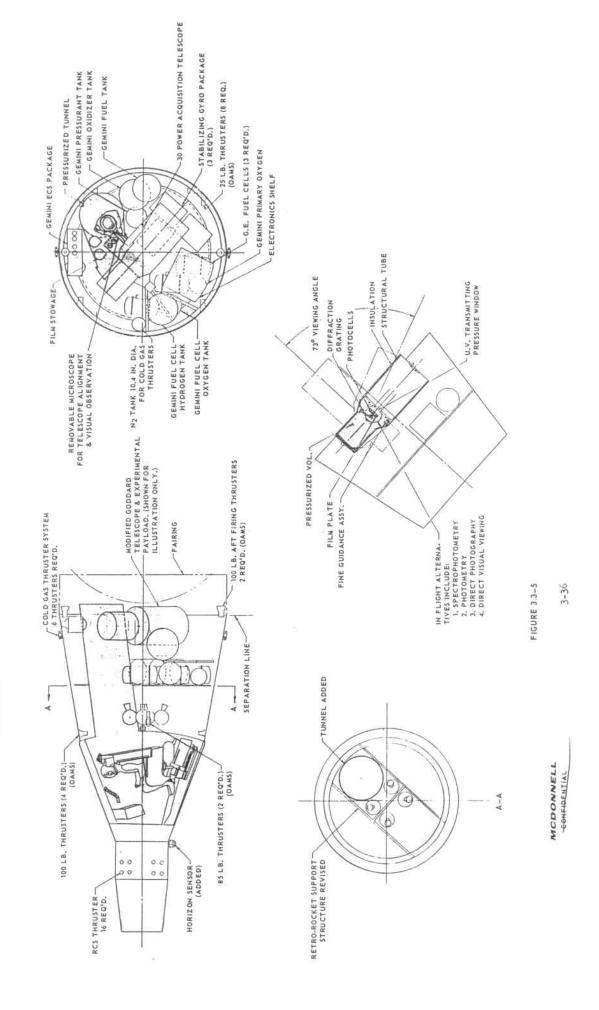
GEMINI SPACECRAFT - ADVANCED MISSIONS CONFIDENTIAL

REPORT NO. B766 ~ 26 MAY 1965

ONE MAN GEMINI WITH ASTRONOMICAL TELESCOPE



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ASTRONOMICAL TELESCOPE INSTALLATION ALTERNATIVES

36.		1				19	からの 大学 できる ないのかない 大学 上		
	IN RE-ENTRY VEHICLE	ADJACENT TO CREWMAN	15	18 IN. DIA 1/4	ON	MIRROR	AUTOMATIC HATCH	NONE	MINIMUM CHANGE LOWEST COST SMALLEST TELESCOPE
	END LOOKING, END FIXED 28 IN, SKIRT ADDED	HATCH AND STUB TUNNEL	9	32 DIA. x 89*	YES	MOVE AND HOLD ENTIRE SPACECRAFT	SKIRT	MODERATE	SIMPLE INSTALLATION
	BODY FIXED SKIRT NOT ADDED	HATCH AND STUB TUNNEL	S	26 DIA. × 73.5	YES	MOVE AND HOLD ENTIRE	BLOW OUT DOOR	EXTENSIVE	MINIMUM CHANGE
67° VIEWING ANGLE	END POINTING 28 IN. SKIRT ADDED VARIABLE ANGLE	HATCH AND STUB TUNNEL	an.	34 DIA. × 94.5 26 DIA. × 73.5***	YES	SPACECRAFT IN ROLL ONLY TELESCOPE IN PITCH	SKIRT	EXTENSIVE	HAS PROBLEM OF TUNNEL TO TELESCOPE CONNEC. TION
	SIDE LOOKING BODY FIXED 8 IN, SKIRT ADDED OR 14 IN, SKIRT ADDED**	HATCH AND STUB TUNNEL		34 DIA. × 94.5 OR 40 DIA. × 94.5**	YES	MOVE AND HOLD ENTIRE	SKIRT AND BLOW OUT	EXTENSIVE	SIMPLE INSTALLATION
ONE MAN GEMINI WITH ASTRONOMICAL TELESCOPE	DESCRIPTION OF TELESCOPE INSTALLATION	ACCESS TO TELESCOPE	DURATION (DAYS) MAXIMUM	EQUIPMENT - VOLUME LIMIT	HATCH IN HEAT SHIELD	TELESCOPE POINTING	ADDITIONS	REARRANGEMENT OF ADAPTER EQUIPMENT	GENERAL COMMENTS ON INSTALLATION AND OPERATION

*BASED ON INTERFERENCE WITH RETROGRADE SUPPORTS
***WITH SHORT SPECTROMETER
***WEIGHT LIMITED DUE TO ALTITUDE REQUIREMENT FOR PRECISE POINTING & GLY LAUNCH

FIGURE 3.3-6

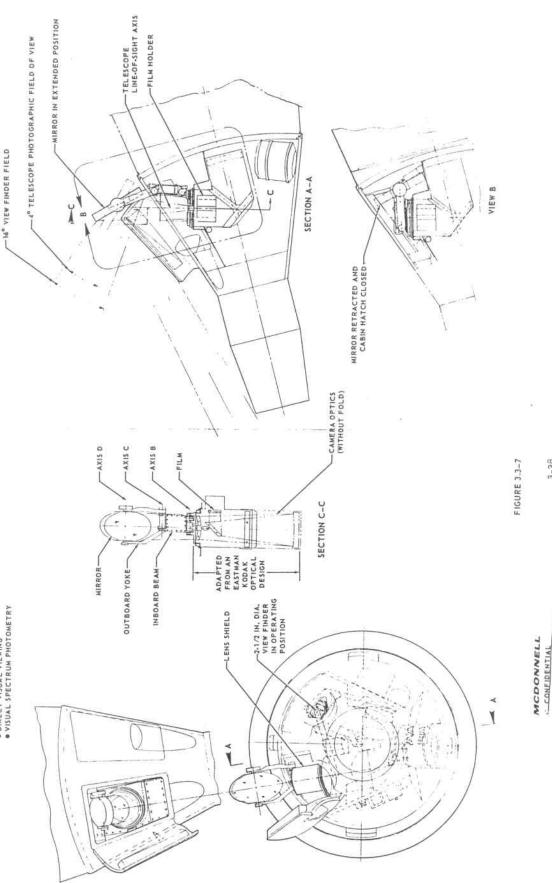
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RE-ENTRY VEHICLE TELESCOPE INSTALLATION

WIDE FIELD OF VIEW PHOTOGRAPHY
 DIRECT VISUAL VIEWING
 VISUAL SPECTRUM PHOTOMETRY



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3.3.2 (Continued)

Figure 3.3-7 is shown in Figure 3.3-8.

3.3.3 Attitude Control System - The attitude control system consists of the Gemini OAMS attitude control for slewing to acquire stars, control gyros or inertial wheels for fine attitude control, a pointing angle error detector in the astronomical telescope, and a nitrogen cold gas momentum desaturation system. The purpose of the fine attitude control system is to precisely point the telescope during photographic exposures or photometric measurements. It is necessary to keep the disturbance torques on the spacecraft low and the control gain (ft lbs. per arc second pointing error) high for precise pointing.

3.3.3.1 <u>Disturbance Torques</u> - The primary disturbance torques on the space-craft shown in Table 3.3-3.

TABLE 3.3-3

DISTURBANCE TORQUES

GRAVITY GRADIENT TORQUE

MAXIMUM	6.9 × 10 ⁻³ FT. LBS.			
VEHICLE ONE DEGREE FROM ZERO TORQUE POSITION	2 × 10 ⁻⁴ FT. LBS.			
GAS LEAKAGE	A CONTRACT OF THE PROPERTY OF			
	6 × 10 ⁻⁵ FT. LBS.			
AERODYNAMIC TORQUE				
100 NA.MI. ALTITUDE	2.5×10^{-2} FT. LBS.			
200 NA WI ALTERNA	2.5 x 10 - FT. LBS.			
200 NA.MI. ALTITUDE	8×10^{-4} FT. LBS.			
(SEPARATION OF CENTER OF PRESSURE AND CENTER OF	GRAVITY -0.5 FT.)			
MAN BREATHING				
	6×10^{-4} FT. LBS.			
HEART BEAT	6×10^{-4} FT. LBS.			

NOTE:

THE LAST TWO FACTORS ASSUME THE ASTRONAUT DISTURBANCES ARE ATTENUATED BY A FACTOR OF TWO.

With a circular orbit altitude of 200 na. mi. and an attitude with the spacecraft longitudinal inertial axis within one degree of the normal to the orbit

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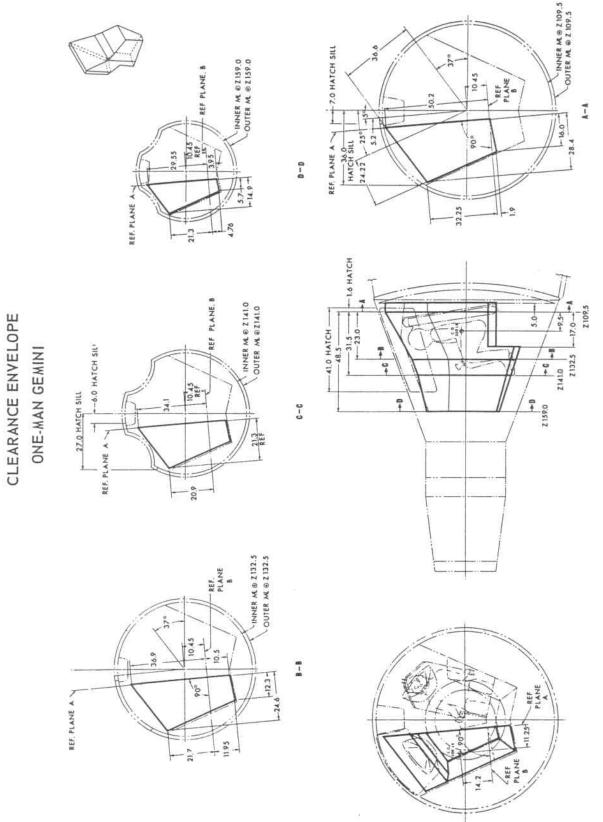


FIGURE 3.3-8

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3.3.3.1 (Continued)

plane, the torques from the disturbances are each less than 10⁻³ ft.-lbs. An altitude much higher than 200 na. mi. is undesirable for a GLV-launched one-man Gemini since the size telescope which can be carried decreases greatly, as discussed in Section 3.3.1.

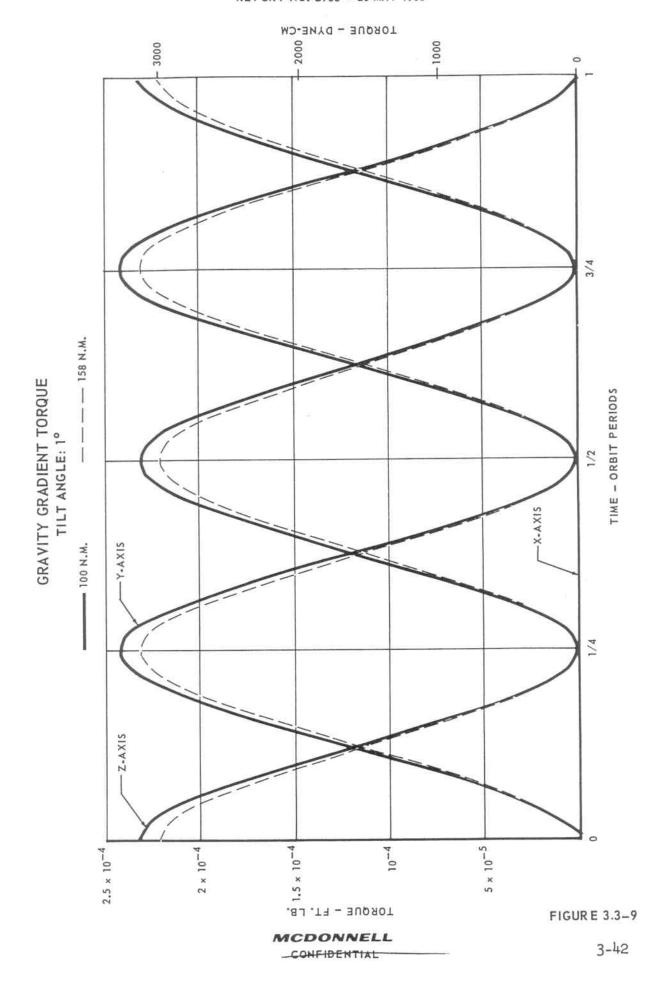
The gravity gradient torques are periodic with a period of half the orbit period, while the aerodynamic torques have a period equal to the orbital period. The disturbance torques along each spacecraft axis for the fixed roll attitude suitable for stellar measurements are shown in Figures 3.3-9 and 3.3-10, while the peak torques at other attitudes and altitudes are given in Figures 3.3-11 and 3.3-12.

A long-time, constant attitude control system can be used to compensate for pointing angle errors due to these slowly varying torques. The largest disturbance, aerodynamic torque, is shown in Figure 3.3-12. The separation of the center of gravity and center of pressure for the spacecraft with a 26 inch diameter telescope is less than three inches when the astronaut is in the viewing position at the telescope. The nighttime aerodynamic torques are thus approximated by the 3 inch center of gravity-center of pressure line in Figure 3.3-12. The variation in the peak gravity gradient torque with spacecraft pitch or yaw attitude misalignment, shown in Figure 3.3-11, demonstrates the advantage of alignment within 0.5 to 1 degree. The addition of the third horizon scanner, 90 degrees from the other two, permits an initial alignment and periodic adjustments with a 0.5 degree accuracy. The disturbance torque corresponding to a 0.5 degree misalignment is 1.2×10^{-14} ft. lbs.

The attitude disturbances due to astronaut arm motions can be quite large. A typical arm motion has two 0.16 ft-lbs sec. impulses of opposite sign separated by approximately one second. The corresponding spacecraft attitude disturbance is

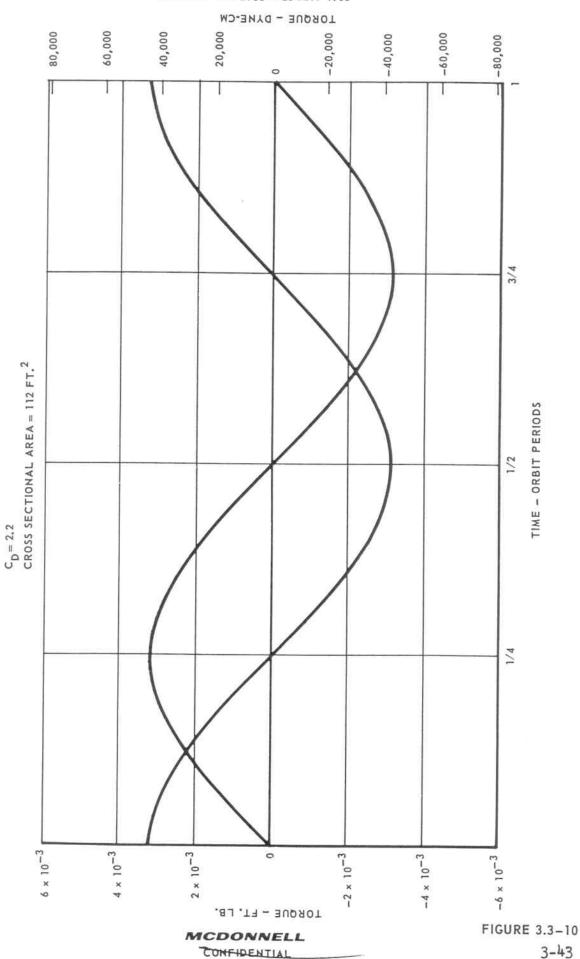
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AERODYNAMIC TORQUE ALTITUDE = 158 N.M.

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GRAVITY GRADIENT TORQUE ON THE SPACECRAFT

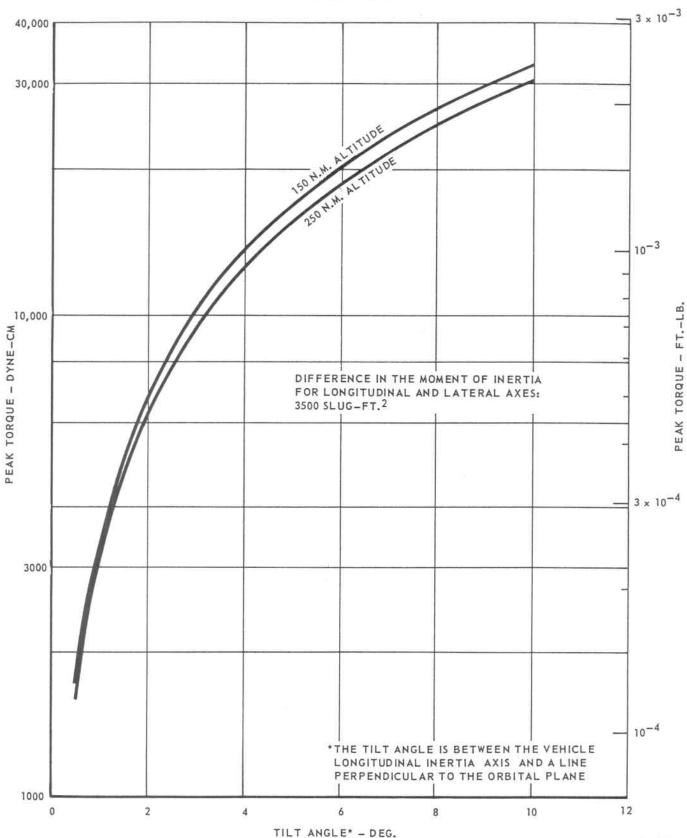


FIGURE 3.3-11

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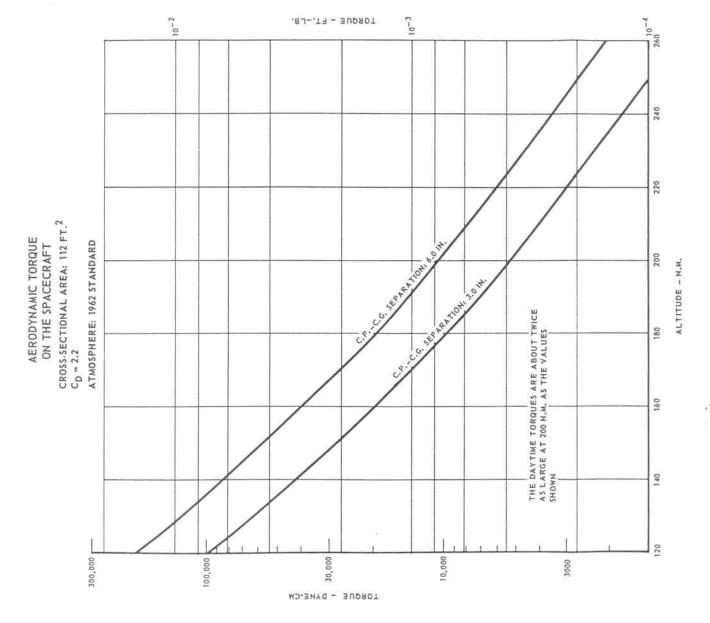


FIGURE 3.3-12

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3.3.3.1 (Continued)

seven arc seconds in the absence of fine attitude control.

3.3.3.2 <u>Fine Attitude Control</u> - The fine attitude control can use either control gyros or inertia wheels with a momentum storage capacity of 4 to 7 ft-lb. sec. for each control axis. A cold gas system for desaturation is utilized. Either the gyro or the inertia wheel control system can have the capability for stabilizing the spacecraft to within two arc. sec. in the absence of astronaut body or limb motions.

The control gyro is a better choice than the inertia wheel for compensating for astronaut body and limb motions since the gyro can have a closed loop time constant of the order of one second. Fractional arc second pointing stability can be achieved by use of a fine inertia wheel control or image motion compensation near the focal plane of the telescope.

Three things can be done to compensate for high frequency disturbances due to the astronaut which are too fast for compensation by the momentum wheels. First, the astronaut can be isolated; second, the telescope can be isolated magnetically or pneumatically, and, third, an image motion compensation control can be added to the telescope. The third device would be similar to shimmer compensation devices in ground observatories.

The low impulse cold gas system is required with the control momentum system since the minimum impulse of the Gemini OAMS (0.25 lbs. sec./thruster) corresponds to an angular momentum of 2 (0.25 lbs. sec.) (7.5 ft) = 3.75 ft. lbs. sec. which is comparable to the angular momentum to be stored.

The total fine attitude control system weight is estimated to be 190 lbs., including the momentum exchange system, electronics, fine pointing error detector, cold gas reaction system, and displays and controls for the astronaut.

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- 3.3.3.3 Attitude Control Propulsion System The attitude control propulsion system for the one-man Gemini consists of:
 - A. Re-entry control system Same as Gemini
 - B. Retrograde system Same as Gemini
 - C. OAMS Same as Gemini with one 22 inch fuel tank, one 22 inch oxidizer
 tank and one pressurant tank. The OAMS weight is summarized in Table 3.3-4

OAMS PROPELLANT REQUIREMENTS

ATTITUDE HOLD:

DUTY CYCLE: LESS THAN 67%

60 LBS.

LIMIT CYCLE: $\theta = \pm$ 0.2 DEG.

 $\theta = \pm$ 0.03 DEG./SEC.

ATTITUDE SLEW:

40 LBS.

NORMAL SLEW RATE: θ 1 DEG./SEC.

ORBIT CIRCULARIZATION:

185 LBS.

CONTINGENCY (16%):

47 LBS.

TRAPPED PROPELLANT:

16 LBS. 348 LBS.

TANKAGE, LINES, AND VALVES

376 LBS.

TOTAL DAMS WEIGHT

TOTAL PROPELLANT:

724 LBS.

D. <u>Cold gas system</u> - The cold gas system to be added to the Gemini adapter consists of a nitrogen storage tank, regulator, relief valve, and two modules of three thrusters each.

A preliminary estimate of system characteristics is:

Storage tank diameter - 10.4 in.

Loaded weight of nitrogen - 5.5 lbs.

Thrust for each chamber - 0.25 to 0.5 lbs.

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3.3.4 (Continued)

Electrical signal width - 20 to 10 milli-sec.

Impulse per pulse - 0.005 lb. sec.

3.3.3.4 Star Position Detector for Fine Attitude Control System - The purpose of the star position detector is to generate a signal with an accuracy better than 0.1 arc second for use as an error signal in the fine attitude control system. If the light from a guide star is separated into four beams by a prism, or slit jaws, near the focal plane of the telescope and directed into four photomultipliers, the difference of the signals for each pair of phototubes can be used for the control signal for each of two axes.

The detector can detect angular displacements of 0.1 arc seconds for eighth magnitude stars with an integration time of one second and aperture diameter of 16 inches since the signal is sufficiently larger than the background and noise.

The error signal is the change in the photomultiplier output when the star image is displaced. The photomultiplier output for an eighth magnitude star, shown in Figure 3.3-13, is 10⁴ counts/second and the corresponding fluctuation is 100 counts/second for a one second integration time. If the edge splitting the star image is positioned so that the photomultiplier output is nearly linear up to a peak 10⁴ count/second change for a one arc second displacement and 1000 count/second change for a 0.1 arc second displacement, the ratio of the 0.1 arc second signal (1000 counts/second) to the rms fluctuation in the photomultiplier output (100 counts second) will be 10/1. The use of guide stars of 5.5 magnitude of brighter enables the integration time to be reduced to 0.1 seconds while still maintaining a signal to noise ratio of 10/1.

Two sources of background counts superimposed on the guide star signal are the photomultiplier thermionic dark current emission and the integrated star light in the detector field of view. The dark current background can be reduced to less than

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STAR POSITION DETECTOR OUTPUT

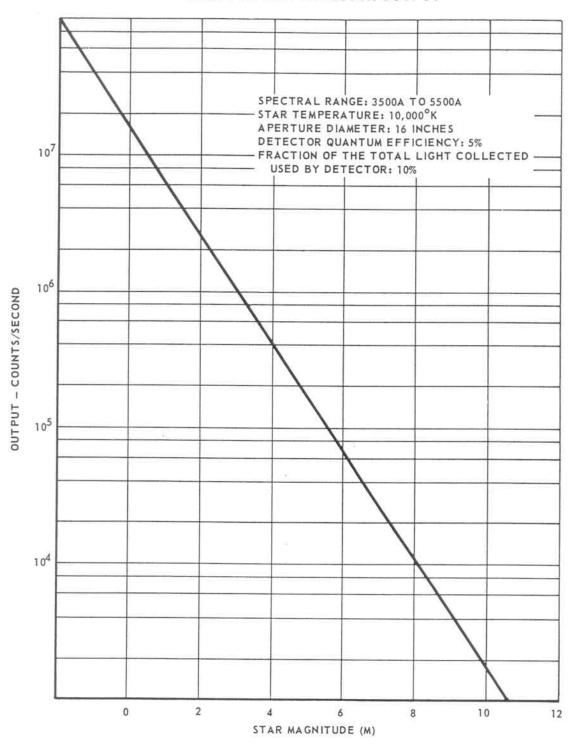


FIGURE 3.3-13

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3.3.3.4 (Continued)

200 counts per second by cooling the phototube, as shown in Figure 3.3-14, or by using a tube with a restricted long wavelength sensitivity. The restricted long wavelength sensitivity detector is satisfactory for hot guide stars, but is undesirable for the cooler stars which have a larger fraction of their output in the red region.

The background due to integrated starlight is not consequential for fields of view of 30 arc seconds or less since even near the galactic equator, the photomultiplier output caused by this background is less than 80 counts/second.

- 3.3.4 <u>Electrical Power System</u> A third fuel cell section is used for the one-man Gemini to provide redundancy with an increased peak power load due to the added telescope instrumentation and fine attitude control system. The power and energy requirements and the resulting electrical power system reactant weights are listed in Table 3.3-5.
- 3.3.5 Operational Description of Mission After insertion into an 87 na. mi. perigee, 200 na. mi. apogee orbit, 185 lbs. of CAMS fuel is used at apogee for circularization. The attitude is manually adjusted with 0.5 degrees of the perpendicular to the orbit plane using the horizon sensors sequentially. The separation of attitude adjustments is 90 degrees in orbit position.

For star acquisition, the roll attitude control system is used with a roll angle indicator to manually position the spacecraft within about one degree of the required roll attitude for a selected star. The telescope optical axis pitch angle is then adjusted using a pitch angle indicator and the telescope or telescope mirror dri

Following the rough pointing, the 10 to 30 power acquisition telescope, which has a 1 to 3 degree field of view, is used to make fine adjustments in the spacecraft roll angle and telescope optical axis pitch angle to bring the guide star within the

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STAR POSITION DETECTOR DARK CURRENT BACKGROUND

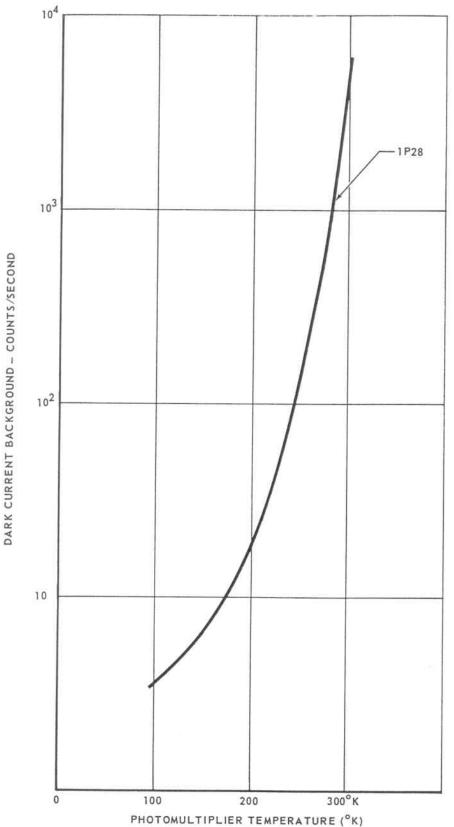


FIGURE 3.3-14



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TABLE 3.3-5

ASTRONOMICAL TELESCOPE MISSION ELECTRICAL POWER SYSTEM MISSION DURATION: 5 DAYS

PEAK POWER	WATTS			
BASIC GEMINI EQUIPMENT STEADY LOADS	382			
BASIC GEMINI EQUIPMENT INTERMITTENT LOADS	578			
TELESCOPE INSTRUMENTATION	115			
TELESCOPE ACTIVE THERMAL CONTROL	40			
FINE ATTITUDE CONTROL SYSTEM	280			
PEAK ELECTRICAL LOAD	1,395			
DIODE AND DISTRIBUTION LOSSES	112			
PEAK FUEL CELL OUTPUT WATTS	1,507			
ENERGY	WATT-HOURS			
BASIC GEMINI EQUIPMENT	52,200			
TELESCOPE	11,600			
FINE ATTITUDE CONTROL SYSTEM	12,000			
TOTAL LOAD	75,800			
DIODE AND DISTRIBUTION LOSSES	7,020			
TOTAL MISSION FUEL CELL OUTPUT	82,820			
POWER SYSTEM				
FUEL CELL REACTANTS	104 LB.			
REACTANTS TANKAGE	SAME AS 14 DAY GEMIN			
RE-ENTRY BATTERIES	4-SAME AS 14 DAY GEMIN			

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3.3.5 (Continued)

acquisition range of the star position detector. The pitch drive is then locked and the automatic fine tracking is initiated.

Stability - For the re-entry module installation of the telescope, the effectiveness of compensation for the harmful effects of astronaut motions by using a fast space-craft attitude control system, optical image motion compensation, and electronic image motion compensation can be determined. The telescope image stability is measured by the star position detector and photographic star image. An experiment on flexible support isolation of astronaut motions can be accomplished; however, the available space is very limited.

For the adapter module installation of the telescope, the tunnel provides space for other experiments such as a controlled floating support for the astronaut. If the telescope diameter is reduced from 26 to about 22 inches, 100 lbs. is made available for the support. The support has six servo driven reaction weights and six photodetectors to sense the position of the support with respect to the spacecraft. As the astronaut moves an arm, for example, the body and support move in the opposite direction. The photodetectors sense the motion and provide a signal to the reaction weight servo drives which move the weights to balance the arm motions and keep the support in a fixed position. This type of support should be very useful in a large space station observatory since the astronaut can use an eyepiece for optical alignment and star acquisition while mechanically isolated from the spacecraft.

- 3.3.7 <u>Astronomical Measurements</u> The high resolution and extended spectral range for a space telescope offer many possibilities for optical measurements as discussed in References 3.3-1 to 6:
 - Ultraviolet flux from hot stars (Important for stellar evolution and interstellar gas dynamics studies).

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3.3.7 (Continued)

- Chemical composition of the stars and interstellar gas (Search for unknown components).
- Photometery of dense clusters (Determine mass of luminous giant stars in the center of the globular clusters).
- 4. Absolute intensity of zodiacal light.
- Ultraviolet sky survey.
- 6. Observations of close double stars with rapid orbit period.
- 7. Spectrometry at wavelengths less than 1000 A.
- 8. IR spectrometry.
- 9. Interferometric spectrometry.
- 10. Visual observations.
- 11. Photographic observations.
- 12. Coronagraphic observations.
- 13. Observations using an image intensifier.
- 14. Measurement of manual tracking accuracy.

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3.4 Artificial Gravity - Three methods of providing artificial gravity are discussed. The first method involves rotation of the Gemini spacecraft while directly connected to the burned-out stage II of the Gemini Launch Vehicle. The second method rotates the docked Gemini-Agena orbiting vehicle. The general configuration and characteristics of these methods are shown in Figure 3.4-1. The third method is accomplished by rotating the Gemini spacecraft while cabin-connected to either the Agena or to Stage II of the Gemini Launch Vehicle. These configurations are shown in Figures 3.4-2 and 3.4-3.

Operational conditions presented in Table 3.4-1 indicate that methods of using Gemini thrusters are feasible if their application to operations other than spin or despin are limited. Ablation thruster specifications require a guaranteed life of 425 seconds of burn time for the attitude control thrusters and 557 seconds of burn time for the maneuver thrusters. It is anticipated that the maneuver thrusters can be used for both rendezvous and for artificial gravity. Since rendezvous requires predominantly longitudinal thrusts, the major portion of the design life of the lateral and vertical thrusters can be used for artificial gravity. The Agena attitude control system could also be used if provided with additional storage of cold gas propellant.

The alternate position of the crew members for the first method, shown in Figure 3.4-1, would provide an eyeballs-in g force, but would require some restraint for artificial gravity operation. In addition, viewing the Gemini instrument panels would be difficult.

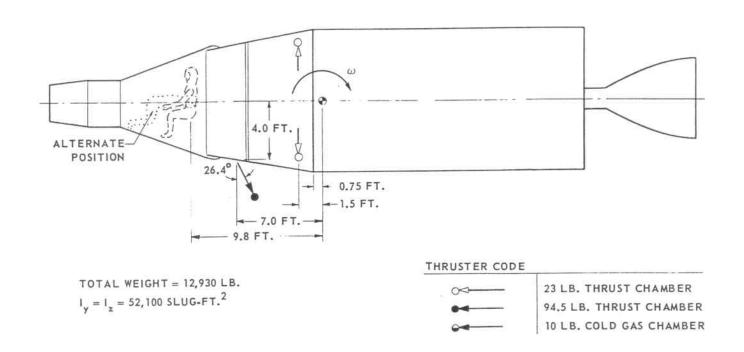
At rotational speeds greater than 4 to 5 rpm, normal head motions generally result in nausea due to Coriolis effects. The relatively high rates of rotation for directly connected vehicles, shown in Table 3.4-1, may be justified by restricting duties and movements during spin or by head restraint. The cable-connected

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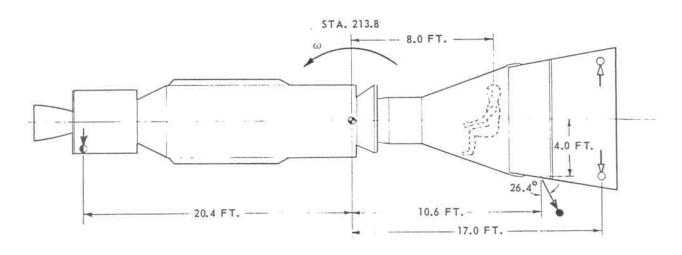
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INTEGRAL SPIN CONCEPTS

A) GEMINI DIRECTLY CONNECTED TO STAGE II OF GLY



B) DOCKED GEMINI-AGENA VEHICLE

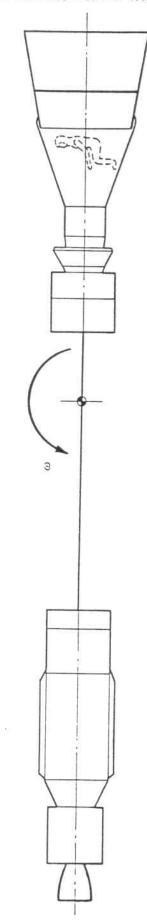


TOTAL WEIGHT = 14,130 LB. $I_y = I_z = 62,000 \text{ SLUG-FT.}^2$

FIGURE 3-4-1

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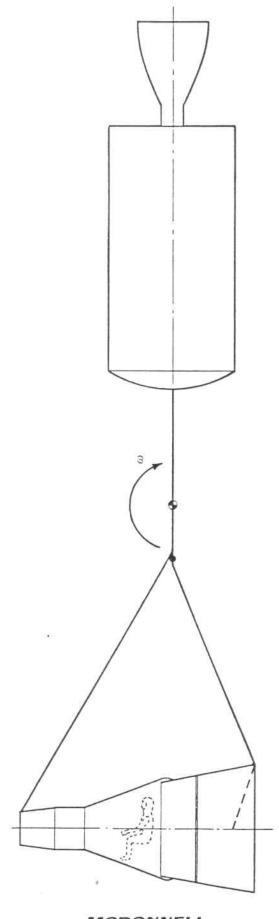


CABLE-CONNECTED GEMINI-AGENA CONFIGURATION

FIGURE 3.4-2

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CABLE-CONNECTED GEMINI-STAGE II OF GLY CONFIGURATION

FIGURE 3.4-3

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