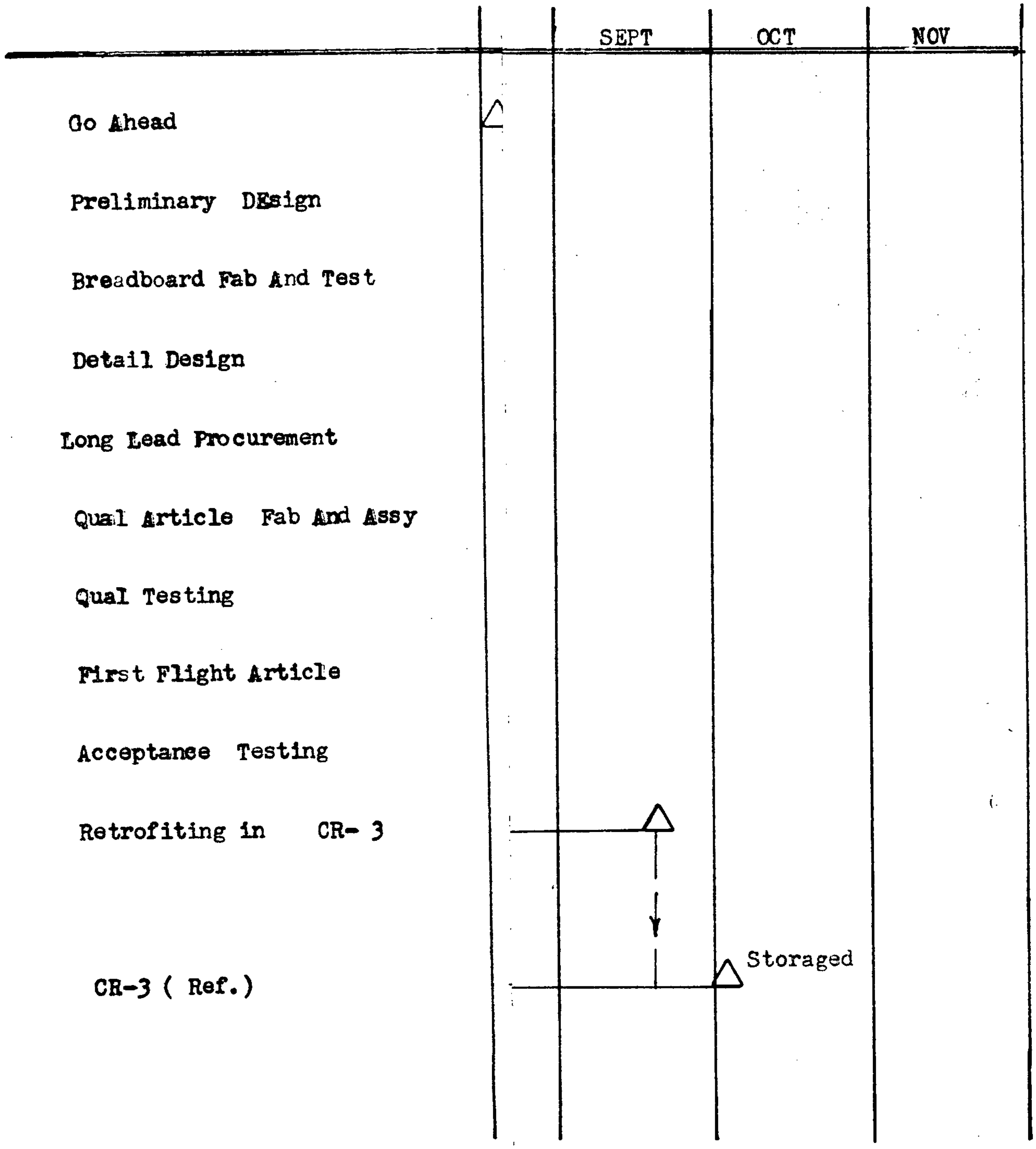
b) Unit cost for manufacturing, system integration, systems testing, and other launch preparations [redacted] 50X1

c) Total price for 15 flights consisting of CR-3 through CR-16 and QR-2 [redacted] 50X1

5.0 COST EFFECTIVENESS

As will be noted from Paragraph 1.2 above it is estimated that with the use of PIBS, 900 more stereoscopic pairs could be obtained per mission which is a 15% gain. Therefore 15 flights (CR-3 - 16 incl. plus QR-2) with PIBS would generate stereoscopic pairs which would be the equivalent number obtained from 17.647 missions without PIBS (15 ÷ .85). The gain in coverage with use of PIBS would therefore be the equivalent to the yield from 2.647 missions resulting in a cost savings to the Government in the approximate net amount of [redacted] computed as 50X1 follows:

	<u>MILLIONS</u>
2.647 flights at an estimated cost of [redacted] per flight	[redacted] 50X1
Less - Estimated cost of 15 PIBS units	



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