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BURNER II IMPROVED CENTAUR

Integration Study

D2-116103
JANUARY 1970

Volume I — Technical

AEROSPACE GROUP ■ SPACECRAFT BRANCH
THE BOEING COMPANY
SEATTLE, WASHINGTON

BURNER II/IMPROVED CENTAUR INTEGRATION STUDY

FINAL REPORT-VOLUME I

D2-116103

SUBMITTED TO:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LEWIS RESEARCH CENTER

IN COMPLIANCE WITH

NASA CONTRACT NAS 3-11803

JANUARY 1970

AEROSPACE GROUP - SPACECRAFT BRANCH
THE BOEING COMPANY
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ABBREVIATIONS & ACRONYMS

AGE	Aerospace Ground Equipment
AVE	Airborne Vehicle Equipment
CST	Combined System Test
DTS	Data Transmission Set
EMI	Electromagnetic Interference
ESA	Explosive Safe Area
ETR	Eastern Test Range
FCE	Flight Control Electronics
GSE	Ground Support Equipment
G&CT/S	Guidance and Control Test Set
IF	Intermediate Frequency
KSC	Kennedy Space Center
LeRC	Lewis Research Center
LCC	Launch Control Console
LCCE	Launch Control & Checkout Equipment
LFMK	Launch Facility Modification Kit
LSR	Launch Support Rack
MECO	Main Engine Cutoff (Centaur)
MSFN	Manned Space Flight Network
MST	Mobile Service Tower
PSS	Premature Separation Switch
RCS	Reaction Control Subsystem
RCSSE	Reaction Control Subsystem Servicing Equipment
RF	Radio Frequency
RTG	Radioisotope Thermal Generator
S&EA	Structure & Equipment Assembly (Burner II stage less rocket motor)
SESP	Space Experiments Support Program
SMAB	Solid Motor Assembly Building
SNR	Signal to Noise Ratio
UES	Universal Environmental Shelter
UT	Umbilical Tower
VCO	Voltage Control Oscillator
VIB	Vertical Integration Building

VOLUME I

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report presents the results of a Centaur/Burner II integration study conducted for NASA under the technical direction of Lewis Research Center, Contract NAS3-11802. The objectives of the integration study were:

1. Develop conceptual engineering designs to integrate efficiently the Burner II with the Centaur launch vehicle.

2. Determine the integration requirements of Burner II Ground Support Equipment (GSE) into the launch complex and evaluate the resulting interface requirements with the launch vehicle GSE.

3. Perform preliminary mission studies to establish performance of Centaur/Burner II with Titan IIIB and Titan IIID boosters for planetary and synchronous equatorial type missions.

4. Establish planning level costs and a program schedule for incorporating the Burner II on the Titan/Centaur launch vehicles.

The results of the study are contained in two volumes. This document, Volume 1, contains the design, GSE, and performance data (objectives 1, 2, and 3). Volume 2 contains the schedule and cost data as well as the integration plan which was originally released and transmitted to NASA as a separate document (Reference 6).

Several other documents were released during the course of the study. Although the initial proposal, References 2 and 3, defined the contractor's proposed approach to accomplishing the study, a detailed study plan, Reference 4, was prepared at NASA's request after the initial parametric performance work was completed. This provided a more detailed "road map" for the remainder of the study and provides a detailed definition of the various study tasks. Two progress reviews were held during the six month study, one at the completion of two months effort, and the other after four months. These are documented in References 5 and 7.

A detailed description of Burner II may be found in Boeing Document D2-82601-5, Mission Planners Guide to Burner II (Reference 8).

1.2 SUMMARY

1.2.1 Background

NASA mission planning reflects the need for an upper stage on the Centaur launch vehicle. Specific studies of the Centaur/Burner II for high energy and synchronous equatorial missions have illustrated the value of the Burner II velocity increment, guidance accuracy and attitude stabilization capability. Forthcoming missions to the outer planets will rely on the Jupiter swingby gravity assist. The potential of the Titan IIID/Centaur/Burner II is shown to be compatible with 1600 - 1700 pound spacecraft for this mission. In addition the Atlas SLV-3C or a Titan IIIB/Centaur/Burner II could send a 1200 - 1800 pound spacecraft around Venus or go direct to Mercury with an 800 - 900 pound spacecraft.

The ability of the Burner II to provide the 5.5 hour coast required for synchronous equatorial missions allows either the Atlas SLV-3C or the Titan IIIB/Centaur to place 1300 - 1400 pound spacecraft in synchronous orbit. Spacecraft of this size are compatible with data relay satellite systems. Burner II eliminates the need for apogee motors and transfer coast attitude control systems in the spacecraft. Thus the spacecraft in orbit is not required to either jettison the spent injection motors or provide sufficient control authority to retain them with the spacecraft. Payloads of up to 2700 pounds can be placed in synchronous equatorial orbit with the Titan IIID/Improved Centaur/Burner II vehicle.

The study contained herein provides a significant step in the process of integrating Burner II with Centaur for future NASA missions.

1.2.2. Scope

The Burner II/Centaur integration study was divided into eleven tasks to cover the broad aspects of the study objectives. The study pursued each of the tasks to the depth required to produce conceptual designs, program documentation visibility, and operational concepts that could be priced to a planning estimate level. The objectives, ground rules, and magnitude of the study effort established the depth at which each of eleven tasks of the study were pursued. The study, of six months duration, included an initial performance evaluation of (2) boosters (Titan IIIB/Centaur and Titan IIID/Centaur), (7) Burner II configurations, and two types of missions for a 28 point performance matrix. Two Burner II configurations were selected for further study involving preliminary designs of a Burner II-to-Centaur adapter and Burner II-to-payload structure and related interface details. The structural design details established were strongly influenced by the ground rule payload weight of 2800 pounds. Integration of the Burner II flight stage with the Improved Centaur and integration of the Burner II GSE into the Titan ITL complex were analyzed. An integration plan was developed to provide the basis for the pricing and schedule outputs of the study. The shroud used in the study was conceptual and does not necessarily represent a final configuration. The Cenatur was the "E" version with 60 minute coast capability.

1.2.3 Summary of Study Results

A summary by task of the study output reveals the following:

1.2.3.1 The 28 point performance matrix analysis indicated that while a significant performance improvement was achieved by integrating a Burner II with the Titan IIID/Centaur and the Titan IIIB/Centaur it made little difference which Burner II configuration was used. With this in mind a selection was made of the Standard Burner II and a growth motor Burner II as the configurations for the detailed integration and performance analysis. It also became apparent that designing for 2800 pound synchronous equatorial payload capability would penalize the lighter weight lower Cg planetary payloads by up to 100 lbs. Consequently a separate weight estimate was made for the adapter to be used with 1200 to 1500 pound planetary payloads for the final payload vs. velocity plots.

1.2.3.2 The mechanical design of the Centaur-to-Burner II adapter and Burner II-to-Payload support structure as well as the structural modifications to Burner II were completed to meet the loads and stiffness criteria imposed by the study ground rules. The resulting adapter design is a semi-monocoque two piece structure. Both sections of the adapter are used for the growth motor Burner II while only one section is used for the shorter Standard Burner II. The structural modifications required for the Burner II stage are primarily gauge changes in the existing design to react the additional loads. The payload support structure provides a bolt circle at the payload interface that is the same as the bolt circle at the top (Sta. 2491.80) of the Improved Centaur. This payload interface definition was selected because of the lack of a specific spacecraft to integrate with and because this approach would allow the spacecraft to be flown on the Improved Centaur with or without Burner II depending on the mission requirements. The weight of the Centaur/Burner II adapter is strongly influenced by the payload weight and Cg location. Weight data was developed for both a 50 percent Cg and 25 percent Cg location for the 2800 pound ground rule payload. For the growth Burner II adapter weight for the 50% Cg location was 209 pounds. With the 25% Cg location, adapter weight decreased to 178 pounds. The adapter design included a separation analysis to verify adequate clearance during in-flight separation of the Burner II from the Centaur.

1.2.3.3 Electrical integration of the Burner II with the Improved Centaur was analyzed in terms of wiring interfaces, signal functional interfaces, power distribution and RF performance. All 12 Burner II-to-Centaur interface wires can be carried through one in-flight separation connector. Trade studies of the routing of payload umbilical wires through Burner II indicate that a second Burner II-to-Centaur connector would be required to get the payload umbilical down to the Centaur umbilical island. An RF link analysis for Burner II and specified ground facilities indicated that the Burner II Telemetry System could be modified for adequate performance at synchronous altitude by an increase in transmitter power from 5 watts to 12 watts and other minor system changes. Burner II Telemetry transmission prior to shroud jettison can be handled by RF slots in the shroud located in relation to the Burner II S-Band antenna to provide an acceptable reradiated antenna pattern.

1.2.3.4 The intentional destruction of Burner II by either range safety command or from premature separation of the Burner II from the Centaur is provided for with the Burner II destruct system mounted in the Burner II-to-Centaur adapter. The command destruct signal comes to Burner II by way of the Centaur command destruct receivers.

1.2.3.5 The Burner II/Centaur guidance systems error analysis revealed that the predominant error associated with Burner II integration with Centaur was the attitude transfer error of 1.0° (all axis) associated with transferring the attitude reference of the Centaur to the Burner II during Burner II gyro uncage. Methods to reduce the attitude transfer error were explored. It has been determined that a reduction in attitude transfer error to .44° is obtained if the Burner II gyros are uncaged during a 30 to 50 second non-guidance-steering segment of the Centaur second burn. Lateral accelerometers added to the Burner II strapped down guidance system sense cross-axis accelerations due to attitude misalignment with the thrust vector during the reference period that Centaur is thrusting along a preprogrammed inertial vector. Corrections are computed in Burner II from the sensed cross-axis accelerations so that the Burner II pitch and yaw gyros can be torqued to be aligned with the established Centaur inertial reference. Centaur modifications for this concept are limited to software. Burner II changes required involve the addition of accelerometers and some computing circuitry.

1.2.3.6 The electromagnetic interference aspect of integrating the Burner II with the Improved Centaur was analyzed in terms of interface signals, grounding, and RF coupling. The latching type relays used on Burner II for signal interfaces are highly insensitive to EMI and sufficient testing has been done on Burner II with EMI environment in excess of the Centaur/Burner II predicted levels to verify a satisfactory signal interface. The grounding philosophies of the Burner II (single point ground) and the Centaur (single point ground except for the igniters and the recirculating pump) are different but analysis of the specific circuits involved indicate that no adverse effects will occur. The destruct ordnance initiate circuit is not involved in the grounding differences because no ground exists on the Burner II side of the interface for this circuit.

1.2.3.7 Field operations for processing the Burner II at the ETR were studied and detailed functional flow diagrams prepared. The flow diagrams were used as a basis for establishing ETR and Seattle requirements for ground support equipment, services and facilities. A primary consideration was environmental control of the payload. A concept of payload encapsulation within the nose shroud was developed to provide environmental control of the payload from the time it is encapsulated in a clean room until vehicle launch. Equipment required to support this concept includes a transporter assembly with suitable positioning hardware to independently support the shroud and the Burner II/Payload combination. The only new electrical GSE identified are minor items such as suitcase size Centaur signal simulator, cables, etc. The major new mechanical GSE identified is the transporter mentioned above.

1.2.3.8 The facility requirements for integrating Burner II with the Centaur at K.S.C. include a high bay, explosive safe, clean room for the assembly of the Spacecraft/Burner II/Shroud combination with the spacecraft encapsulation concept. Service tower modifications are minor involving the removal or modifications of some of the folding work platforms.

1.2.3.9 The reliability of the Burner II for a Titan/Centaur/Burner II synchronous equatorial mission is estimated to be .955. This is considered a valid estimate for the first flight of the above vehicle since the Burner II is a mature flight system. This maturity is based on eight successful Thor/Burner II missions out of eight launches and also on the flight experience of the Burner II system components on other vehicles such as Scout, and Thor/Delta. Consideration of the effects of the Van Allen belt radiation exposure for the synchronous equatorial mission profile have been included in the estimated reliability of the Burner II electronic components. The safety analysis of the integration of Burner II with the Titan/Centaur vehicle, including the interfacing with the shroud, the launch facility and the AGE, indicates that the hazards encountered are typical of current missiles and space systems involving ordnance devices, solid and liquid propellants and pressurized systems. The integration can be performed within the normally acceptable risks limits for unmanned space systems.

1.2.3.10 The task of integrating Burner II with the Centaur for a specific mission involves interfaces with the booster, Centaur, shroud, launch facilities and payload contractors as well as the various NASA agencies. These program interfaces were reviewed and an integration plan was established to account for all of the tasks to be performed in the integration of Burner II with Centaur for an ETR launch on the Titan booster. The integration plan provided visibility in terms of Design, Analysis, Testing and Documentation for the Boeing tasks as well as an approximation of the Boeing tasks relative to the other contractor's and NASA's tasks. A schedule was developed showing 15 months from go ahead to first Burner II delivery for a Titan/Centaur mission at ETR. Pricing ground rules were established to provide further program scope to the pricing effort. Volume II of this document contains the Integration Plan and cost information.

1.2.4 Conclusions and Recommendations

It is concluded that the integration of the Burner II flight stage with the Improved Centaur can be accomplished with a minimum impact on the Centaur and Titan programs. Interfaces, both functional and mechanical, are straightforward and similar to concepts presently used on the Burner II and Centaur programs. The largest ground facility requirement effect is related to the payload and the encapsulation concept.

The material developed herein establishes a basis for general mission planning in terms of what the Titan IIIB and Titan IIID with the Improved Centaur can do with the Burner II as a kick stage.

It is recommended that this broad base of information be made more useful by performing an integration study for a specific spacecraft and mission that is applicable to the capability of the Improved Centaur/Burner II. Such a study would answer the mission peculiar questions regarding spacecraft interfaces, specific performance capability, and injection accuracy. Specific information of this type will be required as the detailed mission planning progresses.

2.1 TASK 1 - ANALYSIS AND INTEGRATION

The reason for integrating the Burner II with the Improved Centaur is to achieve a performance gain. The purpose of this task is to explore the performance potential of various Burner II configurations and to select two configurations for further study. Parameters considered other than payload and velocity are those of interest to mission planners such as mass properties, sequencing, guidance accuracy and spacecraft environment.

The study effort was initially directed toward determining the payload versus velocity and synchronous equatorial performance for seven different Burner II configurations on the Titan IIIB and D with the Improved Centaur. The initial performance estimates were based on preliminary weight estimates and in some case preliminary booster and shroud data. Table 2.1-1 indicates the performance matrix of Burner II configurations, Titan Boosters, and missions that were analyzed in the preliminary performance effort.

The results of the preliminary performance analysis as described in reference 5 were used to select two Burner II configurations for more detailed design, interface and performance analysis for integration with the Improved Centaur. The selection criteria used for the Burner II configurations selection involved two things: (1) A rationale of what Burner II configurations were most likely to be available in the applicable time period, and (2) the performance improvement achieved over the basic Titan/Centaur launch vehicle.

TABLE 2.1-1

BURNER II CONFIGURATION	STABILIZATION	SYNCH EQ MISSION		PLANETARY MISSION	
		T-III B/CENT	T-III D/CENT	T-IIIB/CENT	T-III D/CENT
STANDARD BII (1440)	3 AXIS STABILIZATION	X	X	X	X
LARGE MOTOR (2300)	↓	X	X	X	X
TANDEM 1440/1440	↓	X	X	X	X
TANDEM 1440/517 (BIIA)	↓			X	X
TANDEM 2300/1440	↓	X	X	X	X
STANDARD BII (1440)	SPIN STABILIZATION	X	X	X	X
LARGE MOTOR (2300)	↓	X	X	X	X

PRELIMINARY PERFORMANCE MATRIX

The Burner II configurations selected for the detailed portion of the integration study are the standard production version with the 1440 pound propellant TE-364-2 solid motor and a growth version with the 2300 pound propellant TE-M-364-4 motor. The TE-M-364-4 motor is presently under development for NASA by Thiokol Chemical Corporation. An example of the range of performance improvements offered by the Burner II configurations is shown in Figure 2.2-1. It can be seen from the figure that a large payload or velocity gain is achieved by adding a Burner II to the Titan/Centaur vehicle. It can also be seen that it makes a relatively small difference which Burner II configuration is selected from the performance standpoint. The Standard Burner II falls at the lower edge of the performance band and the growth motor Burner II falls in the middle of the range shown.

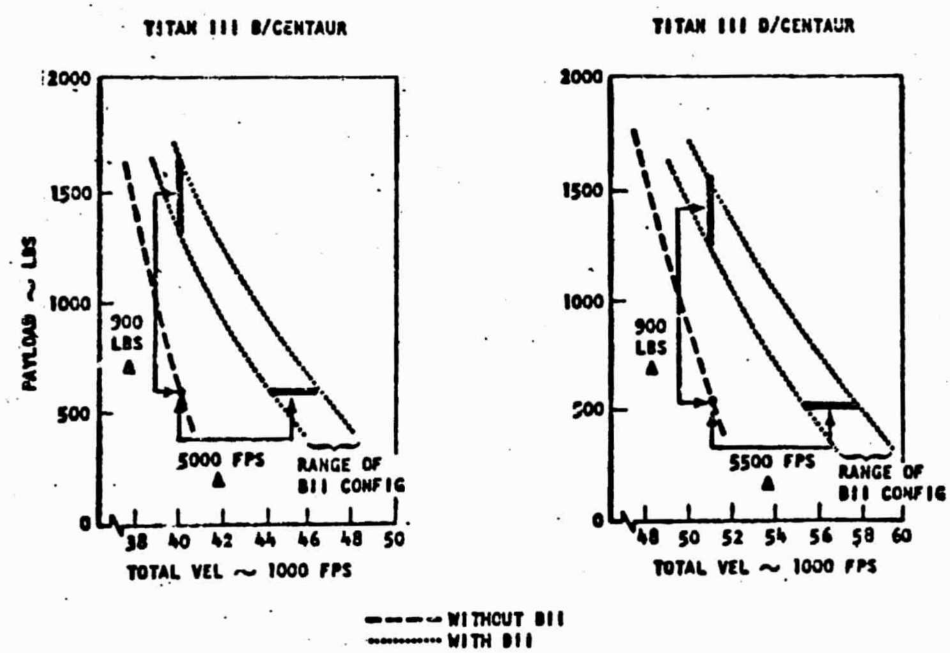


FIGURE 2.2-1

The final performance analysis was conducted for the two Burner II configurations selected after the design analysis effort established final weights for the Burner II, Centaur adapter and spacecraft support. A base line payload weight of 2800 pounds was selected by NASA after reviewing the preliminary synchronous equatorial capability of the Titan IIID/Improved Centaur/Growth Burner II. This payload weight with a 50 percent Cg ground rule* was used for the structural design effort on the Centaur adapter, the Burner II and the Burner II payload support. Early results indicated a significant weight penalty for the 50 percent Cg ground rule so additional design information was developed for a 25 percent Cg location* in the 2800 pound base line payload. The final synchronous equatorial payload capability was developed using the weight statements appropriate for the 2800 pound payload with the 25 percent Cg location. It was determined, however, that the weight range of expected planetary spacecraft is more likely to be 1200 to 1500 pounds. Therefore a third weight estimate was made for Burner II and adapter weights appropriate for a 1200 to 1500 pound payload. The payload versus velocity plots presented in the final performance results are based on the weight statement for a 1200 pound payload. This approach renders the results applicable for realistic mission planning.

2.1.1 Final Performance Results

2.1.1.1 Performance Ground Rules

The data presented in this section are based on the following ground rules:

- Launch Azimuth =90°
- Launch Site - ETR
- Parking Orbit Altitude - 100 N.M.
- Flight Performance Reserve (FPR) = RSS (2.5% ΔV for each stage)
- Titan IIID/Centaur shroud jettison @ Step II ignition + 12 seconds
- Titan IIIB/Centaur shroud jettison @ liftoff + 240 seconds.
- Titan IIIB Step II off loaded to maintain a liftoff thrust-to-weight ratio = 1.2
- Eleven foot shroud weight = 4400 pounds.
- Fourteen foot bulbous shroud = 5056 pounds.

The flight performance reserve is assumed to be carried in the Centaur. The Burner II vernier phase is applied to all payload velocity data. For synchronous equatorial applications no vernier is assumed in Burner II due to the inefficiency of the correction mode compared to post injection correction.

2.1.1.2 Titan IIIB/Centaur/Burner II Payload Versus Velocity

Payload versus velocity data, shown in Figure 2.1-2 and 2.1-3 are the Titan IIIB/Centaur with the standard and growth motors in Burner II, respectively. These data provide performance with both a 4400 pound

* percent of payload length from the bottom.

11 foot shroud and a 5056 pound 14 foot bulbous shroud. The shroud performance trade includes the shroud weight, aerodynamic and Core II propellant loading trades. The 11 foot shroud allows an additional propellant loading of 656 pounds while maintaining the 1.2 liftoff thrust-to-weight ratio constraint.

These data indicate the increased performance that can be achieved by the addition of the Standard (TE-364-2) or growth motor (TE-364-4) versions of Burner II in the 0-3000 pound payload region. At a C_3 = 22 Km^2/sec^2, (39,300 fps) the Standard Burner II can provide an 880 pound payload increase and the growth motor Burner II provides 980 pound increase over the Titan IIIB/Centaur capability.

2.1.1.3 Titan IIID/Centaur/Burner II Escape Mission Performance

Payload versus velocity data, shown in Figures 2.1-4 and 2.1-5, are the Titan IIID/Centaur with the standard and growth motor versions of Burner II, respectively. Again data on both shroud configurations are shown. The shroud performance trade includes the shroud weight and aerodynamic effects. There is no liftoff thrust-to-weight ratio constraint for this vehicle, therefore, the Core II stage is always fully loaded.

The Burner II is capable of providing significant performance improvements on this vehicle for payloads less than 3000 pounds. It should be noted that the majority of the performance gain can be achieved by the Standard Burner II with only small additional improvement using the growth motor.

2.1.1.4 Titan IIIB/Centaur and Titan IIID/Centaur Synchronous Equatorial Performance with Burner II

Table 2.1-2 shows the synchronous equatorial performance for the Titan IIIB/Centaur/Burner II and the Titan IIID/Centaur/Burner II. Data are shown with the standard and growth versions of Burner II and the 11 foot and 14 foot shrouds.

The Titan IIIB/Centaur/Burner II capability with the TE-364-2 shows only a small increment in the performance trade between the 11 foot and 14 foot shrouds. Most of the additional performance using the 11 foot shroud is lost due to an increase in the perigee plane change required to match the velocity requirements to the Burner II capability. Using the TE-364-4 allows near optimum plane changes with the velocity match to the Burner II capability being made by off load of the TE-364-4 motor.

The Titan IIID/Centaur/Burner II performance using the TE-364-2 requires all the plane changes to be made at perigee and early shutdown of the Centaur. This limits the performance to the capability of the Burner II (TE-364-2) to provide the final, no plane change, injection. Since excess capability is available in the launch vehicle, no payload loss results from the 14 foot shroud. The Titan IIID/Centaur/Burner II with the TE-364-4 provides significant improvement in performance, however, the large perigee plane change again influences the shroud trade. These data indicate that a much larger motor for synchronous injection is required to achieve the maximum capability of the Titan IIID/Centaur for this mission.

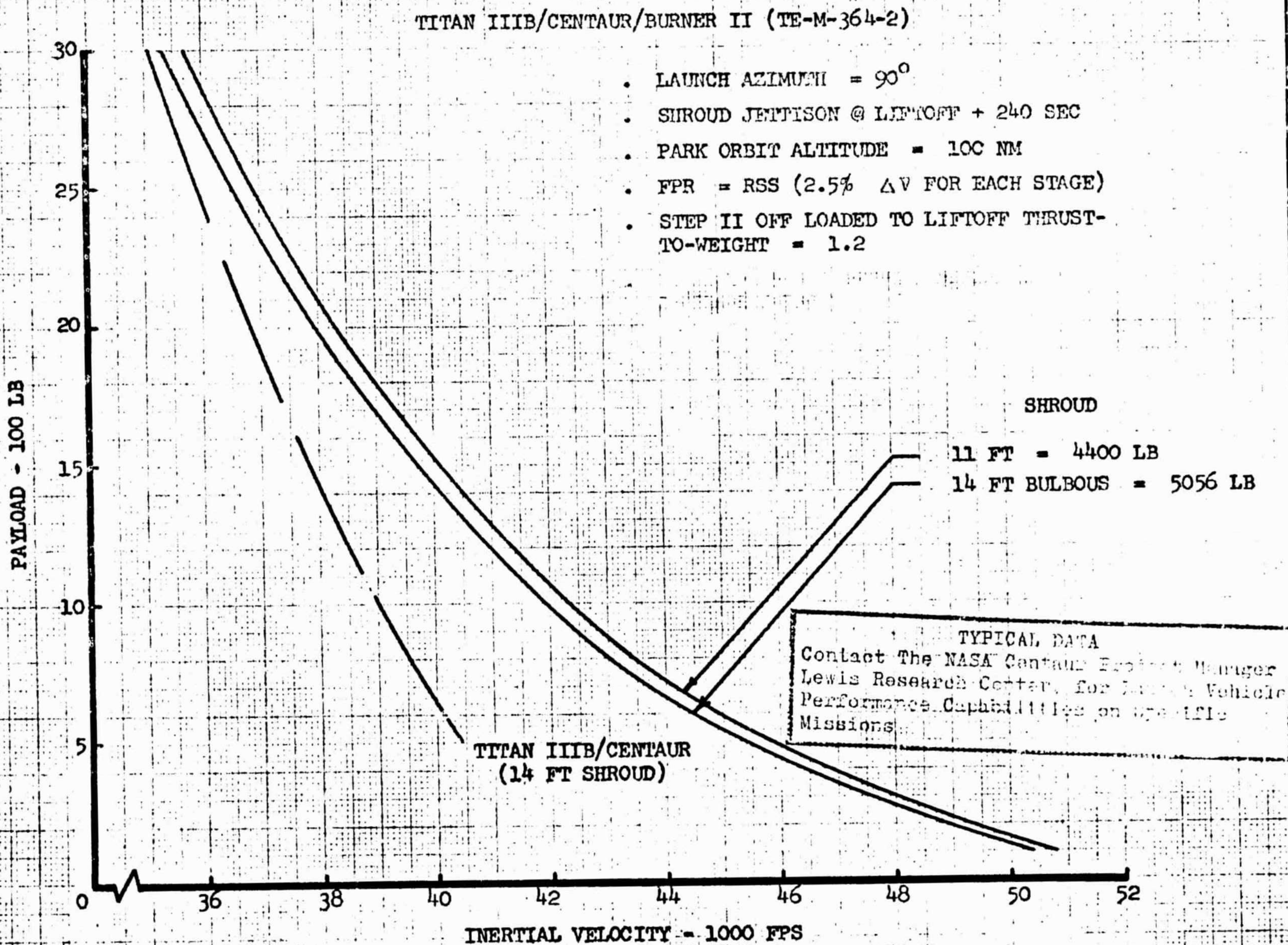


FIGURE 2.1-2
SHEET 1-5

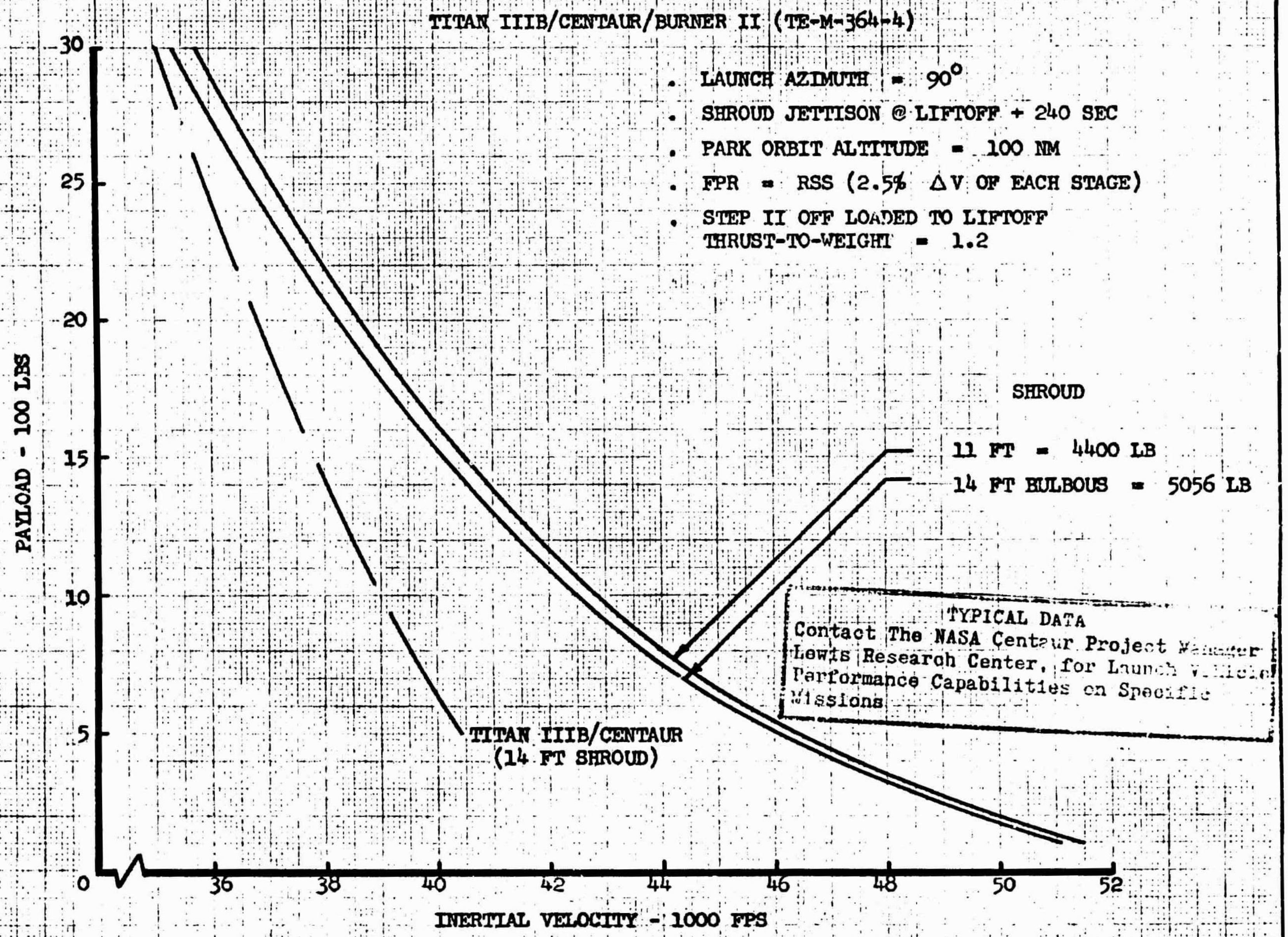

TITAN IIIB/CENTAUR/BURNER II (TE-M-364-4)
• LAUNCH AZIMUTH = 90°
• SHROUD JETTISON @ LIFTOFF + 240 SEC
• PARK ORBIT ALTITUDE = 100 NM
• FPR = RSS (2.5% ΔV OF EACH STAGE)
• STEP II OFF LOADED TO LIFTOFF THRUST-TO-WEIGHT = 1.2
SHROUD
11 FT = 4400 LB
14 FT BULBOUS = 5056 LB
TYPICAL DATA
Contact The NASA Centaur Project Manager Lewis Research Center, for Launch Vehicle Performance Capabilities on Specific Missions
TITAN IIIB/CENTAUR (14 FT SHROUD)
PAYLOAD - 100 LBS
0
5
10
15
20
25
30
36
38
40
42
44
46
48
50
52
INERTIAL VELOCITY - 1000 FPS

FIGURE 2.1-3

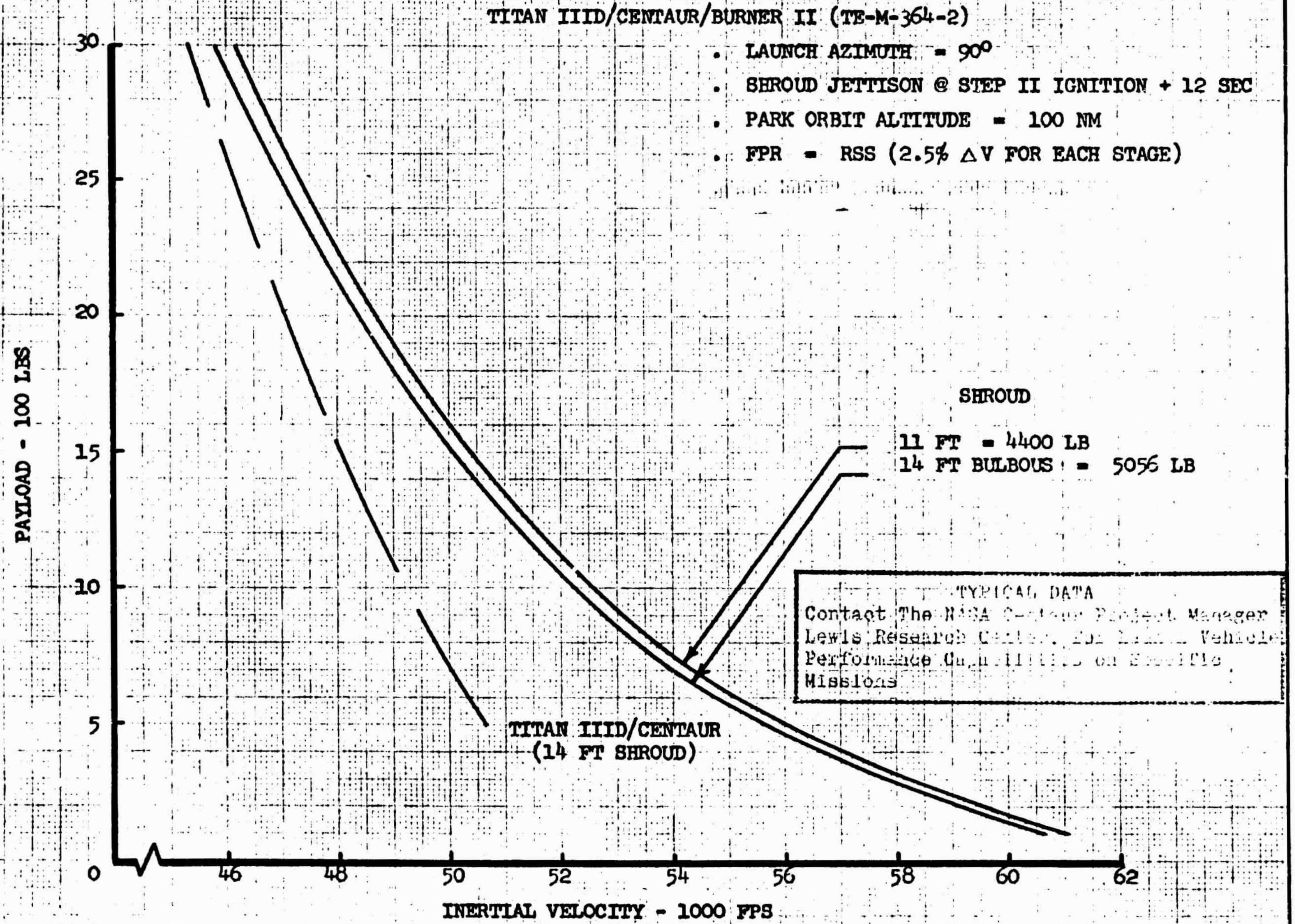


FIGURE 2.1-4

SHEET 1-7

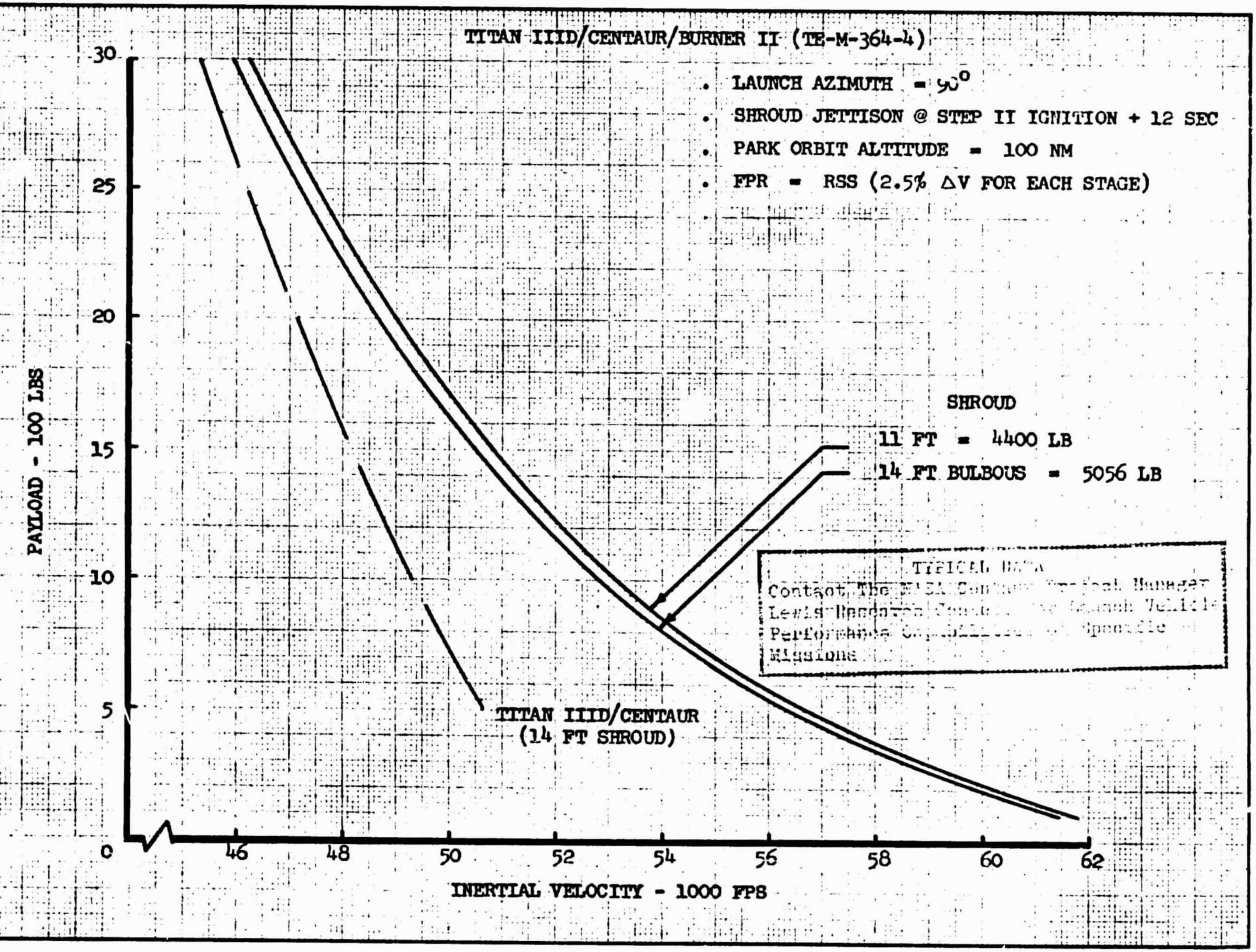

TITAN IIID/CENTAUR/BURNER II (TE-M-364-4)
• LAUNCH AZIMUTH = 90°
• SHROUD JETTISON @ STEP II IGNITION + 12 SEC
• PARK ORBIT ALTITUDE = 100 NM
• FPR = RSS (2.5% ΔV FOR EACH STAGE)
SHROUD
11 FT = 4400 LB
14 FT BULBOUS = 5056 LB
TITAN IIID/CENTAUR
(14 FT SHROUD)
PAYLOAD - 100 LBS
INERTIAL VELOCITY - 1000 FPS
0
5
10
15
20
25
30
46
48
50
52
54
56
58
60
62

FIGURE 2.1-5

TABLE 2.1-2

SYNCHRONOUS EQUATORIAL PERFORMANCE - TITAN IIIB/CENTAUR/BURNER II

BURNER II MOTOR	SHROUD	PAYLOAD*
TE-364-2	11 Ft.	1290 Lbs.
TE-364-2	14 Ft.	1260 Lbs.
TE-364-4 (WP = 1840)	11 Ft.	1431 Lbs.
TE-364-4 (WP = 1713)	14 Ft.	1296 Lbs.

TITAN IIID/CENTAUR/BURNER II

**TE-364-2	11 Ft.	1593 Lbs.
**TE-364-2	14 Ft.	1593 Lbs.
TE-364-4	11 Ft.	2690 Lbs.
TE-364-4	14 Ft.	2670 Lbs.

*Burner II/Centaur adapter and payload support designed for 2800 Lb. Payload, for lighter payloads, the heavy adapter and payload support can cause up to 90 pounds penalty.
**Assumes Early Centaur Shutdown

TYPICAL DATA

Contact The NASA Centaur Project Manager Lewis Research Centaur, for Launch Vehicle Performance Capabilities on Specific Missions

2.1.3 Burner II Mass Properties

The weight of the Burner II changes significantly for the Centaur missions. Changes are made to the basic structure depending on mission to accommodate larger payloads, more equipment, greater capacity H_2O_2 system and lengthened rocket motor. Equipment, cabling and RCS propellants increase according to the anticipated payload and mission

Performance weight statements were derived for the various configurations of mission, payload and rocket motor size studied and are shown on Table 2.1-3.

Weight and cg data derived for the configurations studied are shown on Table 2.1-4. cg's are located by Centaur stations which are defined in Figure 2.2-1.

The effect of payload weight and Cg location on the Centaur/Burner II Adapter and Burner II/Payload Support Structure weight is summarized as follows:

Ground Rule P/L Weight	Payload CG Location	Burner II/Centaur Adapter Weight -2 Mtr.	Burner II/Centaur Adapter Weight -4 Mtr.	Burner II/Payload Support -2 Mtr.	Burner II/Payload Support -4 Mtr.
2800 Lbs.	50 Percent		209	130	130
2800 Lbs.	25 Percent	133	178	108	108
1200 Lbs.	Actual*		152	24	24

*From a specific Spacecraft Design.

The equipment additions and weight are based on current or previous usage. The structure weight for modification to basic Burner II, payload adapter, and Burner II/Centaur adapter for the 2800 pound payload are based on structural analysis shown in Section 2.2.5. The structure weight for the 1200 pound payload is extrapolated data.

Inertia about the roll, pitch, and yaw axis were derived and are shown on Table 2.1-5. Values are given with and without payload for the burnout and separation weight conditions.

	SYNCHRONOUS EQUATORIAL MISSION 2800 LB PAYLOAD		PLANETARY ESCAPE MISSION ~ 1200 LB PAYLOAD	
	TE-M-364-2 MOTOR	TE-M-364-4 MOTOR	TE-M-364-2 MOTOR	TE-M-364-4 MOTOR
BASIC BURNER II S&EA (LESS P/L SUPPORT & SEPARATION PROV.)	(169.4)	(169.4)	(169.4)	(169.4)
MODIFICATIONS	(105.4)	(135.4)	(45.0)	(70.0)
STRUCTURE - PRIMARY	+14.0	+46.0	+9.0	+36.0
STRUCTURE - SECONDARY & BALLAST	+10.4	+10.4	+3.0	+3.0
GUIDANCE & CONTROL	-	-	-	-
POWER SYSTEM	+40.0	+40.0	-	-
WIRING	+10.0	+10.0	+10.0	+10.0
REACTION CONTROL SYSTEM	+9.0	+9.0	+9.0	+9.0
TELEMETRY SYSTEM	+8.0	+8.0	-	-
RESIDUAL RCS PROPELLANTS	+1.0	+1.0	+1.0	+1.0
RESERVE RCS PROPELLANTS	+13.0	+11.0	+13.0	+11.0
PAYLOAD SUPPORT/ADAPTER	(108.0)	(108.0)	(24.0)	(24.0)
ROCKET MOTOR INERTS	(128.0)	(148.0)	(128.0)	(148.0)
WEIGHT AT BURNOUT	510.8	560.8	366.4	411.4
PROPELLANT	1440.0	2300.0	1440.0	2300.0
EXPENDED INERTS	13.2	17.0	13.2	17.0
CONTROL H_2O_2	3.5	5.5	3.5	5.5
CONTROL N_2	.5	.5	.5	.5
WEIGHT AT STARTBURN	1968.0	2883.8	1823.6	2734.4
COAST CONTROL N_2	1.0	1.0	1.0	1.0
SEPARATION H_2O_2	10.0	10.0	10.0	10.0
WEIGHT AT SEPARATION	1979.0	2894.8	1834.6	2745.4
BURNER II/CENTAUR ADAPTER	(133.5)	(178.5)	(115.7)	(152.7)
STRUCTURE & SEPARATION PROV.	106.5	150.5	88.7	124.7
DESTRUCT & PSS	14.0	14.0	14.0	14.0
WIRING	13.0	14.0	13.0	14.0

TABLE 2.1-3

PERFORMANCE WEIGHT STATEMENTS

TABLE 2.1-4
WEIGHT AND CG SUMMARY

	SYNCHRONOUS EQUATORIAL MISSION 2800 LB PAYLOAD (25% CG)				PLANETARY ESCAPE MISSION ~ 1200 LB PAYLOAD			
	TE-M-364-2 MOTOR		TE-M-364-4 MOTOR		TE-M-364-2 MOTOR		TE-M-364-4 MOTOR	
	WT LB	CG STA	WT LB	CG STA	WT LB	CG STA	WT LB	CG STA
Payload	(2800.0)	2596.7	(2800.0)	2609.9	(1200.0)	2575.1	(1200.0)	2588.3
Basic BII S&EA (Less P/L Support and Separation Provision)	(169.4)	2532.5	(169.4)	2545.7	(169.4)	2532.5	(169.4)	2545.7
Modifications	(105.4)	2537.4	(135.4)	2548.8	(45.0)	2534.4	(70.0)	2545.8
Structure - Primary	+14.0	2530.1	+46.0	2543.3	+9.0	2530.1	+36.0	2543.3
Structure - Secondary, and Ballast	+10.4	2528.9	+10.4	2542.1	+3.0	2528.9	+ 3.0	2542.1
Guidance and Control	-		-		-		-	
Power System	+40.0	2543.4	+40.0	2556.6	-		-	
Wiring	+10.0	2534.6	+10.0	2547.8	+10.0	2534.6	+10.0	2547.8
Reaction Control System	+ 9.0	2533.5	+ 9.0	2546.7	+ 9.0	2533.5	+ 9.0	2546.7
Telemetry System	+ 8.0	2536.3	+ 8.0	2549.5	-		-	
Residual RCS Propellant	+ 1.0	2538.4	+ 1.0	2551.6	+ 1.0	2538.4	+ 1.0	2551.6
Reserve RCS Propellant	+13.0	2538.8	+11.0	2552.0	+13.0	2538.8	+11.0	2552.0
Payload Support/Adapter	(108.0)	2548.0	(108.0)	2561.2	(24.0)	2548.0	(24.0)	2561.2
Rocket Motor Inerts	(128.0)	2519.9	(148.0)	2528.1	(128.0)	2519.9	(148.0)	2532.1
Weight At Burnout-Without Payload	510.8	2533.6	560.8	2544.6	366.4	2529.4	411.4	2540.3
-With Payload	3310.8	2587.0	3360.8	2599.0	1566.4	2564.4	1611.4	2576.0
Propellant	1440.0	2527.3	2300.0	2534.3	1440.0	2527.3	2300.0	2534.3
Expended Inerts	13.2	2527.3	17.0	2517.9	13.2	2527.3	17.0	2517.9
Control H_2O_2	3.5	2539.3	5.5	2552.5	3.5	2539.3	5.5	2552.5
Control N_2	.5	2538.8	.5	2552.0	.5	2538.8	.5	2552.0
Weight At Startburn-Without Payload	1968.0	2528.9	2883.8	2536.2	1823.6	2527.7	2734.4	2535.1
-With Payload	4768.0	2568.7	5683.8	2572.5	3023.6	2546.5	3934.4	2551.3
Coast Control N_2	1.0	2538.8	1.0	2552.0	1.0	2538.8	1.0	2552.0
Separation H_2O_2	10.0	2539.3	10.0	2552.5	10.0	2539.3	10.0	2552.5
Weight at Separation-Without Payload	1979.0	2529.0	2894.8	2536.3	1834.6	2527.8	2745.4	2535.2
-With Payload	4779.0	2568.7	5694.8	2572.5	3034.6	2546.5	3945.4	2551.3
BII/Centaur Adapter	(133.5)	2505.9	(178.5)	2512.8	(115.7)	2505.8	(152.7)	2512.7
Structure and Separation Provisions	106.5	2506.7	150.5	2513.4	88.7	2506.7	124.7	2513.4
Destruct and PSS	14.0	2513.1	14.0	2526.3	14.0	2513.1	14.0	2526.3
Wiring	13.0	2491.8	14.0	2492.8	13.0	2491.8	14.0	2492.8

SYNCHRONOUS EQUATORIAL
MISSION
2800 LB PAYLOAD (CG @ 25% LTH -APPROX 40" FROM BASE)

	TE-M-364-2 MOTOR				TE-M-364-4 MOTOR			
	WT LB	INERTIA, SL FT^2			WT LB	INERTIA, SL FT^2		
		ROLL	PITCH	YAW		ROLL	PITCH	YAW
AT BURNOUT:								
WITHOUT PAYLOAD	510.8	54.4	44.5	48.6	560.8	59.5	57.2	61.7
WITH PAYLOAD	3310.8	1755.	1619.	1624.	3360.8	1761.	1675.	1679.
AT SEPARATION:								
WITHOUT PAYLOAD	1979.0	103.9	90.6	95.8	2894.8	140.9	175.2	180.9
WITH PAYLOAD	4779.0	1804.	2430.	2435.	5694.8	1841.	3032.	3038.

TABLE 2.1-5

INERTIA SUMMARY

(CONTINUED)

PLANETARY ESCAPE
MISSION
1200 LB PAYLOAD
(C.G. 20" FROM BASE)

	TE-M-364-2 MOTOR				TE-M-364-4 MOTOR			
	WT LB	INERTIA, SL FT^2			WT LB	INERTIA, SL FT^2		
		ROLL	PITCH	YAW		ROLL	PITCH	YAW
AT BURNOUT:								
WITHOUT PAYLOAD	366.4	28.8	27.6	30.8	411.4	33.3	42.2	45.7
WITH PAYLOAD	1566.4	399.	605.	608.	1611.4	403.	645.	648.
AT SEPARATION:								
WITHOUT PAYLOAD	1834.6	77.8	70.5	74.6	2745.4	114.	148.0	152.5
WITH PAYLOAD	3034.6	448.	873.	877.	3945.4	484.	1107.	1112.

TABLE 2.1-5 (Continued)
INERTIA SUMMARY

2.1.3 Sequence of Events.

Table 2.1-6 is a Titan/Centaur/Burner II sequence-of-events for a synchronous equatorial mission. The following discussion highlights some of the Burner II peculiar events.

The Burner II gyros are uncaged during Centaur second burn to achieve an accurate attitude transfer. This method is discussed in detail in Task 5.

Adjustment of Burner II ignition time may be required to compensate for boost dispersion effects on apogee altitude for the synchronous equatorial mission. Since there is a fixed interval between Burner Timer start and ignition, this adjustment is accomplished by starting the Timer following the second Centaur burn on the basis of computed trajectory dispersions.

The hydrogen peroxide warm-up pulse is required 2 to 40 seconds before separation to provide hot H_2O_2 jet response. By programming it to occur 21 seconds before the nominal separation time the Timer start can vary $\pm$ 19 seconds without requiring any additional commands from Centaur.

During the coast phase a slow roll maneuver is used to reduce gyro drift errors (Events 10 through 15). Slow roll consists of a continuous programmed roll on the order of one revolution per hour interrupted halfway through the coast period to pitch 180 degrees. Roll rate can be adjusted over a wide range to suit thermal requirements with little effect on guidance accuracy. The slow rotation of the vehicle cancels the non-random drift errors of the pitch and yaw gyros and also offers a means of thermal control for the payload. The 180 degree pitch reverses the direction of roll gyro constant drift and thereby nulls the drift and torquer errors about the roll axis. The 180 degree pitch maneuver is also required to orient the Burner II for injection. For the escape mission, the coast phase would be quite short so that slow roll maneuver would not be included.

The vernier mode is not required for the synchronous mission and the velocity meter could, therefore, be removed from Burner II. Since the vernier mode is required for the lighter payloads in the escape mission, the vernier is included in the synchronous mission data as well to maintain a standardized Burner II.

For the synchronous mission the vernier mode is not an effective correction on the total mission accuracy and could be eliminated. This is a result of the dominance of the booster and the Burner II pitch attitude errors. Hence, the correction of the Burner II longitudinal velocity errors has a negligible impact on the total mission accuracy.

In the payload phase, orientation and spin-up maneuvers can be performed as required. Ten maneuvers are available in the Burner II programmer, including those used through injection. On-orbit correction capability exists although none has been shown in the sequence-of-events.

TABLE 2.1-6

TITAN/CENTAUR/BURNER II SEQUENCE OF EVENTS (SYNCHRONOUS EQUATORIAL MISSION)

EVENT	TIME	SOURCE
BOOST PHASE		
1. CENTAUR MAIN ENGINE START (2nd BURN)	MES-2	CENTAUR
2. GYRO UNCAGE	MES-2 + 30 SEC	CENTAUR
3. CENTAUR MAIN ENGINE CUTOFF	MECO-2	CENTAUR
4. DISARM DESTRUCT SYSTEM	MECO-2	CENTAUR
5. BURNER II TIMER START	MES-2 + Δt_1	CENTAUR
SEPARATION PHASE		
6. COMMAND H_2O_2 WARM-UP PULSE	SEP MINUS (21 ± 19) SEC.	BURNER II
7. TERMINATE H_2O_2 WARM-UP PULSE	SEP MINUS (20.95 ± 19) SEC.	BURNER II
8. INITIATE SEPARATION SEQUENCE	SEP	CENTAUR
A. ENABLE SEPARATION MODE ATTITUDE CONTROL		BURNER II
B. COMMAND CENTAUR/BURNER II SEPARATION		BURNER II
C. BACK-UP COMMANDS FOR TIMER START AND GYRO UNCAGE		BURNER II
COAST PHASE		
9. TERMINATE SEPARATION MODE; INITIATE COAST MODE	SEP + 6 SEC	BURNER II
10. INITIATE SLOW ROLL (1 REV/HR)	INJ MINUS 5-1/2 HR	BURNER II
11. STOP SLOW ROLL	INJ MINUS 3 HR	BURNER II
12. INITIATE PITCH MANEUVER (PITCH 180°)		BURNER II
13. TERMINATE PITCH MANEUVER		BURNER II
14. START SLOW ROLL (1 REV/HR)	INJ MINUS 2-3/4 HR	BURNER II
15. TERMINATE SLOW ROLL	INJ MINUS 1/4 HR	BURNER II
16. INITIATE YAW MANEUVER TO INJECTION ATTITUDE (YAW 53°)		BURNER II
17. TERMINATE YAW MANEUVER		BURNER II
INJECTION PHASE		
18. SWITCH TO INJECTION MODE; START VELOCITY METER		BURNER II
19. COMMAND BURNER II MAIN ENGINE THRUST	INJ	BURNER II
20. TERMINATE INJECTION MODE; SWITCH TO BURNER II VERNIER MODE		BURNER II
21. ENABLE H_2O_2 DEPLETION SWITCH		BURNER II
22. TERMINATE VERNIER MODE (VELOCITY METER)		BURNER II
23. TERMINATE VERNIER MODE (PRESSURE SWITCH)		BURNER II
24. SWITCH TO COAST MODE		BURNER II
PAYLOAD PHASE		
25. MANEUVER FOR PAYLOAD ORIENTATION (OPTIONAL)		BURNER II
26. TERMINATE COAST MODE; SWITCH TO SPIN-UP MODE (OPTIONAL)		BURNER II
27. SPIN-UP PAYLOAD (OPTIONAL)		BURNER II
28. COMMAND PAYLOAD SEPARATION		BURNER II

2.1.4 Guidance Error Analysis

2.1.4.1 Sample Accuracy Data

A typical accuracy analysis has been completed for the Burner II applications in the Centaur/Burner II Integration Study. Two mission applications were considered. The Titan IIIB/Centaur/Burner II (1440) was assumed for the escape mission accuracy and the Titan IIID/Centaur/Burner II (2300) for the synchronous equatorial application. These applications are representative of the accuracy capability of the Burner II.

Table 2.1-7 presents a list of the error sources that must be considered for any application of the Centaur/Burner II.

Accuracy data for the escape mission has been developed for the Burner II alone and combined with a Centaur burnout covariance matrix provided by NASA LeRC. For the purpose of this analysis, a 100-second coast with a 30-degree pitch maneuver was assumed following Burner II separation.

The data presented in Table 2.1-8 shows the combined covariance matrix referenced to a geocentric inertial coordinate system. Table 2.1-9 shows the Burner II contribution to this covariance matrix. The analysis was completed by propagating the Centaur covariance matrix via a state transition matrix to the Burner II burnout point. The Burner II covariance matrix was added to provide the total mission accuracy.

The synchronous equatorial mission accuracy data are shown in Table 2.1-10. These data represent the contribution of the Burner II only. A complete accuracy analysis would require the definition of the booster covariance matrix at Centaur burnout, propagation to synchronous altitude and combination with the Burner II errors. The gyro drift errors in this application are partially compensated by the use of a slow roll maneuver. The data shown in Table 2.1-7 identifies the magnitude of the resulting drift error.

Figure 2.1-6 is presented to show the effect of the Centaur attitude transfer error on the total Burner II error. The increase in the yaw error for the escape mission is due to the cross coupling of the pitch to yaw error during the 30 degree pitch maneuver. This coupling is primarily due to the Centaur roll attitude transfer error. The mission errors contributed during Burner II burn are dominated by the Centaur attitude transfer error. For instance, the cross plane velocity error for the escape mission, increased from 24.9 fps to 56.8 fps during Burner II burn due to this error.

TABLE 2.1-7
BURNER II ERROR SOURCE DATA FOR THE CENTAUR INTEGRATION STUDY

ERROR SOURCE		THREE SIGMA DATA TE-364-3	TE-364-4
Burner II Impulse		±0.6%	±0.75%
TE-364 Expended Inert		±2.7 Lb.	±4.0 Lb.
Stage Weight Tolerance		±3.0 Lb.	±3.0 Lb.
H_2O_2 Expended During Burn		5.5 Nom. 13.7 3σ	10.0 Lb. Nom. 25 Lb. 3σ
*Gyro Drift		1°/Hr.	1°/Hr.
Gyro Torque		.11%	.11%
Timing		.02%	.02%
Thrust Offset	Pitch Yaw	0.28° 0.10°	0.28° 0.10°
Control Impulse Normal	Pitch Yaw	525 Lb-Sec 525 Lb-Sec	620 Lb-Sec 620 Lb-Sec
Rocket Motor Thrust Align with Ref. (Gyro)		0.07°	0.07°
Velocity Meter	Time Prop. Vel. Prop.	.016 ft/sec² .041%	.016 ft/sec² .041%
Centaur Attitude Transfer Error	Pitch Yaw Roll	.442 .442 1.0°	.442 .442 1.0°

*Slow Roll Gyro Drift$_{P\&Y}$ = $0.24\sqrt{T/6}$ where T = Coast Time in Hours

$R = 0.39\sqrt{T/6}$

TABLE II

TITAN IIIB/CENTAUR/BURNER II

COVARIANCE MATRIX - 1σ

	FEET			FEET PER SECOND		
	X	Y	Z	$\dot{X}$	$\dot{Y}$	$\dot{Z}$
	12.528×10^7	-7.1821×10^7	-5.2353×10^7	1.3812×10^5	1.3451×10^5	$-.75118 \times 10^5$
		4.6013×10^7	2.4788×10^7	$-.6965 \times 10^5$	$-.7163 \times 10^5$	$.3075 \times 10^5$
			2.843×10^7	$-.6015 \times 10^5$	$-.58522 \times 10^5$	$.42798 \times 10^5$
				269.2	244.3	44.2
					282.5	-103.4
						506.1
RSS	11193	6783	5332	16.4	16.8	22.5

COORDINATE SYSTEM: GEOCENTRIC INERTIAL 1950 TRUE OF DATE REFERENCE

LAUNCH DATE: JAN. 1, 1970 12.00 HOURS

MISSION: C_3 = 22 KM^2/SEC^2

PAYLOAD: 1800 LBS

TABLE 2.10-9

BURNER II COVARIANCE MATRIX - 1 σ FPS

	X	Y	Z	$\dot{X}$	$\dot{Y}$	$\dot{Z}$
	0	0	0	0	0	0
		0	0	0	0	0
			0	0	0	0
				123.8	108.5	98.2
					143.3	-15.8
						308.0
RSS	0	0	0	11.1	12.0	17.5

TABLE 2.1-10

TITAN IIID/CENTAUR/BURNER II (2300)*
SYNCHRONOUS EQUATORIAL ERROR ANALYSIS

3 σ	APOGEE-PERIGEE	386 NM
3 σ	SEMI-MAJOR AXIS	193 NM
3 σ	PERIOD	1096 SEC
3 σ	INCLINATION	0.26 DEG

PAYLOAD = 2690 LB.

APOGEE PLANE CHANGE = 2.0 HRS

COAST TIME = 5.5 HRS

* THESE DATA REPRESENT THE BURNER II ERRORS ONLY

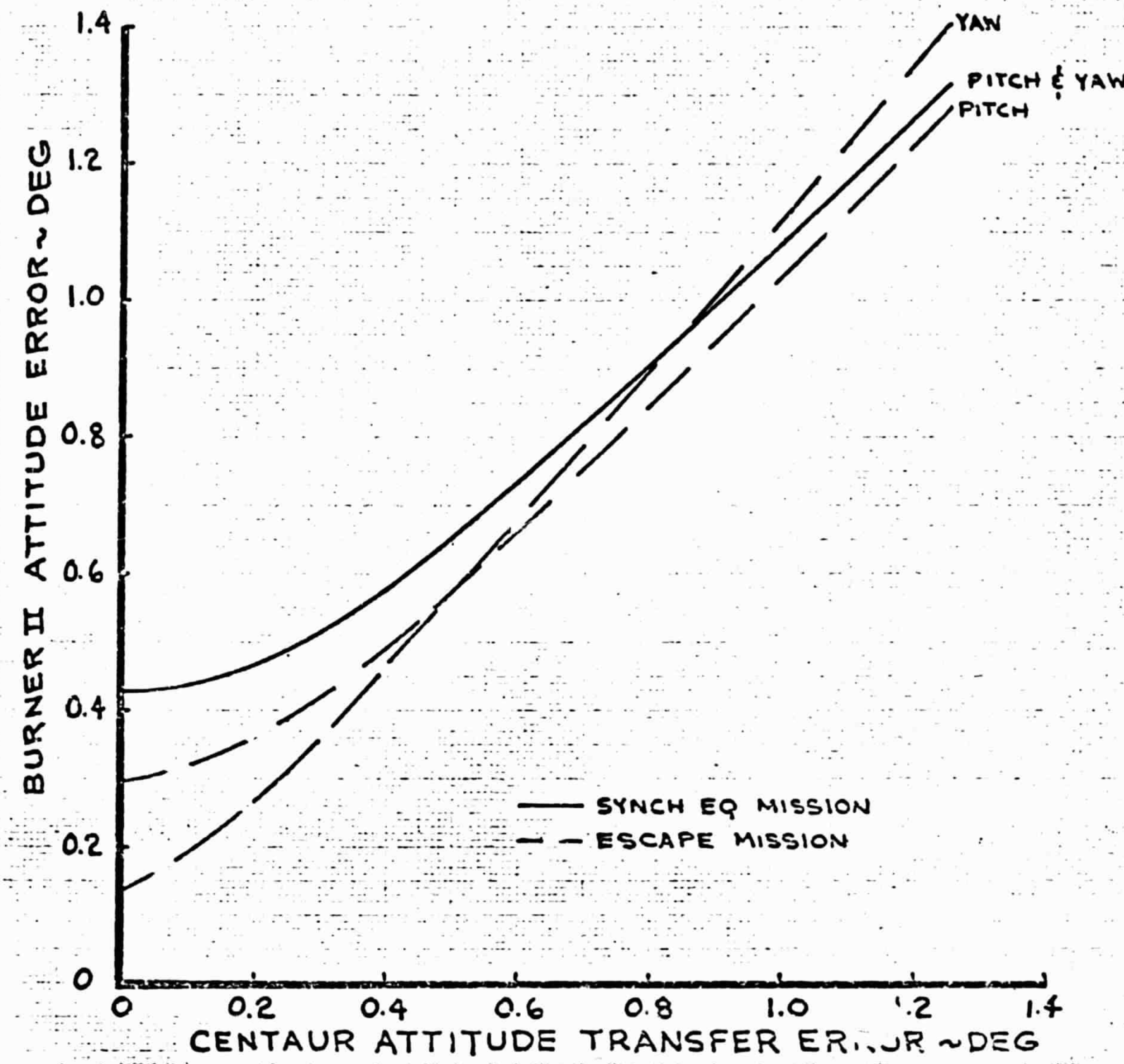


FIGURE 2.1-6

	INITIALS	DATE	REV BY INITIAL	DATE	TITLE	MODEL
CALC	DR	8/27/9			EFFECT OF CENTAUR ATTITUDE TRANSFER ERROR ON TOTAL BURNER II ATTITUDE ERROR	
CHECK						
APPD.						
APPD.						

U3 4013 8000 REV 1/66

REV LTR____________

2.1.4.2 Burner II Accuracy Definition Techniques

The techniques for defining the total mission accuracy for Centaur/ Burner II applications are outlined in the following text. The mission ground rules include the following:

- Escape orbit altitude = 100 Nautical Miles
- C_3 = 22 KM^2/Sec^2
- Payload = 1820 Pounds
- Burner II coast time = 100 Seconds
- Pitch maneuver during coast = 30 degrees
- Burner II vernier control will be used.

The following data is compiled to define the attitude errors during Burner II burn.

Error Source	Attitude Errors 3 Pitch	Yaw	Roll
Centaur Attitude Transfer	.442	.442	1.0°
Burner II Gyro Drift 1°/Hr	0.03	0.03	0.03
Burner II Gyro Torquing 0.11%	0.03		
Burner II Timing .02%	0.01		
Burner II Thrust Offset	0.28	0.10	
Burner II Control Impulse Normal	0.04	0.04	
Burner II Thrust Aline W/Ref.	0.07	0.07	
Cross Couple Pitch to Yaw		0.50	
Root Sum Square	.531	.680	1.0

The longitudinal velocity errors are then defined as follows:

Burner II Impulse ±0.6%	28.5 fps
TE-M-364-2 Expended Inert ±2.7 Lb.	2.6 fps
Burner II Inert Wt. Variation ±3.0 Lb.	5.2 fps
H_2O_2 Consumption	21.7 fps
Root Sum Square	31.2 fps

Since the velocity meter is used in this application, the remaining residual error must be defined. An error distribution with a standard deviation of E is corrected by a system with a capability limit of ± L. All errors below the limit are perfectly reduced to zero, thereby producing a large probability of having zero error. All errors above the limit are reduced to the limit. The standard deviation of the resultant error distribution is shown by R where

$$R = \sqrt{(L^2 + E^2)(1-P) - \sqrt{2/\pi}\, EL e^{-L^2/2E^2}}$$

where P is the probability of the error being less than the limit.

Or $$\left(\frac{R}{E}\right)^2 = \left[\left(\frac{L}{E}\right)^2 + 1\right](1-P) - \sqrt{\frac{2}{\pi}}\ \frac{L}{E}\ e^{-\frac{1}{2}\left(\frac{L}{E}\right)^2}$$

The correction capability for this mission is 27.1 fps then L/E = 2.6 and R/E = .045 for P = 2.6. The remaining velocity error for the Burner II is 1.4 fps.

Therefore:

Longitudinal Velocity Error	1.4 fps
Velocity Meter Error (f (ΔV))	1.9
Velocity Meter Error (f (t))	0.8
3σ Root-Sum-Square	2.5 fps

The total Burner II velocity errors due to attitude and longitudinal velocity error are then formed into a covariance matrix (1σ)

$\dot{T}$	$\dot{N}$	$\dot{R}$
1.2	-2.1	-0.9
-2.1	357.8	0
-0.9	0	217.1

Where: T, N, R is an orthogonal coordinate system with $\overrightarrow{I_T}$ down range, $\overrightarrow{I_R}$ vertical and $\overrightarrow{I_N}$ normal to the orbit plane.

The covariance matrix at Centaur burnout is propagated by a state transition matrix using the following equation:

$$[A] = [S][B][S]^T$$

Where: B is the initial Centaur burnout covariance matrix
S is the state transition matrix
A is the Centaur covariance matrix at Burner II burnout

The Centaur matrix is added to the Burner II matrix following transformation into the desired output coordinate system.

When orbital missions are being considered, the final covariance matrix is transformed into the desired orbital elements by the appropriate transformation matrix.

2.1.5 Payload Environment

2.1.5.1 Summary

The payload design limit environments are summarized in Figure 2.1-7. It is recommended that the payload primary structure be designed and tested for the indicated loads and stiffness and that the entire payload with components be qualified to the acoustic spectrum while in a reverberation chamber. Payload equipment may be procured to the specified random vibration and shock environments. Shock levels introduced by payload separation may exceed those estimated for operation of the booster and must be estimated when details of the separation system become known. Vibration tests of the entire payload are not recommended except to verify adequacy of structural stiffness (modal survey) and workmanship. This can be accomplished by subjecting the payload to a low level sinusoidal sweep environment.

Thermal environment to the payload has not been investigated. It is assumed that the fairing will provide the insulation necessary to maintain proper thermal control for the payload during boost.

2.1.5.2 Payload and Equipment Limit Loads During Boost

Figure 2.1-8 specifies limit loads for three loading conditions as a function of system or equipment weight. These data are considered suitable for use in preliminary design of payload and Burner II primary and secondary equipment support structures. The data are intended to envelope loads produced by all phases of booster flight including possible amplification of acoustic-vibration inputs to lighter weight equipment. The adequacy of these loads will be verified by detailed dynamic analyses of the combined upper stage/booster as the design becomes firm. This method of data presentation forms a consistent and compact set of loads which may be utilized conveniently by various contractors working the same design. A similar approach has been used to design Burner II/payload combinations flown on other boosters.

The above data considers only the 2800 pound payload with the large motor. The Titan/Centaur boost loads of 8g axial, ± 2.5g lateral are most critical for this configuration. For payload weights less than 2000 pounds using the large motor or 1000 pounds using the standard motor, the acceleration loads shown in Figure 2.1-9 must be considered as an additional singular axial load condition for both Burner II and payload design. Loads produced by Burner II motor ignition and decay transients are less than those considered for the steady state boost and Burner II burnout conditions.

2.1.5.3 Acoustic Environment

Figure 2.1-10 displays an assembly of acoustic data for Titan/Centaur, Titan IIIC, and Burner II/Thor. The estimated maximum sound pressure levels within the Centaur fairing cavity are shown by the dotted line. This estimate is based on an extrapolation of Titan IIIC flight data and assumed structural characteristics of the Centaur fairing.

RECOMMENDED PAYLOAD ENVIRONMENTS

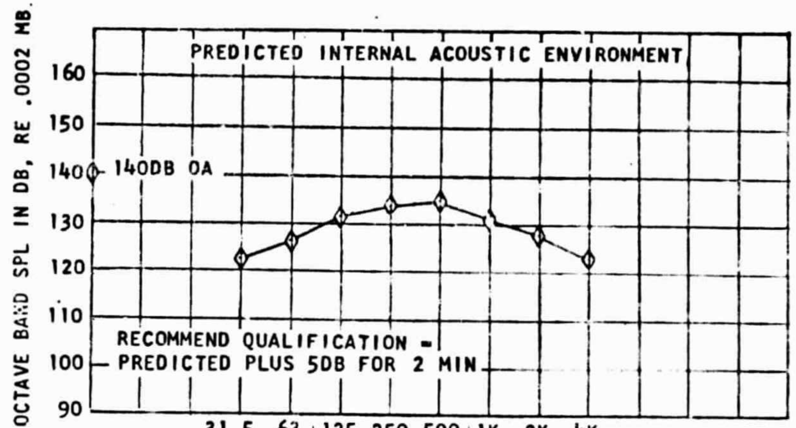
- DESIGN LIMIT LOAD REQUIREMENTS (PRIMARY STRUCTURE)

AXIAL	LATERAL
8g	±2.5g
2g	±2.5g
-2.5g (TENSION)	

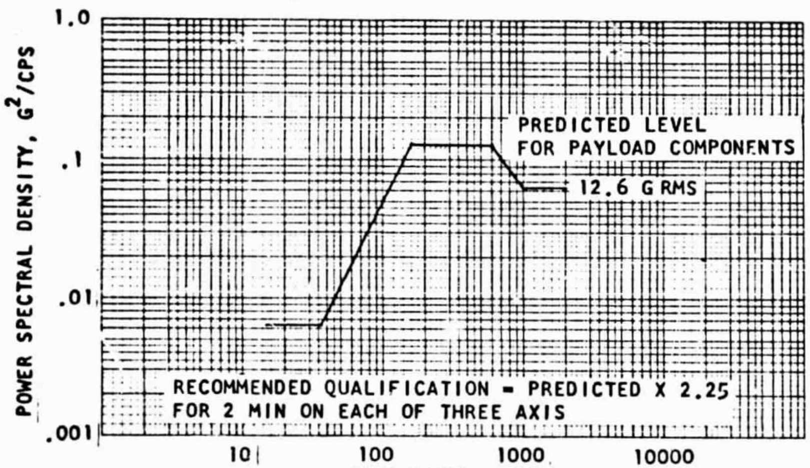
- FREQUENCEY REQUIREMENTS

  LATERAL BENDING FREQUENCY OF 14 CPS AS CANTILEVERED FROM BURNER II INTERFACE

PAYLOAD DESIGN LIMIT LOAD AND FREQUENCY REQUIREMENTS



PAYLOAD ACOUSTIC ENVIRONMENT



- BOOSTER OPERATION

  15g, 8ms SAWTOOTH PULSE

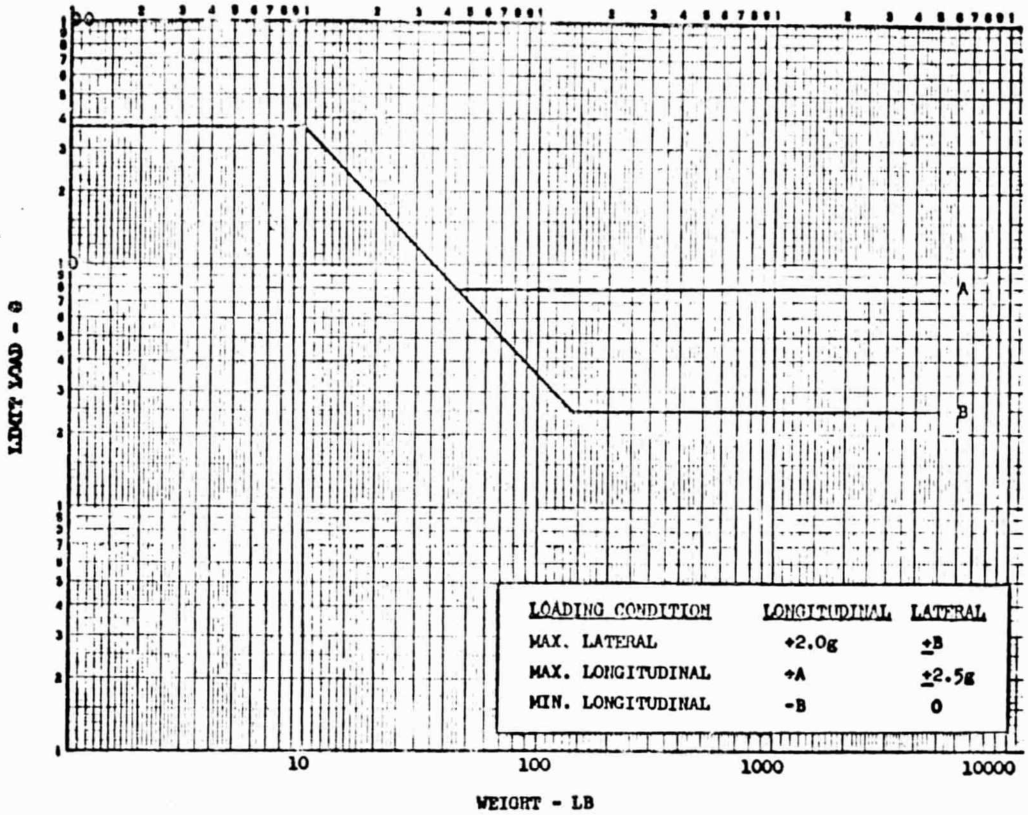
- PAYLOAD SEPARATION

  TO BE DETERMINED

PAYLOAD SHOCK ENVIRONMENT

FIGURE 2.1-7

PREDICTED MAXIMUM INERTIAL FLIGHT LOADS DURING BOOST



LOADING CONDITION	LONGITUDINAL	LATERAL
MAX. LATERAL	+2.0g	±B
MAX. LONGITUDINAL	+A	±2.5g
MIN. LONGITUDINAL	-B	0

FIGURE 2.1-8

MAXIMUM LONGITUDINAL ACCELERATION DURING BURNER II MOTOR FIRING

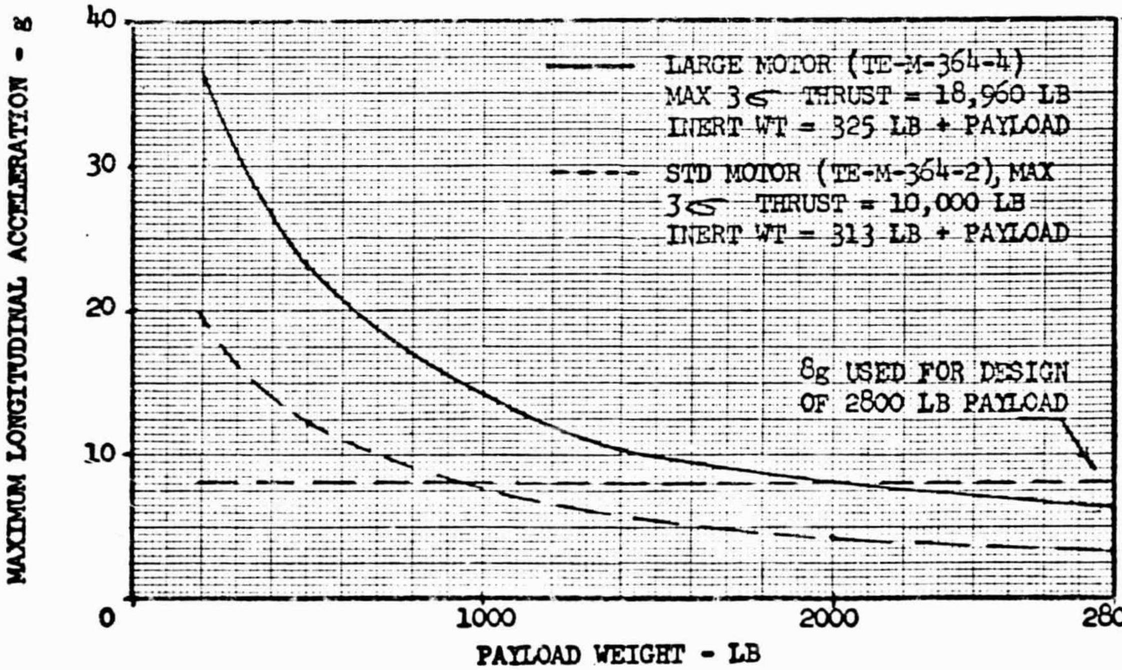
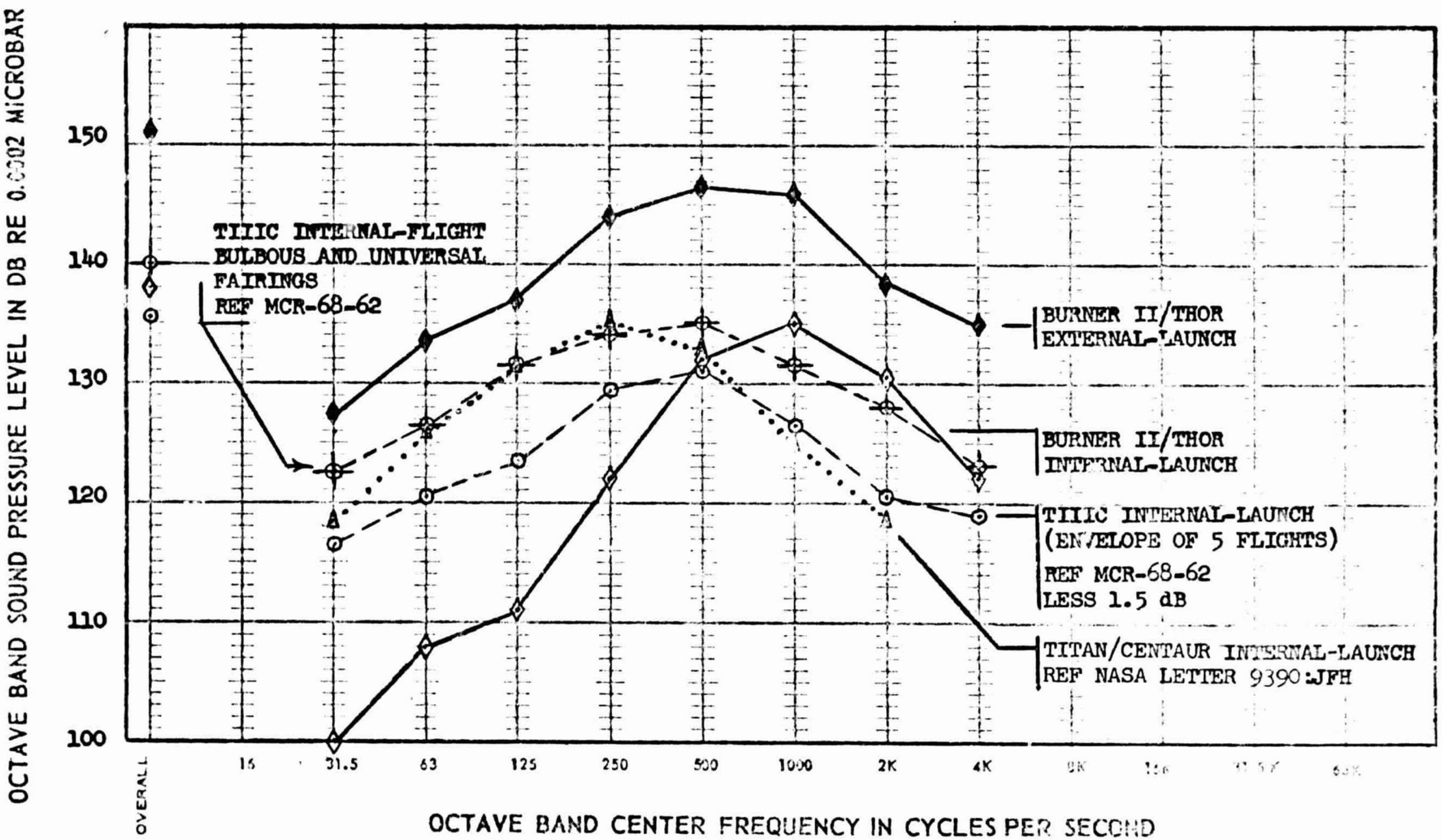


FIGURE 2.1-9



LAUNCH ACOUSTIC ENVIRONMENT
BURNER II/THOR, TITAN IIIC, AND
TITAN/CENTAUR

FIGURE 2.1-10

2.1.5.3 Continued

levels are shown by the dashed lines and were extracted from the Titan IIIC Payload Uer's Guide MCR-68-62. The lower dashed curve represents an envelope based on launch data acquired on five Titan IIIC vehicles employing both a fiberglass fairing and an interim metal fairing. This launch spectrum was reduced 1.5 db to account for greater separation between the noise source and the payload interface on the Titan/Centaur. The upper dashed curve is considered representative of the sound pressure levels occurring within bulbous type fairing during flight.

The solid line spectra represent the external and internal acoustic environment experienced by the Burner II using the Thor booster and the standard Burner II fiberglas heat shield.

Predictions of the Titan/Centaur launch environment closely match the Titan IIIC launch data above 500 cps. Below this frequency, the spectrum is more typical of Titan IIIC flight data with the universal fairing. Since the Centaur data is very preliminary,it is recommended that the maximum Titan IIIC spectrum be used as a design environment for payloads and the Burner II.

The Burner II is qualified for the Thor acoustic levels. These levels equal or exceed the Titan values above about 500 cps, but are significantly less in the lower frequencies. Because of this higher acoustic environment in the low frequency ranges, it is recommended that Burner II testing for this program include an acoustic qualification test. For this test, a Burner II stage would be placed in a reverberation chamber and subjected to the predicted levels plus 5 db for qualification (145 db overall). Vibration response of various equipment components would be measured. The probability of Burner II failure due to the increased sound pressure levels is believed to be quite low. This judgement is based on the conservative method used to qualify Burner II equipment and a review of Titan IIIC flight vibration measurements as discussed in the following section.

2.1.5.4 Burner II Equipment Vibration Levels

The predicted random vibration levels for Burner II equipment were established by subjecting the stage to an acoustic test and enveloping the measured response peaks. Such an envelope is shown in Figure 2.1-11 for the Thor launch induced acoustic environment discussed previously. Each peak represents the response of a rigid component on its Burner II support structure. While the envelope of the peaks has a significant 12.6 grms overall level, the response of individual equipment items range below 3 grms.

Clearly, enveloping of peak responses to establish a predicted component environment is conservative. Additional margin is imposed by qualifying equipment to 2.25 times the spectrum level.

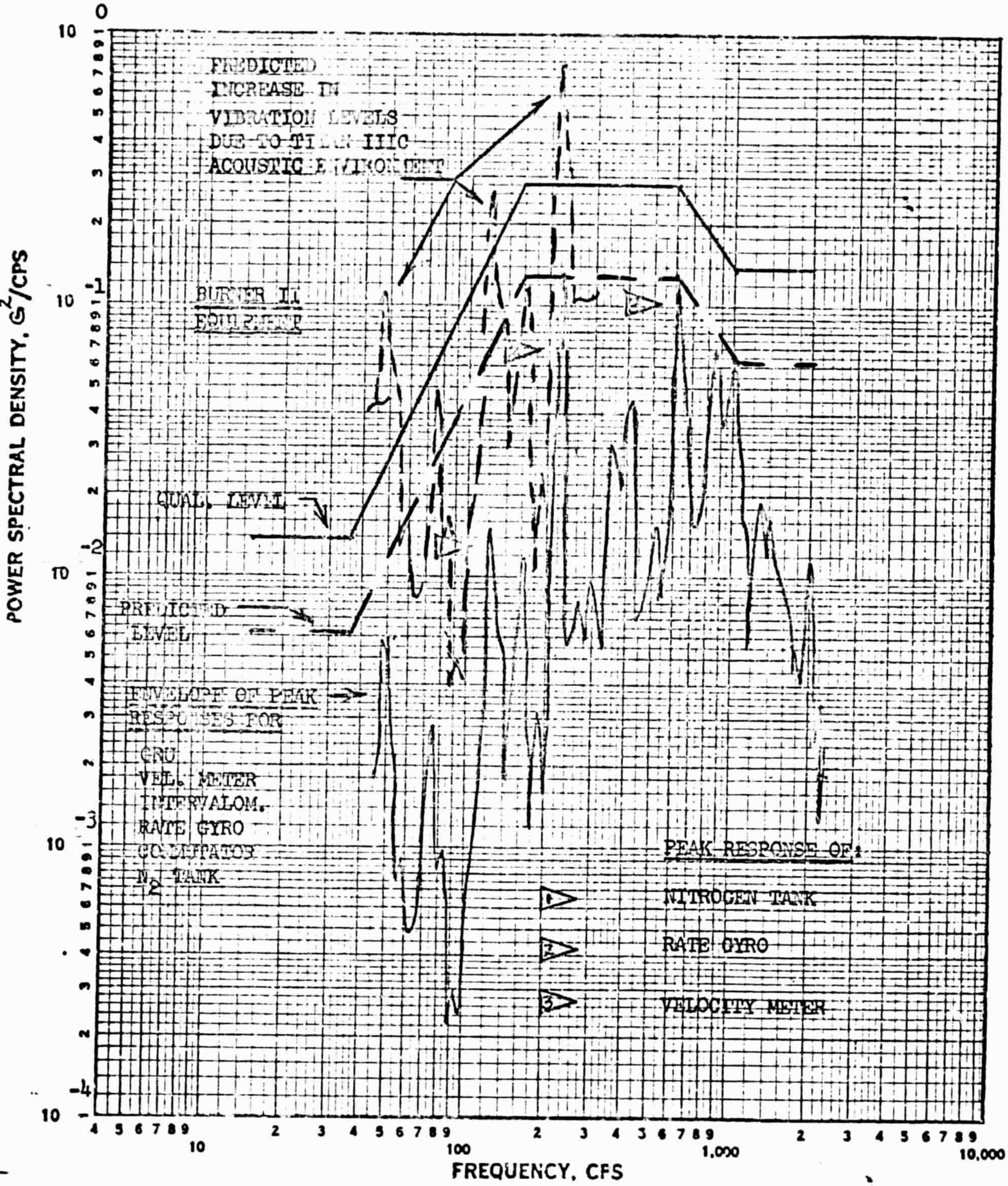
2.1.5.4 Continued

The apparent conservatism in the random vibration environment indicates the Burner II would have a high probability of withstanding the recommended acoustic environment of Section 2.1.5.3. Additionally, Burner II does not contain large area-low density nor brittle items considered susceptible to acoustic induced damage. While a ratio of Titan to Thor acoustic data, shown in Figure 2.1-11, would indicate a significant increase in equipment response below 500 cps (with peaks rising above the qualification level at 50, 120 and 220 cps), the amount of energy contained in these peaks is quite small. The peaks lie in a frequency range generally not considered critical for electronic equipment. Also, Figure 2.1-12 presents a comparison of Titan IIIC flight vibration measurements with the Burner II and payload recommended levels. This data indicates the Titan induced vibration to equipment items is significantly less than predicted for Burner II and payload equipment design. While the flight measurements are at a location below the payload cavity, it does provide some additional confidence that the Titan acoustic environment will not result in failure of components qualified to the recommended random levels.

2.1.5.5 Shock Environment

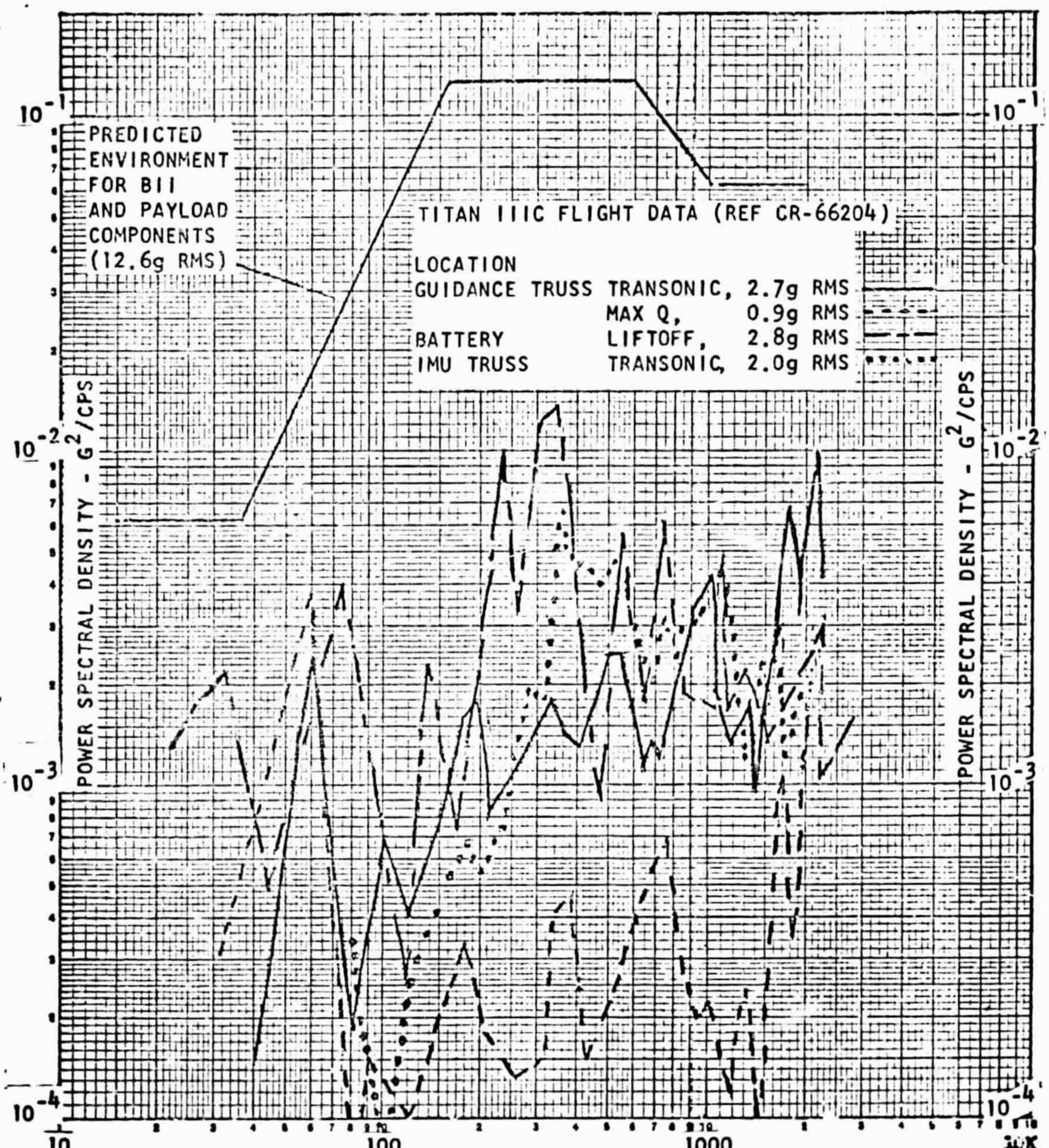
The shock environment to the Burner II and payload equipment introduced by booster operation is considered adequately covered by a 15g, 8ms sawtooth test pulse. This includes fairing jettison, but not payload separation from Burner II. Shock induced by payload separation systems will likely determine the payload component critical shock environments. These will be evaluated on an individual basis.

Fairing removal constituted a potential critical shock environment for Titan IIIC boosted payload components. This source of shock is expected to be greatly mitigated on the Titan/Centaur because of the change in the fairing/booster interface as shown in Figure 2.1-13. The Titan IIIC fairing interface was adjacent to the payload support ring. The resulting shock spectrum environment some six feet above this interface was considered encompassed by a 250g, 0.3ms half-sine pulse as shown in Figure 2.1- (Reference MCR68-62). The Titan/Centaur fairing interface as presently understood will be at the lower end of the Centaur stage. Supports will be provided near the top of the Centaur to enable load sharing between the Centaur tank and fairing; but these are not considered "hard" ties. Shock eminating from fairing release must travel from the Centaur base upward through the tank and adapters before reaching the Burner II and then payload. This travel distance is approximately 28 feet. The shock environment is not expected to exceed that shown for the 15g, 8ms sawtooth pulse.



BURNER II EQUIPMENT QUALIFICATION VIBRATION
LEVEL VS PEAK RESPONSES MEASURED DURING ACOUSTIC TEST

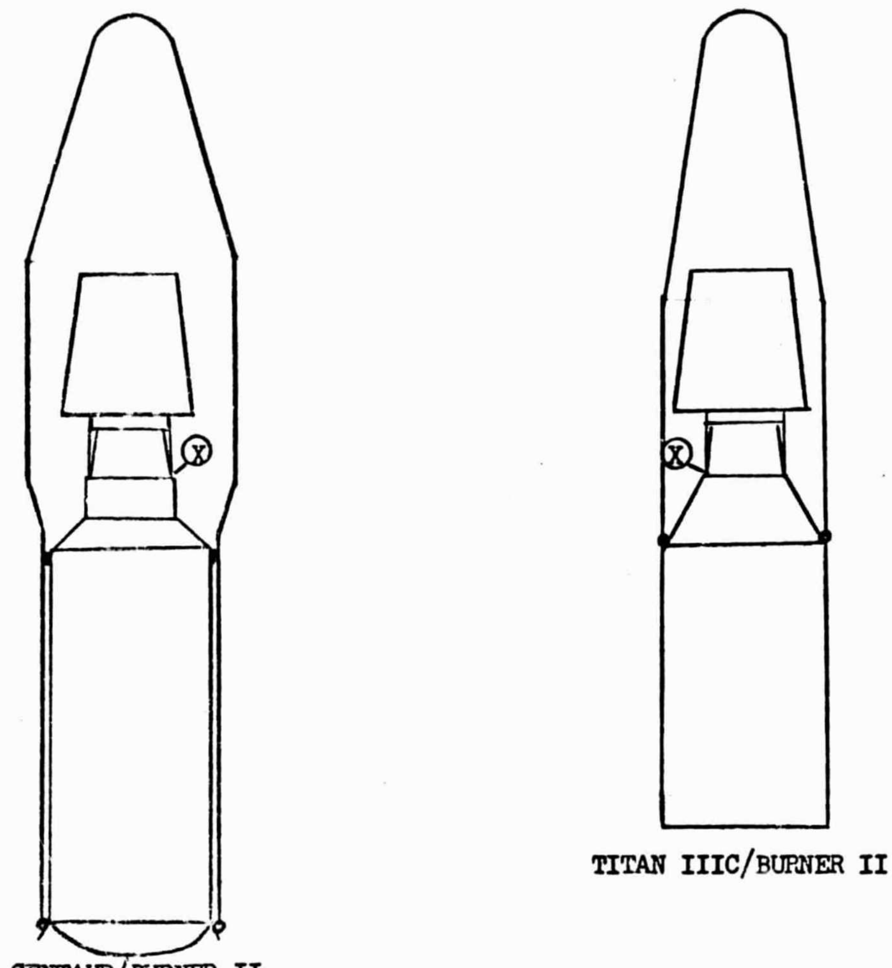
FIGURE 2.1-11



COMPARISON OF BII - PAYLOAD COMPONENT VIBRATION WITH TITAN IIIC FLIGHT DATA

FIGURE 2.1-12

SHOCK ENVIRONMENT



BURNER II/PAYLOAD SHOCK SPECTRA

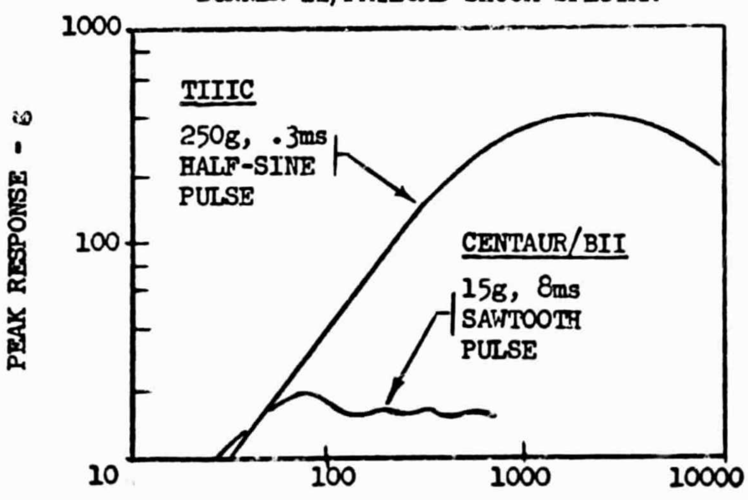


FIGURE 2.1-13

2.2 TASK 2 - MECHANICAL DEFINITION

The purpose of Task 2 was to determine the structural aspects of integrating a payload, the Burner II flight stage, a shroud, the Improved Centaur and related ground handling equipment.

This task consisted of four major areas as outlined below. The following pages discuss the work completed for each of the four study areas.

- Centaur/Burner II Adapter - Work in this area was oriented toward the development of a two-piece adapter section which accommodates both the TE-M-364-2 and -4 motor configurations. A detail configuration was completed and loads and stiffness analyses were conducted. A definition of member sizes, skin gages, ring sizes, etc., was obtained. A separation clearance analysis was conducted to verify the Burner II separation from the Centaur.

- Burner II/Payload Encapsulation - An encapsulation concept was developed which provides for encapsulation of the payload when attached to Burner II during handling and transportation and during times when checkout, ordnance installation, and other access to Burner II is required on the pad. The discussion of Tasks 7 and 8 present details on the installation and usage of the encapsulation barriers.

- Payload Adapter - Work in this area was oriented toward a payload interface ring identical in general aspects to the Burner II/Centaur interface. This will permit configuring the payload to a single interface capable of being launched with or without Burner II. A configuration layout was completed and loads and stiffness analyses conducted.

- Centaur/Burner II Nose Fairing Interface - Interfaces between Burner II, the upper Centaur, and the nose shroud were defined and a conceptual design completed. The interfaces included the payload and Centaur forward equipment compartment encapsulation provisions, nose shroud and Burner II handling and erection provisions, shroud access doors, and umbilical locations.

Figure 2.2-1 below shows the payload specified by NASA and used in the adapter and payload support structure design for this study. Payload weight was based upon the capability of the Titan IIID/Improved Centaur/Growth Motor Burner II (2300 Lb. W_p).

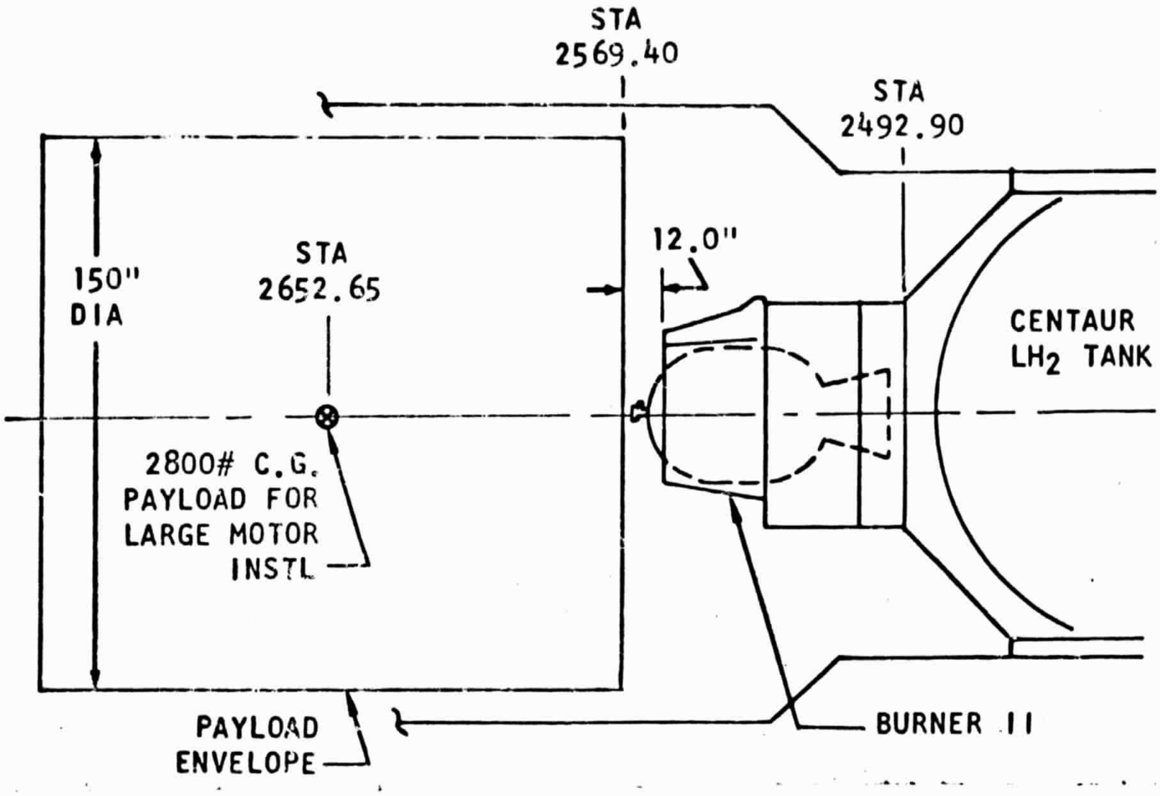


FIGURE 2.2-1

2.2.1 Centaur/Burner II Adapter

Figure 2.2-2 (SKC/I-6) is a layout of a two segment Burner II/Centaur adapter. The adapter is designed to meet the requirement of attaching uniformly to the 65 inch diameter interface on the Centaur, and is a common adapter suitable for both the standard TE-M-364-2 and larger TE-M-364-4 Burner II motors. Only the forward conical section is used for the standard motor, and the straight aft section is added to accommodate the larger motor.

In order to distribute the loads from the three point Burner II base to approximately uniform loads at the Centaur interface and attain the rigid stiffness requirements for the vehicle, a primarily monoque shell arrangement was selected with three tapered longerons and some secondary stiffeners. The forward section is tapered from the 62.2 diameter Burner II to the 65 inch Centaur interface to permit all the Burner II ordnance type fasteners to be located externally for inspection and access. Also, all switches, disconnects and system components are located externally for inspection and access with the exception of the destruct unit which must be located close to the side of the Burner II motor.

The aft section is a straight cylindrical unit which serves mainly as an extension for the larger motor and contains no system components.

The debris shield (or thermal barrier) is a separate assembly that may be installed to fit either adapter configuration. The design of the shield is a flat skin with secondary stiffeners. Aluminum materials are shown for the longeron frames and shell skin adjacent to the longerons because they are stiffness designed. Magnesium is indicated for the intermediate shell skin panels where the skin is buckling critical and extra thickness is an advantage.

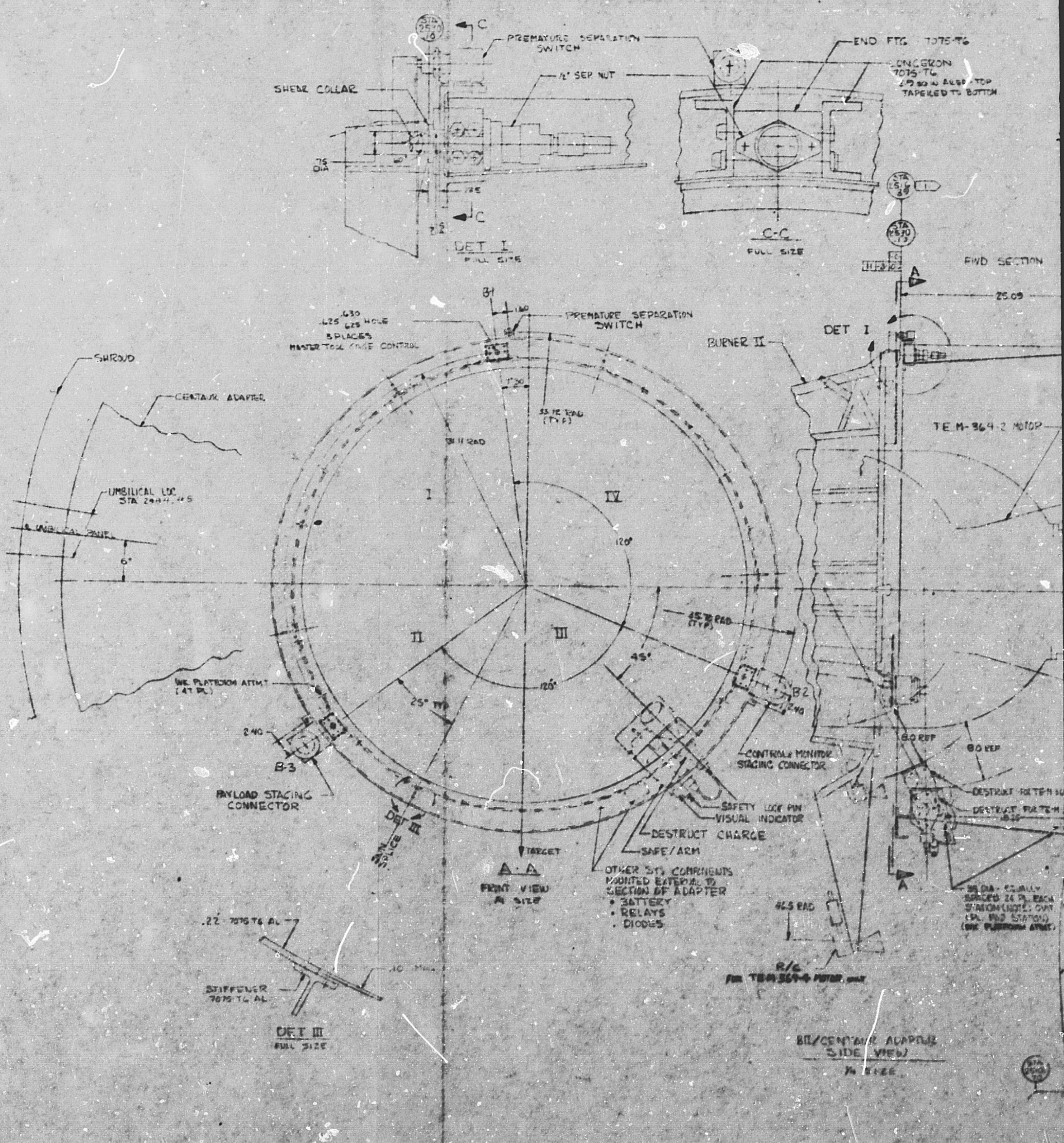
The proposed details associated with separation hardware installations, structural joints and fasteners, and other features are apparent on the layout. Of special note are, two rows of holes in the conical section skin for supporting a removable segmented internal work platform used during Burner II installation and details of a Centaur electronic equipment encapsulation barrier. The barrier encloses the annular opening between the lower section of the nose shroud and the cylindrical extension on Centaur supporting the electronic compartment air conditioning duct. The design shown mates with the ducting defined on SKC-11 which may be superceded by other configurations as the Improved Centaur stage design progresses. However, the barrier shown could easily be moved to accommodate the Centaur.

2.2.2 Payload/Burner II Adapter

The payload support structure concept is shown on Figure 2.2-3. A 12-inch high conically shaped section attached to the Burner II primary structure provides the mating interface with the payload ring. The interface, with a 65.92 bolt circle, is identical to the Burner II/Centaur adapter interface with the Centaur. This feature provides the capability to mount a payload on Centaur with or without a Burner II stage. The conical section consists of an upper ring with a T-shaped cross section, and a lower angle shaped ring, joined by a conical shell.

The support structure is attached to the Burner II structure by three longerons which extend from the base of the Burner II primary beams to the top ring of the payload section. Three truss frames complete the payload ring attachment to the top of the Burner II primary structure. The truss frames provide lateral and torsional stability. A thin gage aluminum skin at the top of the payload support structure forms a part of an encapsulation barrier for the payload.

Each longeron is made of two channels which attach at the lower end to the separation bolt fitting at the base of the Burner II vertical beams. A 1/2 inch diameter bolt catcher is mounted in the fitting to retain the bolt at stage separation. A ground handling lug is provided on one of the two channels of each longeron for handling the Burner II during stage assembly.



FOLDOUT FRAME #1

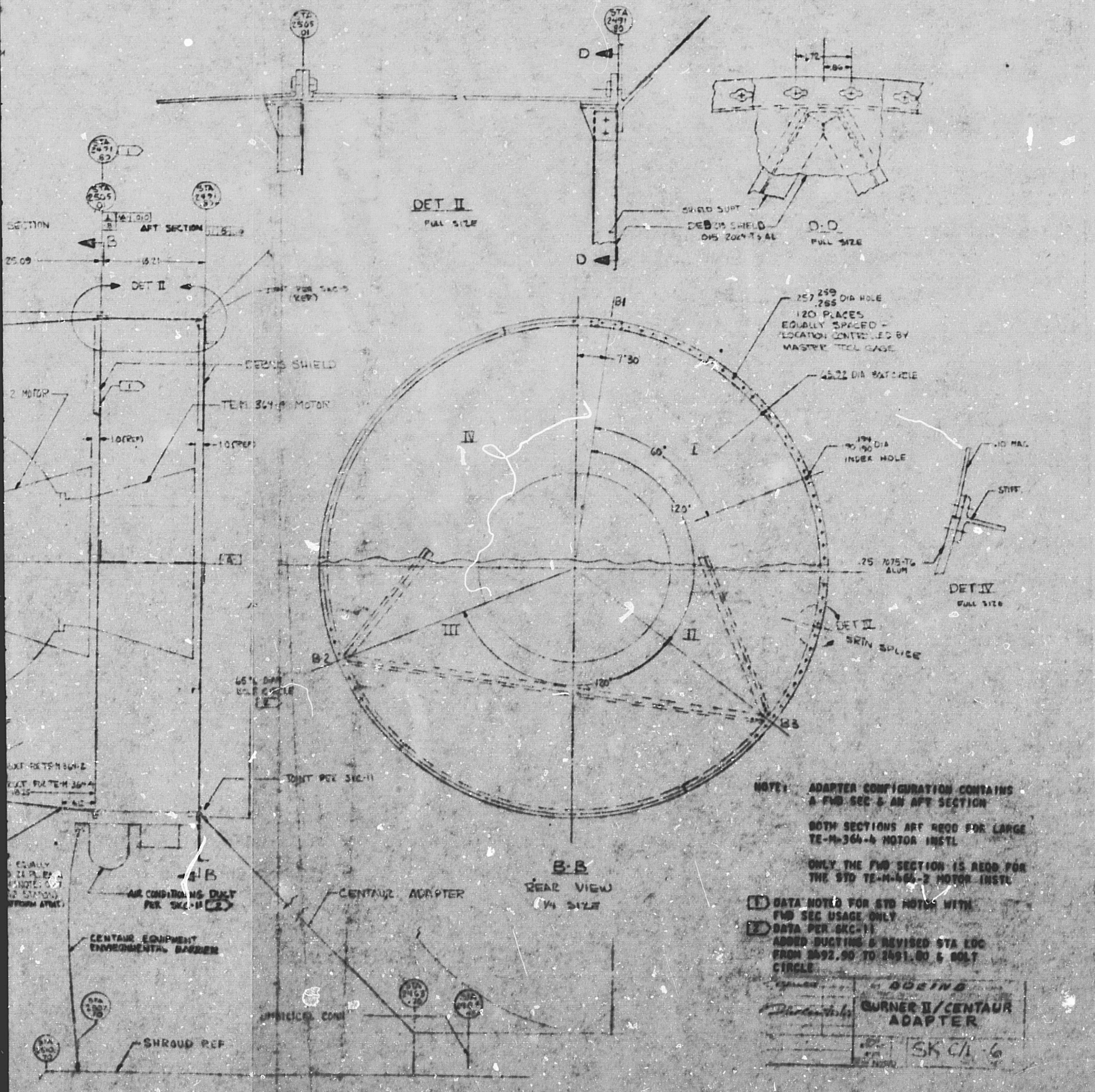
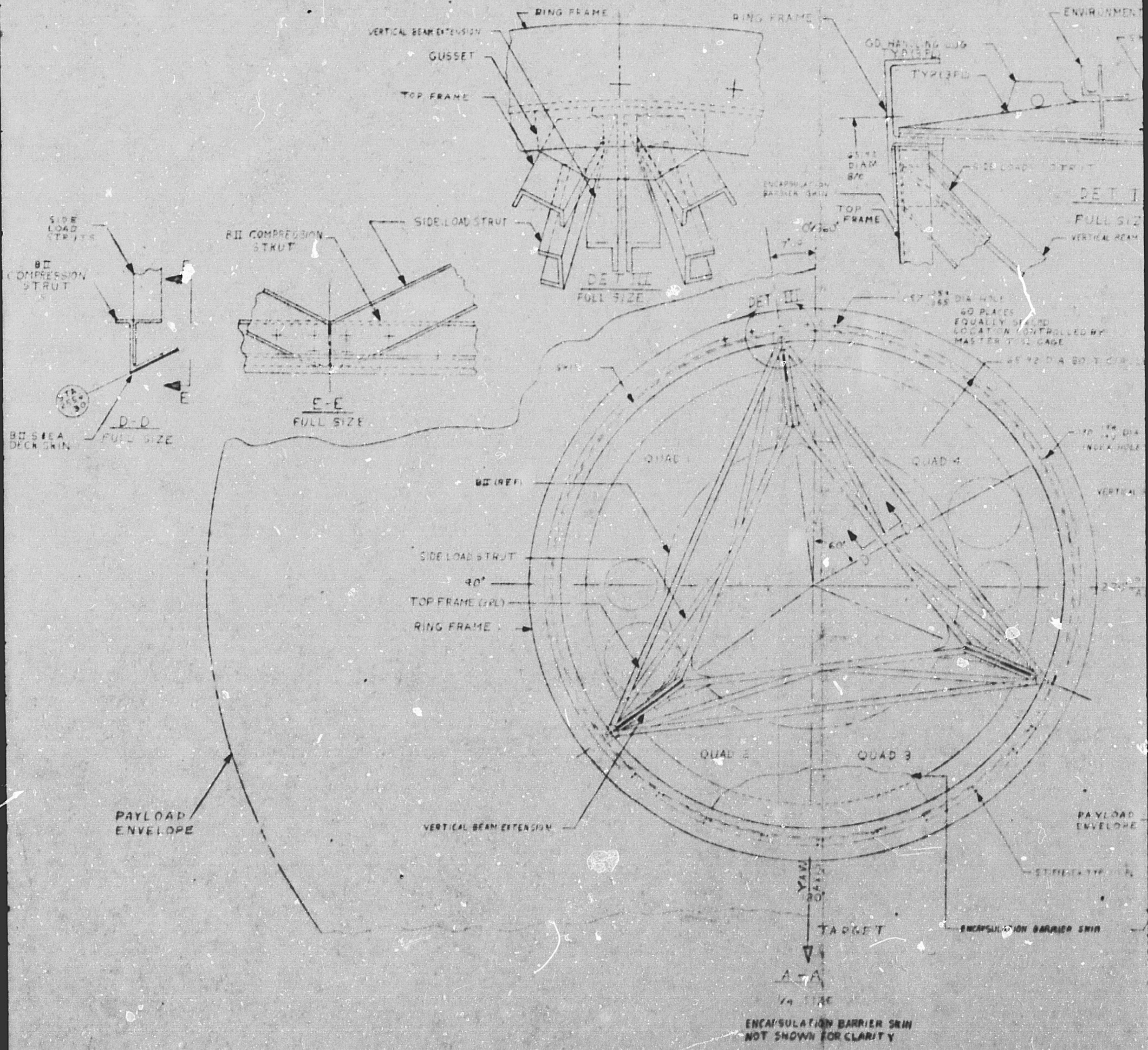
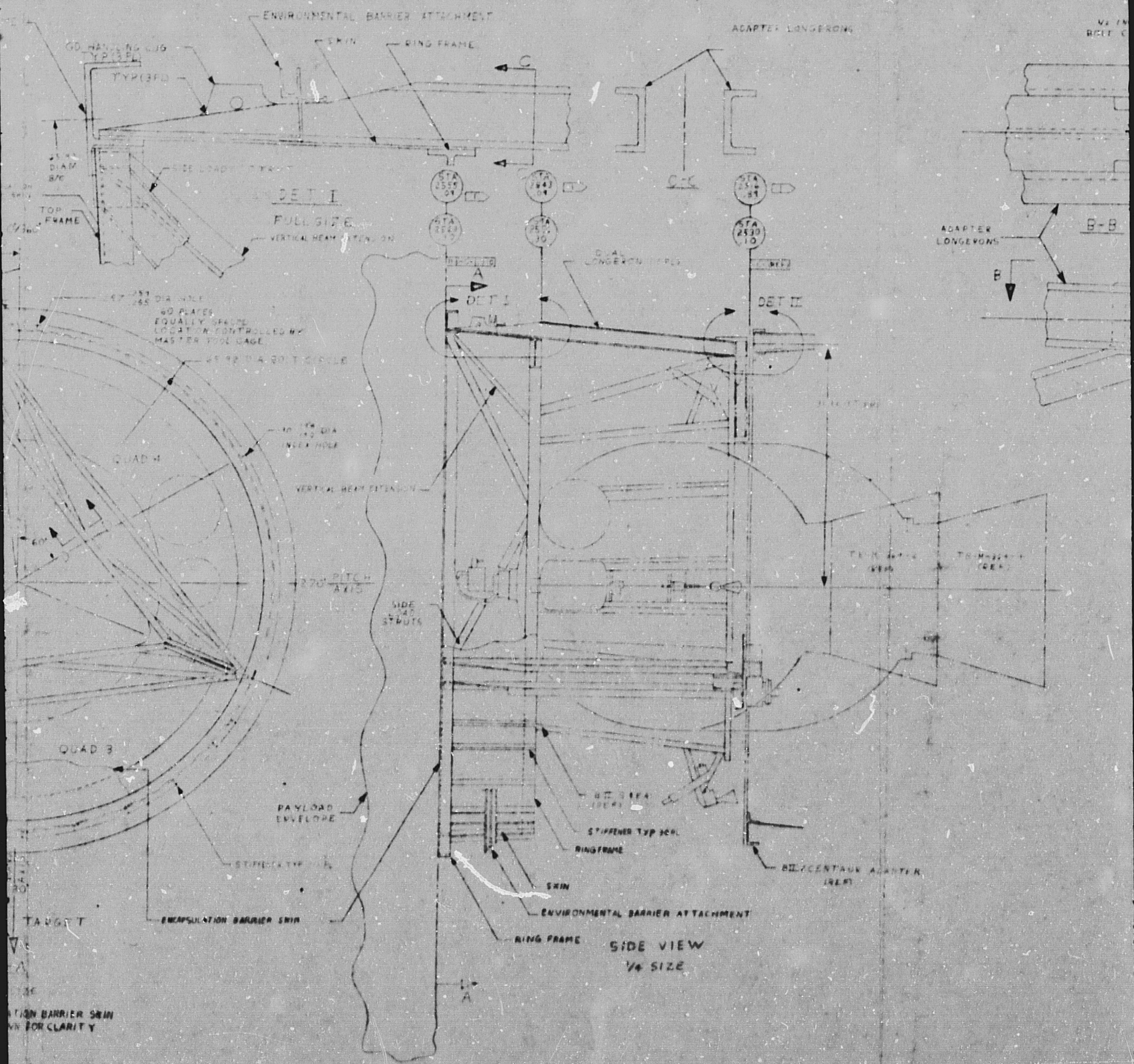

DET II
FULL SIZE
SHIELD SUPT
DEBRIS SHIELD
D-D
FULL SIZE
DEBRIS SHIELD
TEM 364-4 MOTOR
AFT SECTION
120 PLACES
EQUALLY SPACED -
LOCATION CONTROLLED BY
MASTER TOOL GAGE
INDEX HOLE
DET IV
FULL SIZE
STIFF.
DET V
SKIN SPLICE
B-B
REAR VIEW
1/4 SIZE
CENTAUR ADAPTER
AIR CONDITIONING DUCT
CENTAUR EQUIPMENT
ENVIRONMENTAL BARRIER
SHROUD REF
NOTE: ADAPTER CONFIGURATION CONTAINS
A FWD SEC & AN AFT SECTION
BOTH SECTIONS ARE REQD FOR LARGE
TE-M-364-4 MOTOR INSTL
ONLY THE FWD SECTION IS REQD FOR
THE STD TE-M-364-3 MOTOR INSTL
1 DATA NOTED FOR STD MOTOR WITH
FWD SEC USAGE ONLY
2 DATA PER SKC-11
ADDED DUCTING & REVISED STA LOC
FROM 2492.90 TO 2491.80 & BOLT
CIRCLE
BOEING
BURNER II/CENTAUR
ADAPTER
SK C/1-6

FIGURE 2.2-2



FOLDOUT FRAME #1


ENVIRONMENTAL BARRIER ATTACHMENT
SKIN
RING FRAME
ADAPTER LONGERONS
TYP (3 PL)
DET I
FULL SIZE
TOP FRAME
C-C
STA 2559.04
STA 2543.04
STA 2530.10
ADAPTER LONGERONS
B-B
DUAL LONGERON (TYP)
DET I
DET II
QUAD 4
VERTICAL BEAM EXTENSION
270° PITCH AXIS
SIDE LOAD STRUTS
QUAD 3
PAYLOAD ENVELOPE
STIFFENER TYP
STIFFENER TYP 3 PL
RINGFRAME
SKIN
ENVIRONMENTAL BARRIER ATTACHMENT
RING FRAME
ENCAPSULATION BARRIER SKIN
SIDE VIEW
1/4 SIZE
TARGET
A

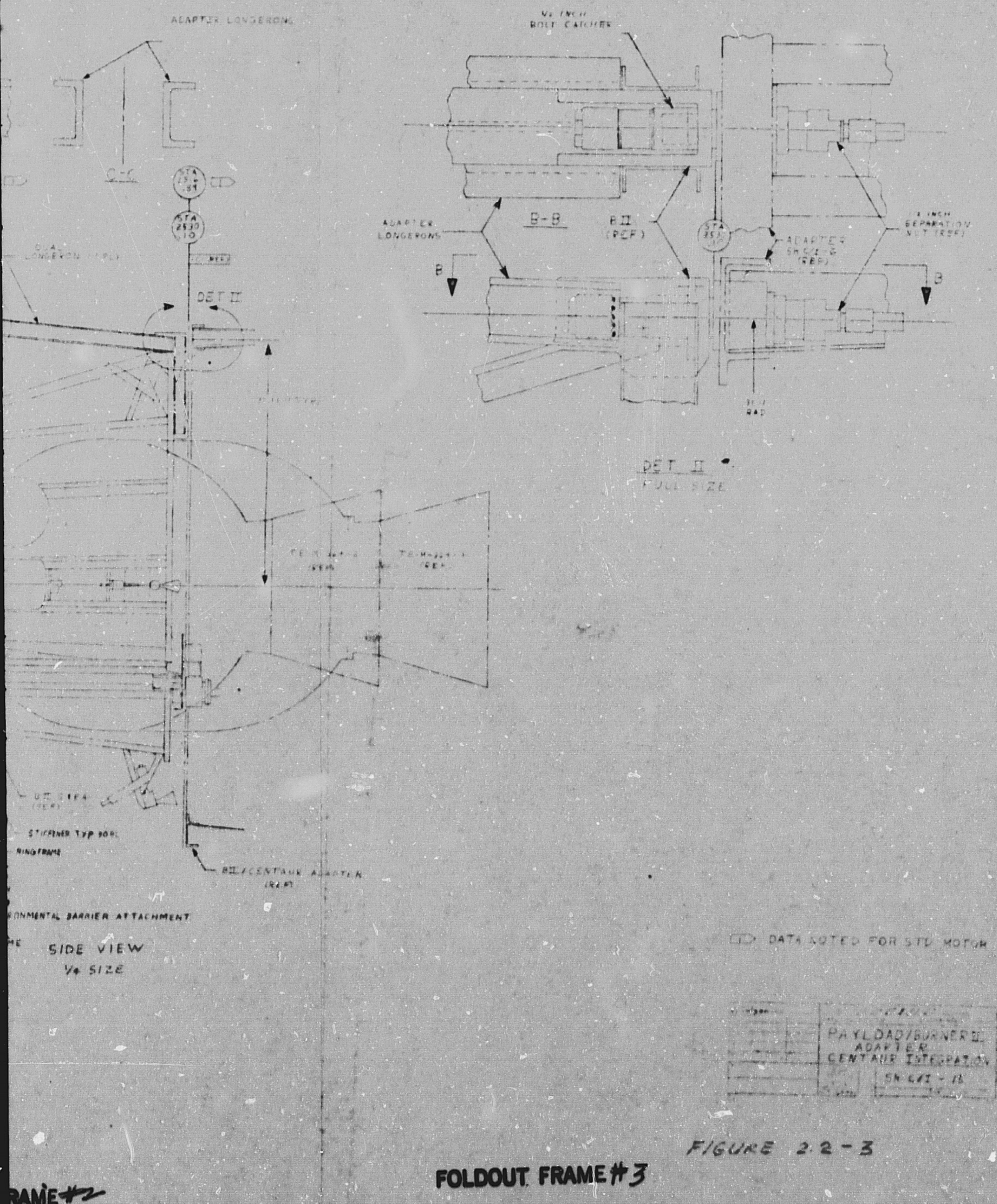


FIGURE 2.2-3

FOLDOUT FRAME #3

FRAME #2

2.2.3 Payload Encapsulation and Centaur/Burner II Nose Shroud Interfaces

NASA specified that the payload would have to be encapsulated within the shroud after installation on Burner II. The encapsulation is to provide environmental control for the payload during the transfer from the payload/Burner II assembly area to the launch pad.

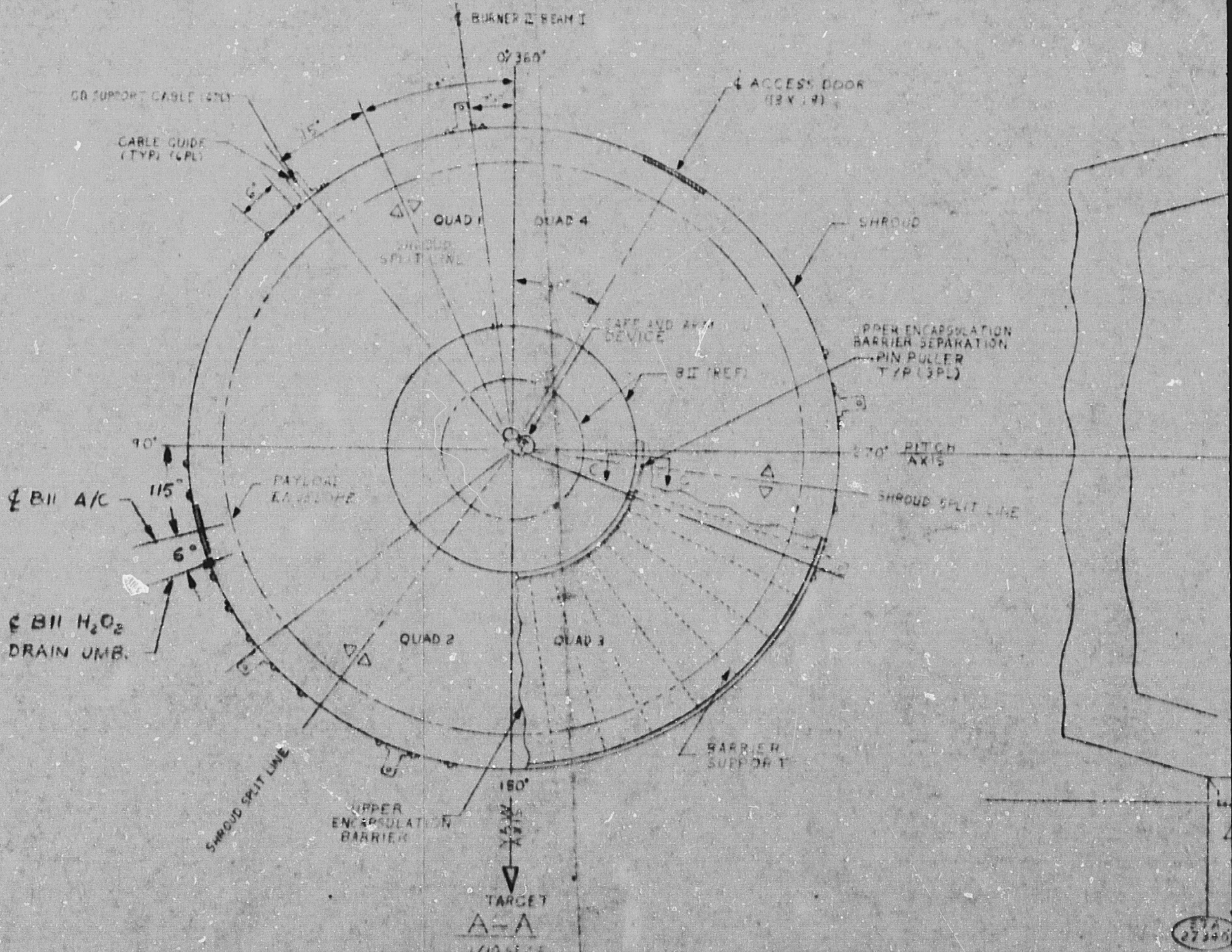
Requirements for payload encapsulation and Burner II interfaces with the standard Centaur nose shroud and upper Centaur stage were analyzed and a conceptual design was prepared. This design, shown on Figure 2.2-4 is based on data provided in Convair-Astronautics drawing SKC-11, and NASA-LeRC drawings CR-600310 through CR600336. The interfaces shown include payload and Centaur encapsulation provisions, shroud and Burner II handling and erection provisions, internal working provisions and personnel access, and Burner II umbilical connector locations. Because of insufficient definition, provisions have not been included for accommodating the internal ducting required to vent the Centaur forward electronic compartment which is shown on drawing CR600319.

2.2.3.1 Encapsulation

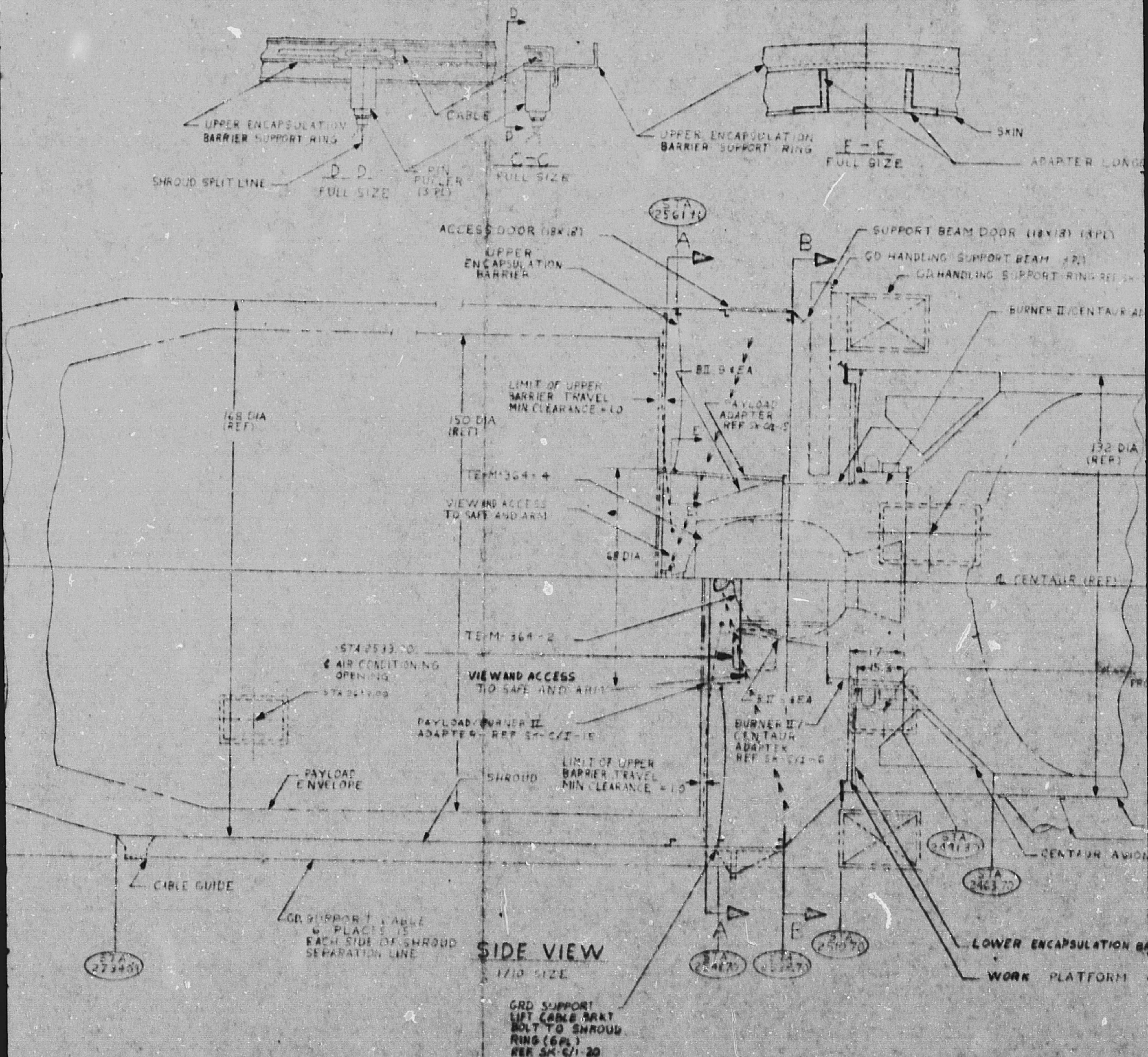
Each of the two encapsulation barriers shown on Figure 2.2-4 is made in three 120 degree segments, of fabric reinforced by radial stiffeners sewn into the material. The 120 degree segments are joined along the nose shroud split lines. The large diameter of each barrier segment is attached to internal structural rings on each of the nose shroud sections, upper and lower. The small diameters are joined to barrier support rings, one installed on the Burner II payload support ring and the other on the cylindrical section supporting the Centaur equipment section air-conditioning duct. A cable and clevis assembly is sewn into the small diameter of each barrier segment. Adjacent segments are joined together in the barrier support ring by explosively actuated pin pullers installed through the ring and mating clevises. Three pin pullers, located radially along the shroud split lines, are installed in each barrier support ring. Barrier release prior to shroud separation is accomplished by firing the pin pullers, which frees the three cable sections locking each barrier into its support ring. The payload compartment encapsulation is completed by a barrier skin installed on top of the payload support ring.

The Burner II and payload are supported within the shroud during erection by a circular handling ring containing three support beams located 120 degrees apart. Three access doors are provided in the conical section of the shroud between Stations 2510.70 and 2528.70 for entry of the beams.

The nose shroud is supported during assembly and erection by lift cables and brackets which are attached to the shroud. Six lift brackets are located between Stations 2528.70 and 2548.70 at 15 degrees on either side of the three shroud split lines. They are attached between shroud stringers with fasteners to nut plates located on the shroud internal rings. Six cable guide brackets are attached in a similar manner at shroud Station 2734.09. Three sets of lift brackets and guide brackets, located 120 degrees apart are used for erection at the pad.



FOLDOUT FRAME #1



FOLDOUT FRAME #2

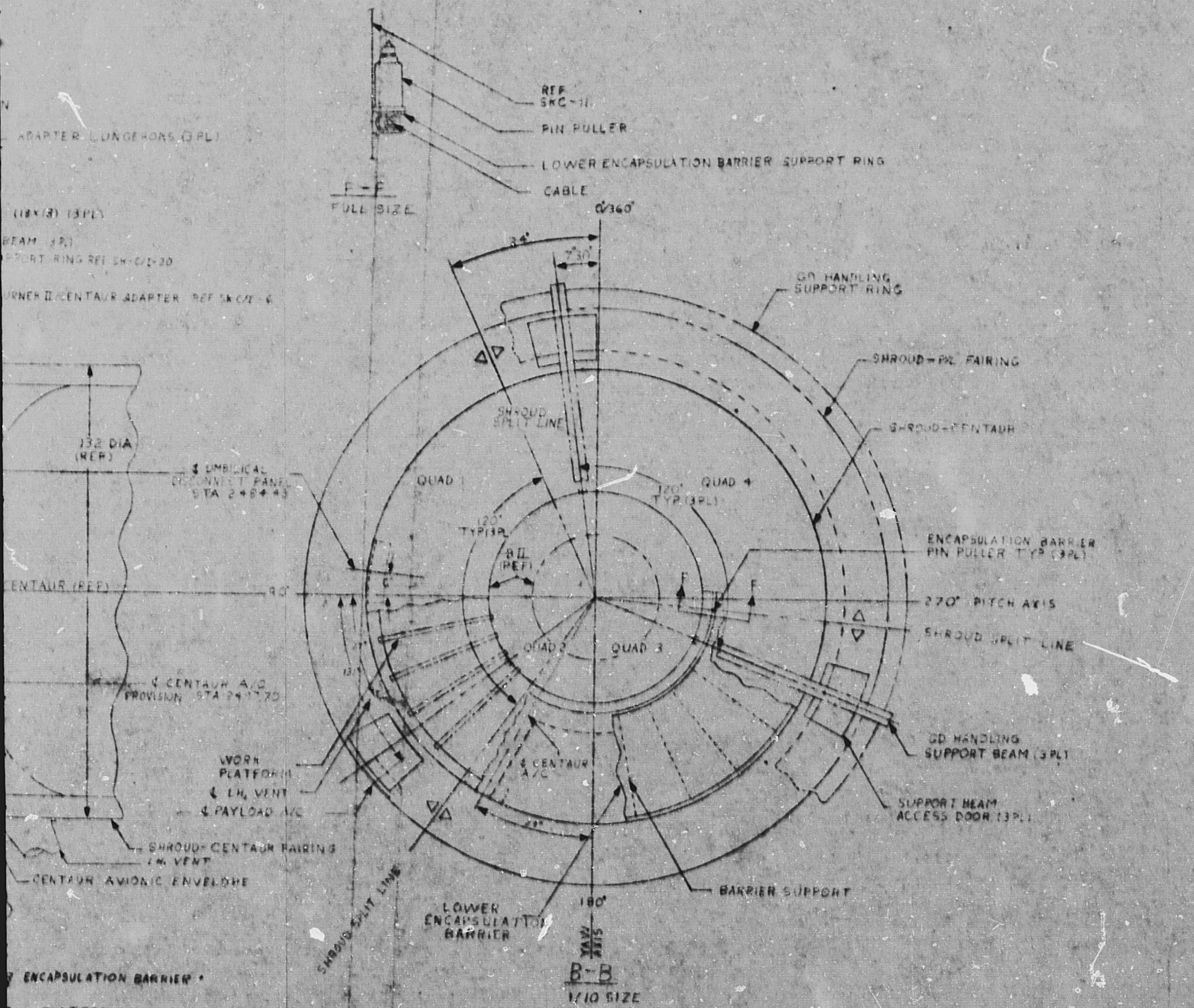


FIGURE 2.2-4

FOLDOUT FRAME #3

2.2.3.2 Nose Fairing Interfaces with Burner II

Access is required within the nose shroud for personnel to install the Burner II/Centaur adapter, the encapsulation barriers and the Burner II separation bolts, to disconnect and remove erection handling equipment, and to test and service the Burner II vehicle. Primary personnel access is provided by a door in the upper shroud cylindrical section. The three doors for the handling ring support beams also provide personnel access when the ring is removed.

Support for personnel within the shroud is provided by the removable internal work platform shown on Figure 2.2-4 and described previously. The outer periphery of the work platform segments are supported on the lower nose shroud field splice ring.

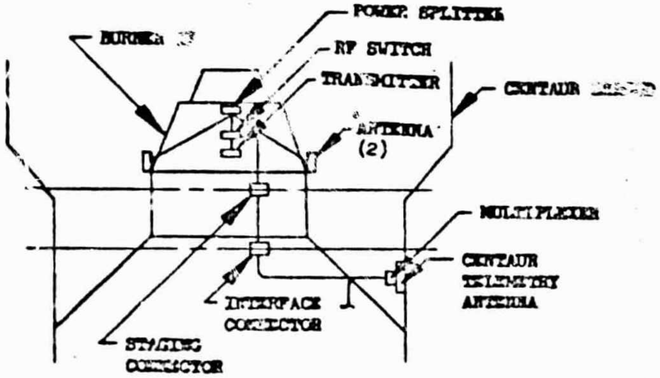
Air conditioning is required for the Burner II compartment within the nose shroud. An opening is required for this purpose between Stations 2825.70 and 2548.70 and located at 105 degrees in plan view..

The Burner II and payload umbilicals are routed from staging connectors located on the Burner II/Centaur adapter at Station 2516.89 (standard motor adapter) to the umbilical disconnect panel located in the Centaur forward electronic compartment. Openings must be provided in the compartment structure adjacent to the panel position to accommodate the cables and connectors. A door, not shown, will be required through the nose shroud adjacent to the panel position to provide working access for installing the connectors on the panel.

An overboard drain umbilical is required to the Burner II H_2O_2 Reaction Control System pressure relief valve. This umbilical will be fabricated in two sections. One inboard section will connect between the Burner II valve and a coupling installed in the shroud skin at Station 2538.70 and 121 degrees. The coupling to the valve will be a lanyard operated self-sealing quick-release type. The lanyard will be connected to a structural ring on the shroud. When the shroud is jettisoned, the lanyard will retract the inboard umbilical from Burner II. The coupling on the shroud skin will be identical to the coupling to Burner II. The ground-half will be connected to an outboard drain umbilical installed on the umbilical tower. A ground lanyard will disconnect the outboard drain umbilical from the shroud at lift-off.

Figure 2.2-5 summarizes the Trade Study for selecting the approach to interface the Burner II RF transmission requirements in the Centaur Nose Fairing. The results of this study show that installation of RF slots in the Nose Fairing to re-radiate the RF energy from Burner II is the best approach. RF windows in the Nose Fairing were considered impractical because of the large aperature required. The RF slots will be covered by RF transparent material to maintain structural and thermal integrity of the Nose Fairing.

An RF slot differs from an RF window in that the slot re-radiates a new radiation pattern essentially independent of the pattern of the originating antenna. An RF window is made large enough and transparent enough to have minimum effect on the originating antenna pattern.

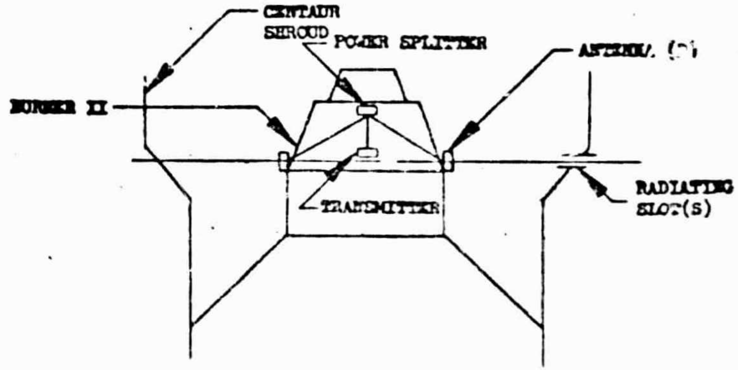


CONCEPT I
USE OF CENTAUR TELEMETRY ANTENNA

PERFORMANCE
- ADEQUATE PERFORMANCE IS ASSUMED BASED ON ESTIMATED VALUES AND AVAILABLE MARGIN > 100 db

REQUIRED MODIFICATIONS
- BURNER II - RF SWITCH
  - COAXIAL CABLING
  - COAXIAL STAGING CONNECTOR
  - COAXIAL INTERFACE CONNECTOR
- CENTAUR - COAXIAL CABLING
  - FREQUENCY MULTIPLEXER

REQUIRED DESIGN/ANALYSIS
- FREQUENCY MULTIPLEXER REQUIREMENTS/SPECIFICATIONS
- CABLE ROUTING/SPECIFICATION
- CENTAUR ANTENNA SUBSYSTEM PERFORMANCE TESTS



CONCEPT II
RF SLOT(S) IN CENTAUR SHROUD

PERFORMANCE
- ADEQUATE PERFORMANCE IS ASSUMED BASED ON STUDY MADE FOR LUNAR ORBITER PROGRAM AND AN AVAILABLE MARGIN > 100 db

REQUIRED MODIFICATIONS
- BURNER II - NONE
- CENTAUR - RF SLOT(S) AND ABSORBER INSTALLATION IN SHROUD

REQUIRED DESIGN/ANALYSIS
- RF SLOT CONFIGURATION AND LOCATION
- SCALE MODELING AND TEST RANGE PATTERNS
- SHROUD MODIFICATION EVALUATION AND TEST

RECOMMENDATION:

USE CONCEPT II FOR THE FOLLOWING REASONS:

1. NO MODIFICATION TO BURNER II AND MINOR MODIFICATION TO CENTAUR SHROUD.
2. SIMPLIFIES INTERFACE REQUIREMENTS AND COORDINATION.
3. DOES NOT REQUIRE NEW EQUIPMENT.
4. REQUIRES LESS TESTING AND ANALYSIS.

FIGURE 2.2-5

2.2.4 Separation Analysis

The Burner II can separate from the Centaur adapter in flight with the same separation system presently used for the Thor/Burner II. The Burner II separation sequence consists of the release of three separation nuts and a six second burn of the aft facing H_2O_2 motors. The H_2O_2 motors (jets) are all normally on during the six seconds phase and are individually pulsed off for control during separation.

Centaur/Burner II separation clearance was analyzed with the design 2800 pound payload (payload Cg 93 inches above payload separation plane; "50% Cg") including the effects of relative translation and rotation caused by control jet forces and control jet plume impingement on the Centaur and Burner II during separation. The analysis was made for the TE-M-364-4 large motor, since its deeper penetration into the adapter presented a worse case. Burner II control H_2O_2 jets of 65 pounds and 125 pounds thrust were evaluated to account for jet mounting as shown on Figure 2.2-6 and extended jet mounting arms being considered to meet control torque requirements with lower thrust motors. The analysis shows more than adequate clearance between the Burner II main engine nozzle lip and adapter structure and equipment.

Figure 2.2-6A which gives the relative longitudinal displacement versus time from separation initiation, shows that 0.82 and 1.13 seconds for the 125 pound H_2O_2 jets and 1.13 and 1.56 seconds for the 65 pound H_2O_2 jets is required to clear the destruct mechanism and the adapter ring at the separation plane. Table 2.2-1 which gives relative lateral displacement shows that worse case lateral displacement at the destruct system, the most critical to clearance, is less than 2 inches out of an available clearance of 8.75 inches with less than 2 inches displacement at the separation plane, out of an available clearance of 16.0 inches. Relative velocities imparted during the 6 second H_2O_2 separation phase are greater than 20 ft/second for the 125 pound thrust jets and over 10 ft/second for the 65 pound thrusters.

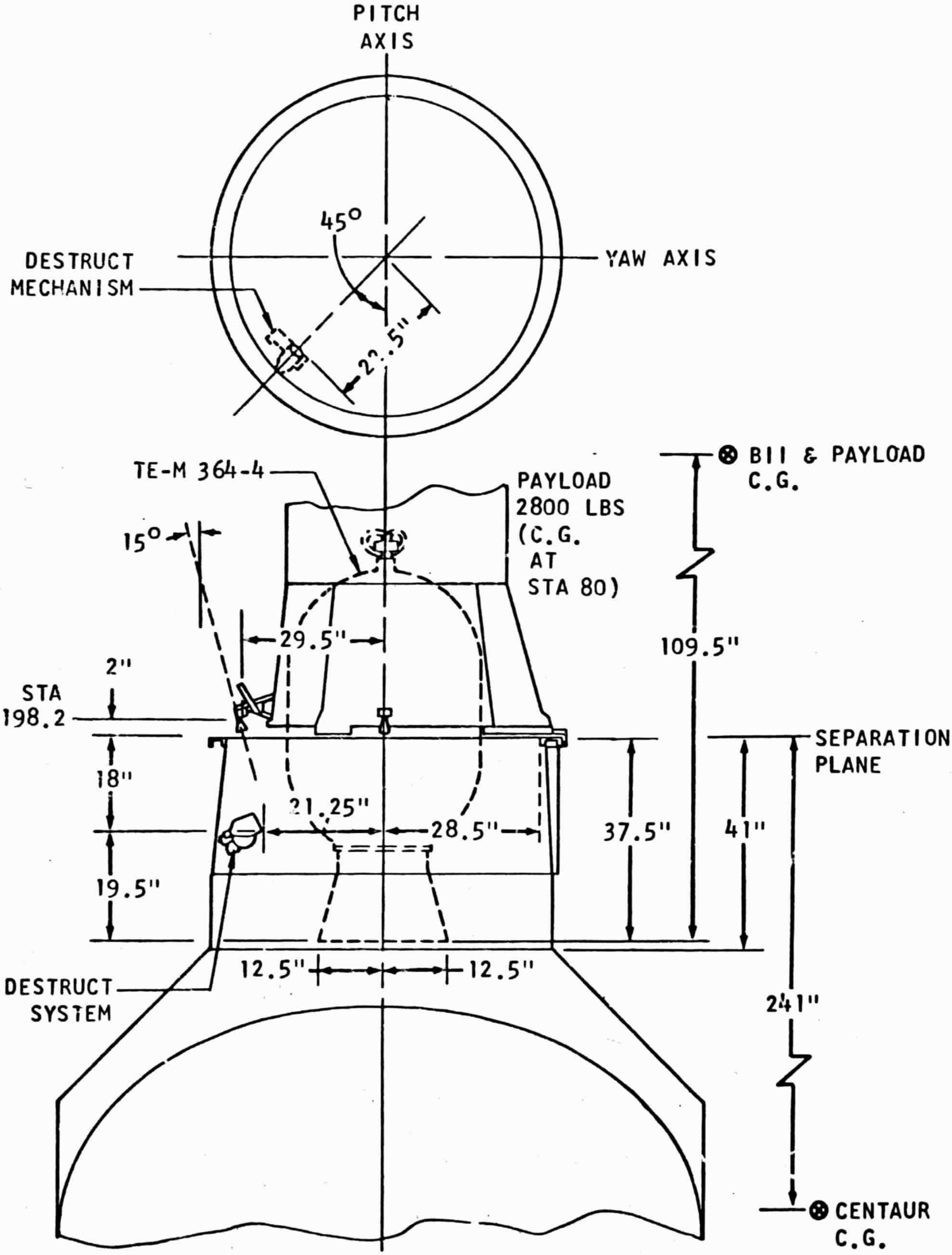

PITCH
AXIS
45°
DESTRUCT
MECHANISM
YAW AXIS
TE-M 364-4
PAYLOAD
2800 LBS
(C.G.
AT
STA 80)
BII & PAYLOAD
C.G.
15°
29.5"
109.5"
2"
STA
198.2
SEPARATION
PLANE
18"
28.5"
37.5"
41"
19.5"
12.5"
12.5"
DESTRUCT
SYSTEM
241"
CENTAUR
C.G.

FIGURE 2.2-6

LONGITUDINAL DISPLACEMENT - VS - TIME FROM SEPARATION

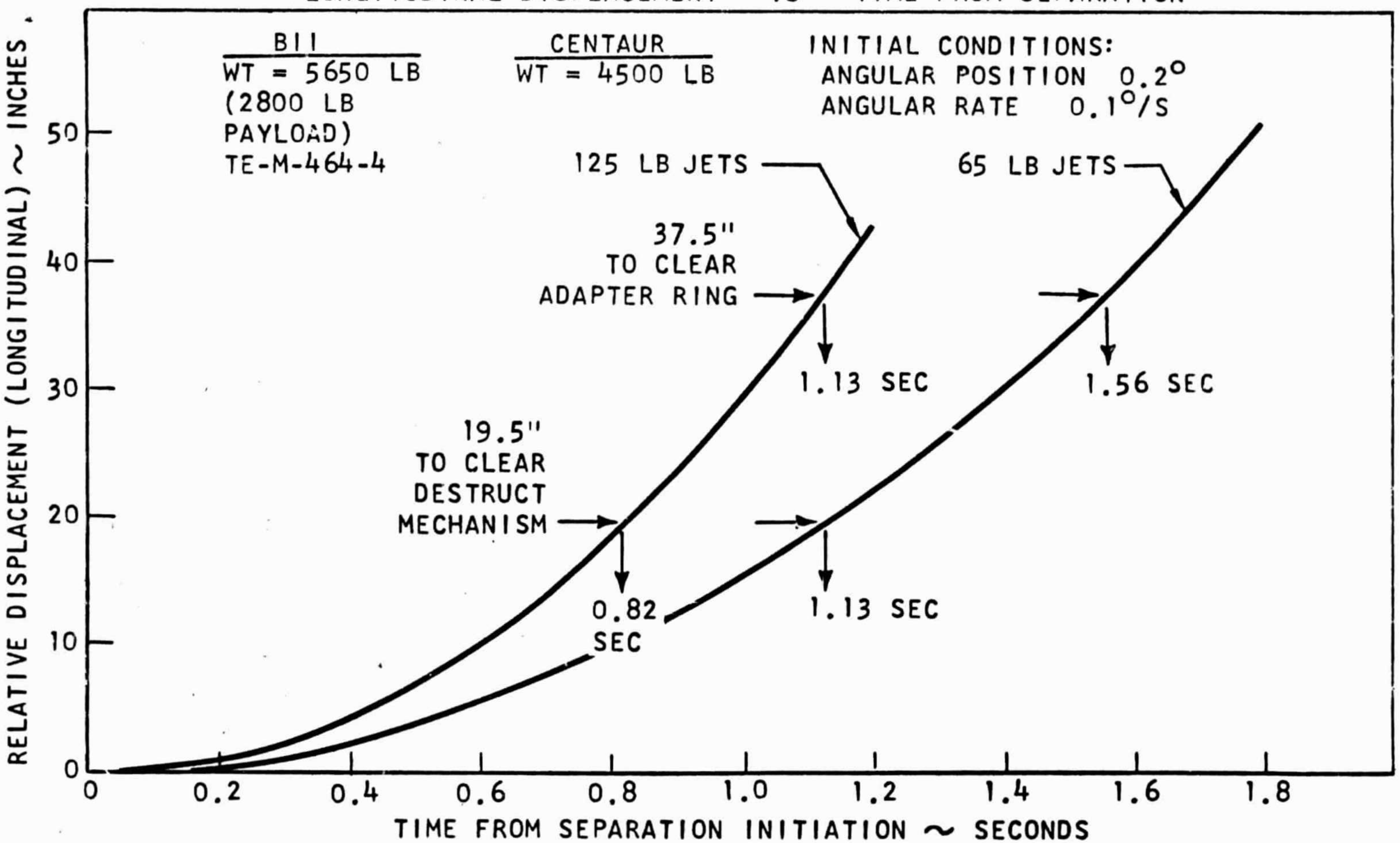


FIGURE 2.2-6a: CENTUAR-BURNER II-SEPARATION

TABLE 2.2-1

CENTAUR/BURNER II - SEPARATION LATERAL DISPLACEMENT

SINGLE AXIS - DISPLACEMENT INCHES

SOURCE	DESTRUCT MECHANISM LONGIT DISP = 19.5" 125 LB JETS 0.82 SEC	65 LB JETS 1.13 SEC	SEPARATION PLANE LONGIT DISP = 37.5" 125 LB JETS 1.13 SEC	65 LB JETS 1.56 SEC
1. CENTAUR ACCELERATION (+)	0"	0"	0"	0"
2. BURNER II H_2O_2 JET FORCE DURING STABILIZATION (2 JETS ON)				
CENTAUR ROTATION (+)	.23"	.15"	.32"	.20"
CENTAUR TRANSLATION (+)	.08"	.06"	.11"	.08"
BII TRANSLATION (+)	.09"	.07"	.12"	.09"
3. BURNER II H_2O_2 JET FORCE (−) (4 JETS ON)	-.42"	-.43"	-.83"	-.84"
4. BURNER II ROTATION TO ZERO (+) GYRO ATTITUDE	.16"	.21"	.21"	.30"
5. BURNER II DEAD ZONE $\pm$ 0.2° (+)	.38"	.38"	.38"	.38"
6. CENTAUR CONTROL FORCES				
CENTAUR ROTATION (+) (0.1 o/s)	.34"	.47"	.47"	.66"
CENTAUR TRANSLATION (+) (MIN IMPULSES 0.25 LB-SEC)	.02"	.02"	.02"	.03"
SUM OF DISPLACEMENTS, INCHES	0.87"	0.91"	0.80"	0.90"
TWO AXIS DISPLACEMENT				
RSS = ($\sqrt{2}$)(SINGLE AXIS), IN.	1.23"	1.27"	1.13"	1.27"
CLEARANCE AVAILABLE, IN.	8.75"	8.75"	16.0"	16.0"
NET CLEARANCE, IN.	7.5"	7.5"	14.9"	14.7"

2.2.5 Strength and Stiffness Analysis

This section discusses the design criteria and basic structural requirements used in the analysis of the primary structure and defines the structural sizing required to meet the strength and stiffness requirements. Structural sizing is presented for the Burner II/Centaur adapter, Burner II structural modification, and the payload adapter. A typical stiffness analysis is included in this section to illustrate the methods of analysis which were used to predict the flexural stiffness and shear stiffness of the study configurations.

Structural sizing is presented for two payload configurations, each weighing 2800 pounds. One configuration has a center of gravity at 50% of its length as shown on Figure 2.2-1 and the other has a center of gravity at 25% of its length. The payload interface was defined by study ground rules as a ring type which reacts distributed loads. The large motor (TE-M-364-4) Burner II configuration was considered for all structural sizing since it produces a more severe loading requirement.

The study analysis determined that the bending structure of the Burner II and the adapters was generally designed by stiffness rather than strength requirements. The shear structure was generally found to be strength designed.

The payload adapter design and structural weight is strongly influenced by the requirement for distributed loads at the payload interface. The ring structure required to distribute the interface loads into the Burner II three longeron structure accounts for approximately 50% of the adapter weight.

The Burner II structure requires modification to support the weight of the large motor and to react the shear loads from the 2800 pound payload.

2.2.5.1 Design Criteria and Requirements

The structural design criteria and requirements are summarized in Figure 2.2-7.

SAFETY FACTOR CRITERIA	
Limit	1.0
Ultimate	1.25
DESIGN LIMIT LOAD REQUIREMENTS	
Axial	Lateral
8g	±2.5g
2g	±2.5
-2.5g (Tension)	
FREQUENCY REQUIREMENTS	
6 cps Cantilevered From Centaur Adapter	

FIGURE 2.2-7

DESIGN CRITERIA & REQUIREMENTS

2.2.5.1 Continued

The structure is designed not to yield at limit flight loads nor fail at 1.25 times limit loads.

The design limit load requirements result from the boost condition. The combined condition of 8g axial, ±2.5g lateral was specified by NASA-Lewis in memo 9361:CR1. An additional combined load of 2g axial, ±2.5g lateral and a -2.5g (tension) singular condition are used to design structure for tensile loads. The combined condition is meant to cover possible loading induced by upper atmospheric turbulence in the maximum Q α flight regime. The 2.5g tension load was observed in an analysis of the Stage 1 engine shutdown event as reported in Martin Report MCR-67-332 (Vol. II, Part I, IX-1).

The 6 cps lateral bending frequency requirement of the upper stage as cantilevered above the Centaur adapter will reduce both dynamic loads and interaction with the booster control system to acceptable levels. This value was recommended by Boeing on the basis of previous loads and dynamic studies and was accepted as a study ground rule by NASA.

2.2.5.2 Design Limit Loads

Figure 2.2-8 displays the upper stage design limit bending moment, shear and axial loads resulting from application of the 8g axial, 2.5g lateral factors to the maximum weight payload (2800 pounds) and Burner II with the large motor. The bending moment is shown for both the 50 and 25 percent payload c.g. distances above the Burner II interface. Loads for the other two inertial load conditions of 2g axial combined with ±2.5g lateral and the 2.5 axial tension can be found by appropriate ratio of the above values. These two conditions are not critical for any of the structure.

The design incorporates three longerons connecting the top of the payload adapter with the base of the Burner II. The majority of bending moment at the base of the payload will be reacted by a couple action in the longerons. The shear load at the base of the payload and the bending moment caused by this shear will be transmitted through the adapter and Burner II structure.

Much of the primary structure is designed by the stiffness considerations defined in Section 2.2.5.3 rather than by the above loading requirements.

2.2.5.3 Preliminary Stage Stiffness Distribution

Figure 2.2-9 presents a bending and shear stiffness distribution which will provide the 6 cps stage bending frequency above the Centaur adapter. The method used for establishing this stiffness distribution is defined in Section 2.2.5.4. Stiffness requirements for both the 50 and 25 percent payload c.g. height above the Burner II interface are presented. The shear stiffness remains the same for both conditions since the shear rigidity is determined primarily by strength requirements. Although the data shows

UPPER STAGE DESIGN LIMIT LOADS

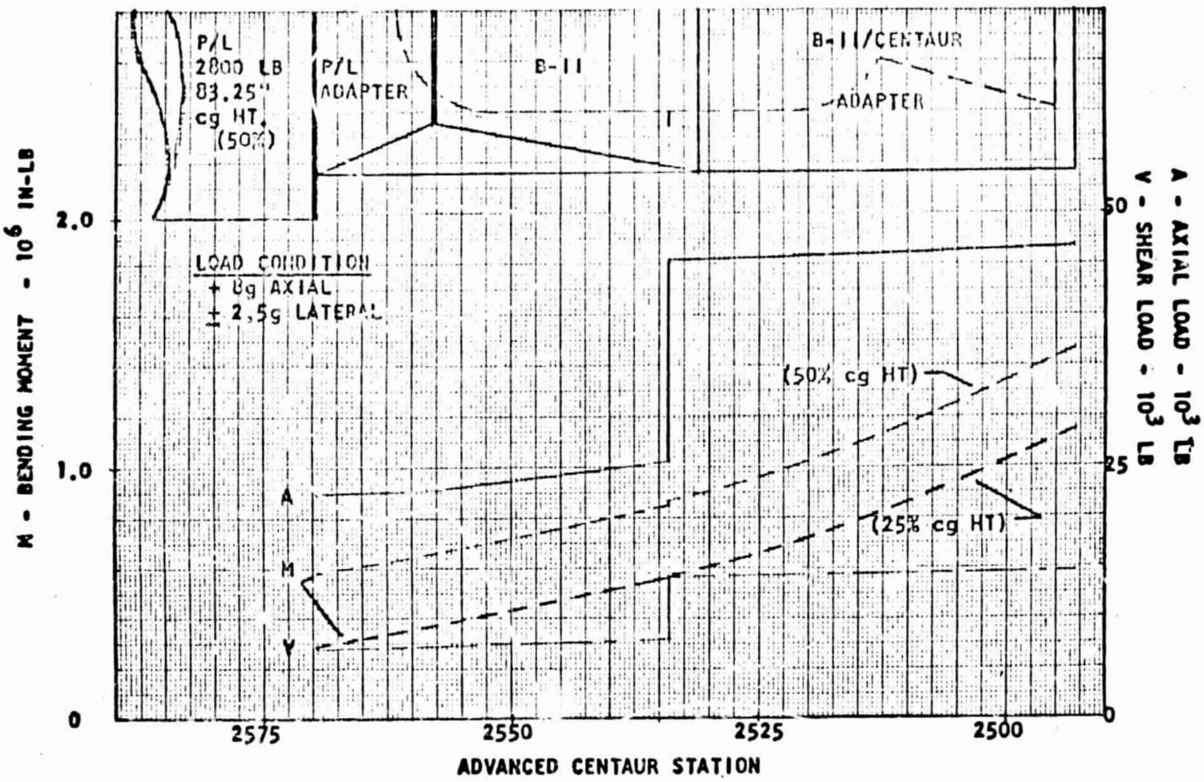


FIGURE 2.2-8

PRELIMINARY STAGE STIFFNESS DISTRIBUTION

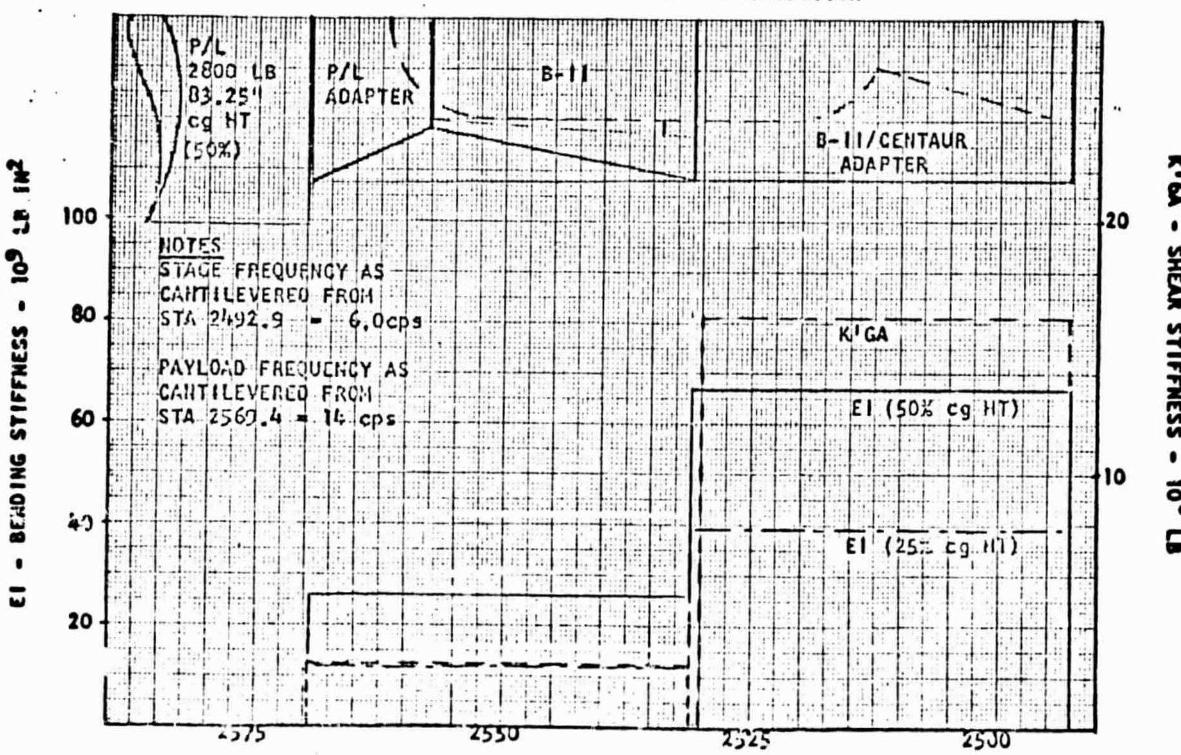


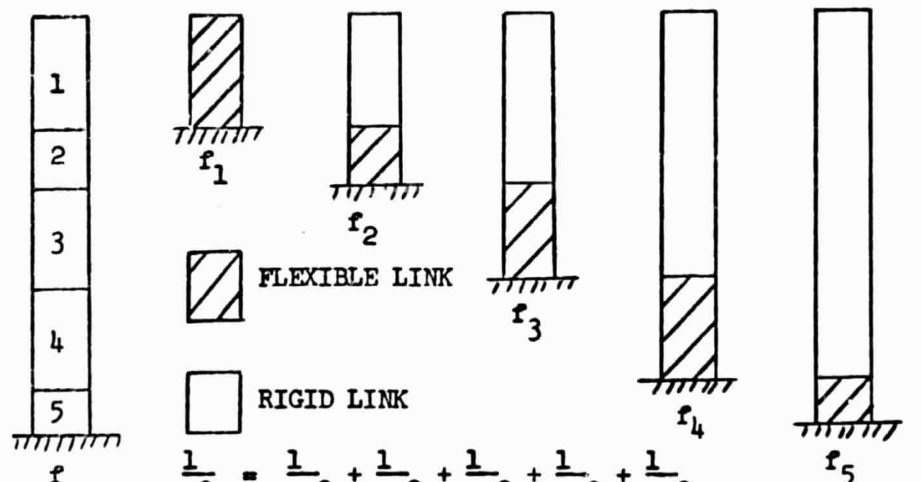
FIGURE 2.2-9

2.2.5.3 Continued

a constant shear and bending stiffness over the adapter and Burner II, the actual hardware stiffness may be tapered to provide the same equivalent stiffness over these sections.

2.2.5.4 Estimation of Stiffness - Link Technique

An approximation of the first mode cantilever bending frequency (f) of a complex structure can be determined by use of Dunkerley's equation as shown in Figure 2.2-10. The configuration is first divided into a convenient number of structural sections or links. The cantilever bending frequency of each link model is computed as a function of link stiffness assuming the mass above the link is infinitely rigid. Approximate equations for these models are easily derived by energy methods (An example is shown in Figure 2.2-11). The link frequencies f_1---f_n are then combined as shown below. Overall stack cantilever frequencies determined by this technique are within ±4% of those obtained by more detailed analysis using a digital computer program which solves the exact equations for a vibrating Timoshenko beam.



$$\frac{1}{f^2} = \frac{1}{f_1^2} + \frac{1}{f_2^2} + \frac{1}{f_3^2} + \frac{1}{f_4^2} + \frac{1}{f_5^2}$$

FIGURE 2.2-10 - FREQUENCY ESTIMATION TECHNIQUE

Five links were considered in the preliminary stiffness analysis of the Burner II/Centaur configuration. They included the payload, payload adapter, Burner II, Burner II/Centaur adapter, and the upper adapter ring supporting the Burner II. The frequency required for each link to yield a combined freqeuncy of 6 cps is 13.4 or say 14 cps. The relationship between shear and bending stiffness distribution for a particular link was established so their combined effects produced a 14 cps link.

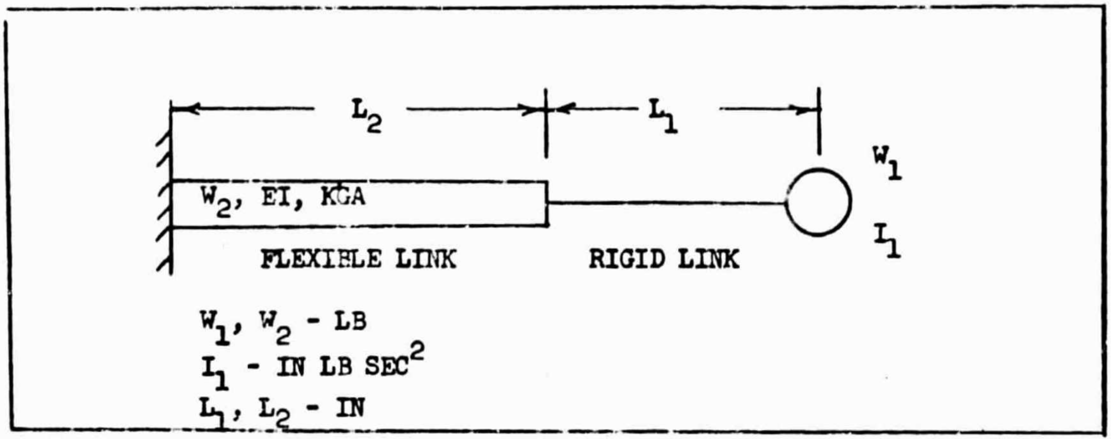


FIGURE 2.2-11 - TYPICAL LINK MODEL

Figure 2.2-11 illustrates a typical link model where the rigid element is simulated by a concentrated mass and moment of inertia. The flexible link mass is assumed uniformly distributed over its length. Applying energy methods, the cantilever frequency as a function of the bending stiffness becomes

$$f(cps)_{EI} = \frac{1}{2\pi}\sqrt{\frac{12\,EI\,K_3}{K_1 + K_2}}$$

where

$$K_1 = \frac{W_2}{g}\left(\frac{9}{5}L_1^{\,2} + \frac{13}{5}L_1 L_2 + \frac{33}{35}L_2^{\,2}\right)$$

$$K_2 = \left[\frac{4W_1}{g}\left(L_2^{\,2} + 3L_1 L_2 + 3L_1^{\,2}\right)^2 + 9I_1\left(2L_1 + L_2\right)^2\right]/L_2^{\,2}$$

$$K_3 = \frac{L_2^{\,2} + 3L_1 L_2 + 3L_1^{\,2}}{L_2^{\,3}}$$

The link frequency as a function of the shear stiffness can be approximated by

$$f(cps)_{KGA} = \frac{1}{2\pi}\sqrt{\frac{K'GA\,(g)}{L_2\,W_1}}$$

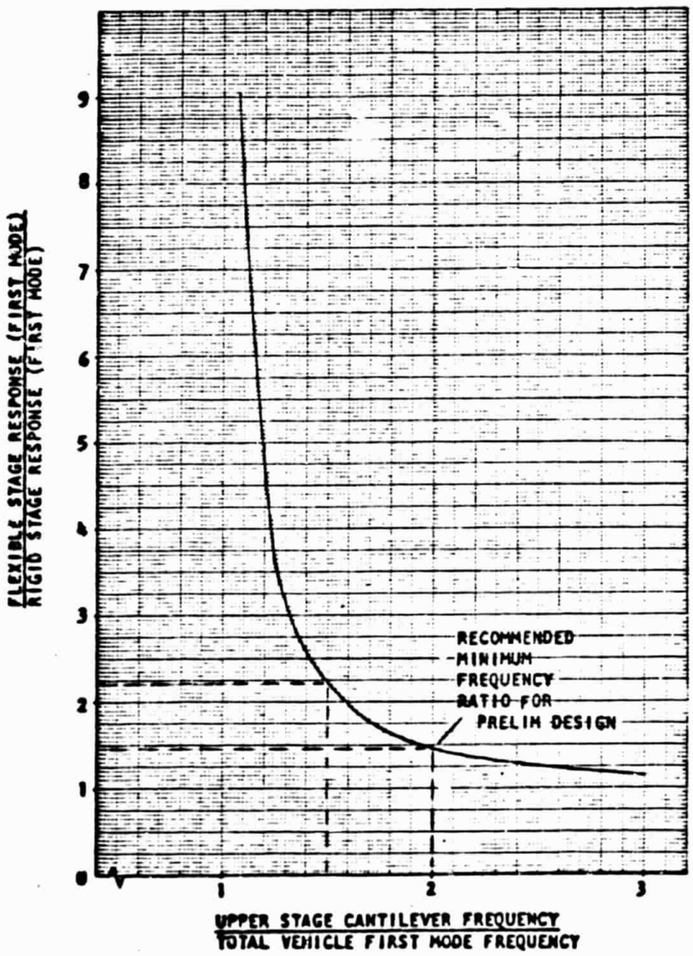
The resultant link frequency is approximately

$$\frac{1}{f^2} = \frac{1}{f^2_{EI}} + \frac{1}{f^2_{KGA}}$$

The frequency contribution from each stiffness can be set equal to establish preliminary distributions or adjusted to correspond to actual hardware values.

2.2.5.5 Effect of Upper Stage Flexibility On Upper Stage Response

The effect of payload flexibility on upper stage response has been studied by Boeing for Atlas and Thor boosted vehicles. One such indicator is shown in Figure 2.2-12. The ordinate is a ratio of the flexible payload response in the first free-free mode of the total vehicle to the response of a rigid payload attached to the same booster. The abscissa is a ratio of the payload frequency as cantilevered from the booster interface to the total vehicle first free-free mode frequency. To reduce responses resulting from payload or upper stage flexibility, the upper stage cantilever frequency should be at least 1 1/2 times the total vehicle first mode frequency. For preliminary structural sizing, a frequency ratio of 2 is recommended to allow for uncertainties in upper stage mass-structural definition. (i.e. using the Titan IIIC mode data in Figure 2.2-13 as representative for the Titan IIID/Centaur.)

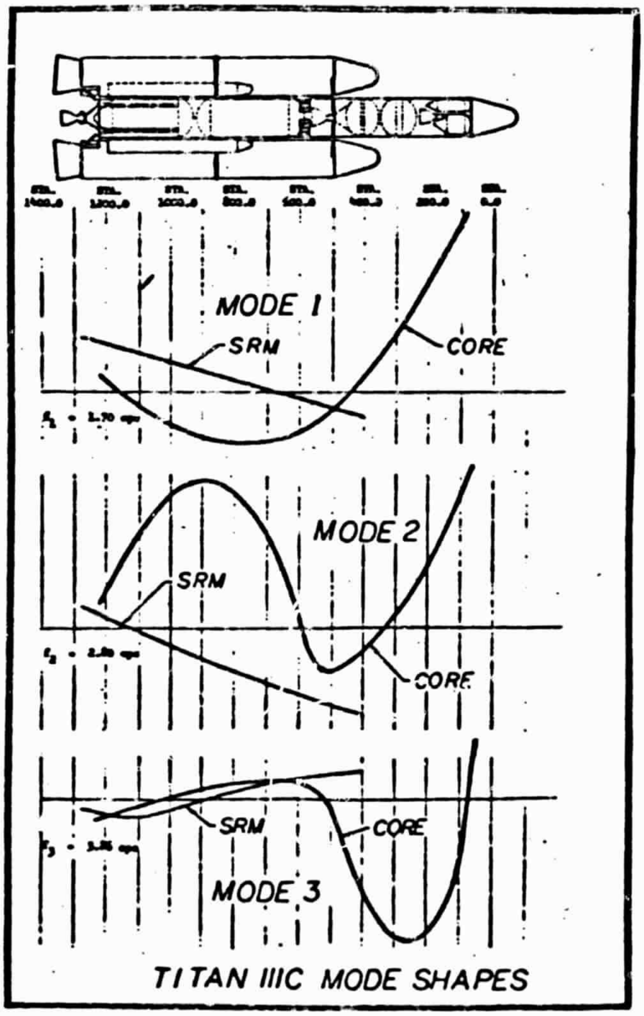


EFFECT OF UPPER STAGE FLEXIBILITY ON UPPER STAGE RESPONSE

FIGURE 2.2-12

2.2.5.5 Continued

Figure 2.2-13 displays the first three bending modes of the Titan IIIC during flight. If these are assumed respresentative of the Titan IIID/ Advanced Centaur vehicle, the upper stage cantilever frequency should be 5.6 cps or greater to minimize payload response due to its flexibility. Note that the frequency should be based on the second mode since the upper stage response in the first two modes due to booster thrust vectoring would be additive.



TITAN IIIC MODE SHAPES

FIGURE 2.2-13

2.2.5.5 Continued

A qualitative assessment of the Titan IIIC and Titan IIID/Advanced Centaur indicates the two vehicles have essentially the same total weight, however, the Titan IIIC is about 20 feet shorter between the Titan base and payload interface. Assuming both vehicles have the same stiffness characteristics, the Titan IIID/Advanced Centaur free-free frequencies would be about 0.8 of the Titan IIIC for the same payload. Based upon the previous criterion, the minimum upper stage frequency above the Centaur should be 4.5 cps. Therefore, selection of 6 cps appears sufficiently conservative from a viewpoint of reducing upper stage response due to its flexibility.

2.2.5.6 Adapter Analysis

The Burner II/Centaur adapter is designed to meet the link frequency requirements of 14 cps and provide adequate strength to support the Burner II and payload for the design load conditions. The adapter must also redistribute the concentrated loads introduced from Burner II. Adapter loads and a definition of major structural areas are shown in Figure 2.2-14.

The analysis of the adapter can be divided into three major areas:

- The concentrated load redistribution structure
- The shear panels adjacent to the redistribution structure
- The forward ring which redistributes the lateral shear loads

The shear panels are strength critical while the redistribution structure and the ring are designed by the frequency requirements.

ADAPTER LOAD DISTRIBUTION

50% PAYLOAD CG LOCATION

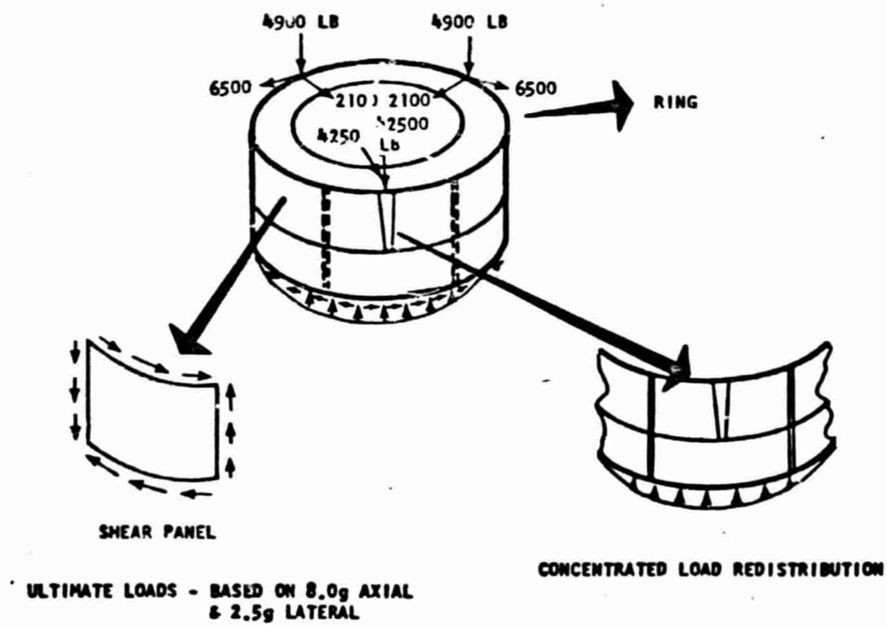


FIGURE 2.2-14

2.2.5.6 Continued

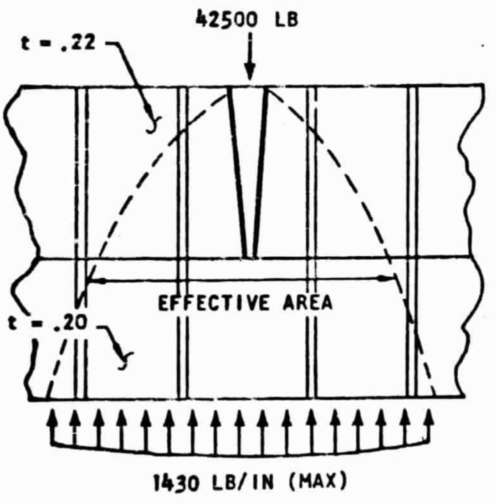
The concentrated load redistribution structure consists of a tapered longeron which unloads into a shear panel. The structural sizing in this area is defined by the frequency requirements which are in terms of the beam bending stiffness of the adapter. In simple terms, this requirement is satisfied by providing sufficient load carrying area in the adapter cross section to attain the necessary section moment of inertia. The effective longeron areas at the top and bottom of the adapter are determined by this method.

The shear lag effects of unloading the tapered longeron must be considered to define the effective area acting with the longeron at other stations in the adapter. To define the effective area and the resulting distribution at the adapter lower interface involves a rigorous analysis which includes the effects of the stiffness of the Centaur adapter. Experience has shown, however, that the distribution can be estimated by assuming a 25° shear lag angle on either side of the tapered longeron. The skin gages and load distributions are then defined as shown below.

Structural sizing of the concentrated load redistribution structure is defined in Figure 2.2-15 and 2.2-16 for the 50% and the 25% payload c.g. locations. Comparison of the two designs shows that the design is strongly affected by the payload center of gravity location. The average bending stiffness requirement decreases from 66.4×10^9 lb-in^2 for the 50% c.g. condition to 38.6×10^9 lb-in^2 for the 25% c.g. condition. The member sizes for the 25% c.g. location are approximately 57% of the requirement for the 50% condition.

CONCENTRATED LOAD REDISTRIBUTION STRUCTURE

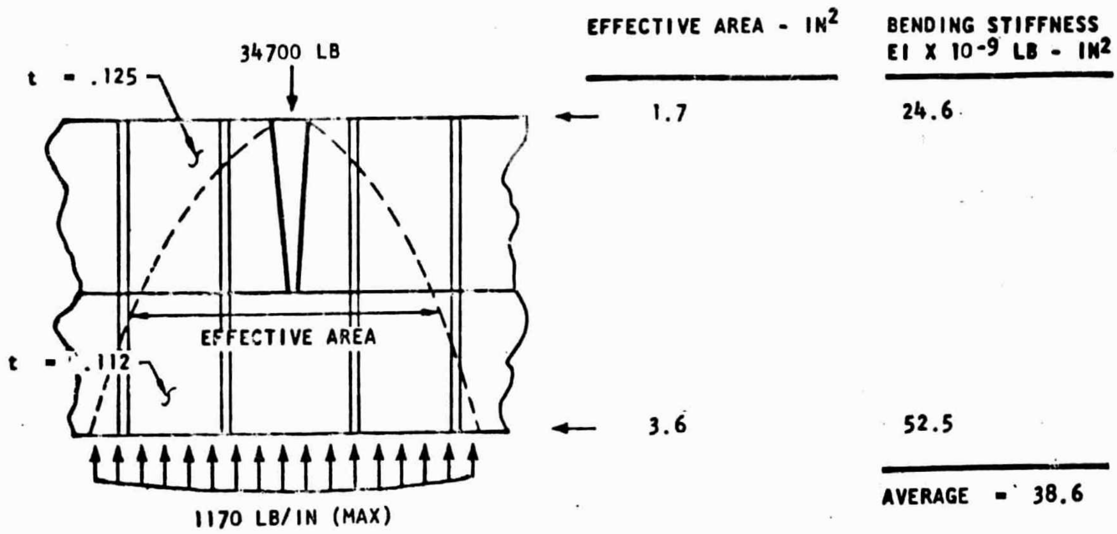
50% PAYLOAD CG LOCATION



	EFFECTIVE AREA - IN^2	BENDING STIFFNESS EI X 10^{-9} LB - IN^2
Top	2.9	42.4
Bottom	6.2	90.4
		AVERAGE = 66.4

FIGURE 2.2-15

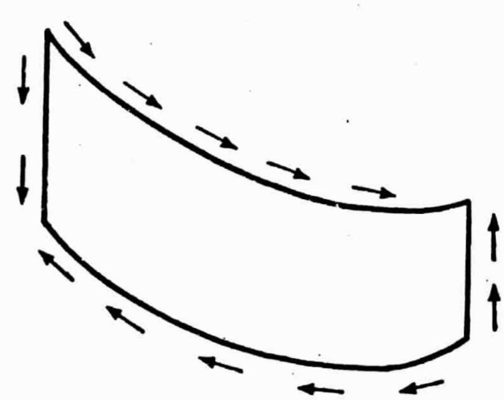
CONCENTRATED LOAD REDISTRIBUTION STRUCTURE



25% PAYLOAD C.G. LOCATION

FIGURE 2.2-16

SHEAR PANEL



	MAGNESIUM			ALUMINUM	
CONFIGURATION	SKIN GAGE	$\bar{t}$	WEIGHT	SKIN GAGE (t)	WEIGHT
UNSTIFFENED PANEL	.10	.10	26.9 LB	.08	33.1 LB
SINGLE MID RING	.09	.098	26.4	.071	
STIFFENED PANEL	.063	.095	25.5		

FIGURE 2.2-17

2.2.5.6 Continued

The shear panels are designed by the 8g axial, 2.5g lateral load condition. A comparison of magnesium and aluminum skin designs is shown in Figure 2.2-17. The selected configuration uses .10 magnesium unstiffened panels. The magnesium panels are approximately 20% lighter than a comparable aluminum panel. By using a fully stiffened panel, a weight saving of approximately 2 pounds could be effected (.8 pounds of payload). This must be balanced against the increased cost and complexity.

A single intermediate ring stiffener does not provide a significant weight saving. The shear panel design is the same for both payload center of gravity locations. The panels are strength critical, and lateral shear loads are not affected by center of gravity location.

The upper ring on the adapter redistributes shear loads from the three Burner II attach points into skins of the adapter. As shown in Figure 2.2-18, this redistribution involves an interaction of the adapter ring, the Burner II lower platform, and the motor structure which is an integral part of the platform. This structural system is sized to provide sufficient stiffness to meet the 14 cps link frequency requirement. Based on a stiffness analysis involving all the bulkhead elements, a ring design with an area of 1.08 square inches is required for the adapter. Sizing of the Burner II lower platform is also based on the bulkhead stiffness analysis.

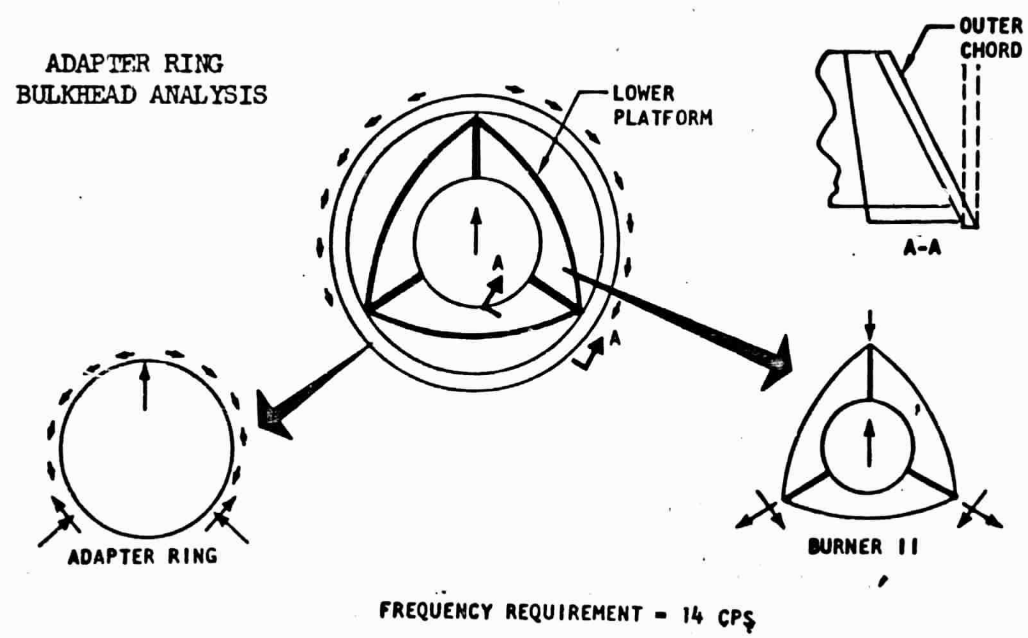


FIGURE 2.2.18

2.2.5.7 Burner II - Payload Support Structure Analysis

Figure 2.2-19 illustrates the type of payload support structure selected. In this design, the bending moments are reacted through the three main longerons external to the Burner II. The lateral shear loads are transferred by shear flow into the upper ring. The upper ring includes a triangular internal strut system to help redistribute these loads into the truss structure which carries the loads to the Burner II upper deck.

The design of the payload support ring structure is dependent on the load distribution at the payload interface. The two extremes of load distribution are shown in the figure. The fully uniform distribution is seldom achieved in practice and the concentrated load condition requires a payload structure capable of reacting concentrated loads. The potential weight saving of the concentrated load approach can be achieved only by integrating with a compatible payload.

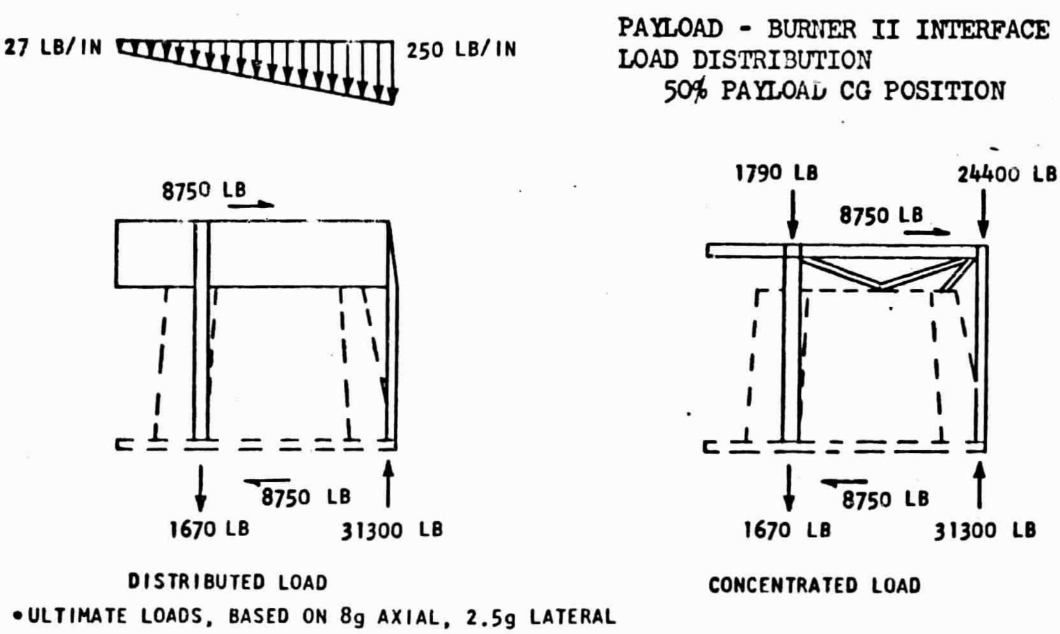


FIGURE 2.2-19

The distributed load condition presents a complex problem in which the degree of load distribution is strongly dependent upon payload structural characteristics.

2.2.5.7 Continued

For this study, the ring support system is sized to have sufficient strength to carry the distributed loads shown. The upper and lower flanges of the ring structure become large (1.25 in^2) due to the torsional moments produced by the distributed ring load.

In actual practice, the loads would be more concentrated over the support points because of payload stiffness. The load distribution could be improved if required, by increasing ring depth, or area, or by providing additional ring support points as shown on some candidate configurations.

The concentrated load configuration assumes semimonocoque payload construction with three longerons. The ring would be sized by stiffness requirements and an area of approximately .75 sq. in. would be required. The concentrated load approach would result in a payload support structure weight approximately 65 pounds lower than the baseline adapter weight.

The baseline payload adapter structure is defined in Figure 2.2-20. The adapter is designed to react a distributed axial load and shear flow at the payload interface. To provide bending stiffness in an efficient manner, external longerons paralleling the Burner II structure have been incorporated. These longerons are tapered over the length of the ring web to shear their loads into the web structure.

This design uses the longerons to provide bending stiffness and the Burner II structure to provide shear stiffness. A truss structure carries the shear loads from the upper ring to the top of the Burner II.

The ring loading in this design introduces a torsion load which is reacted by differential bending of the ring flanges.

The shell structure of the ring was shown to be most efficient when stiffened magnesium skins were used.

PAYLOAD ADAPTER
50% PAYLOAD CG POSITION

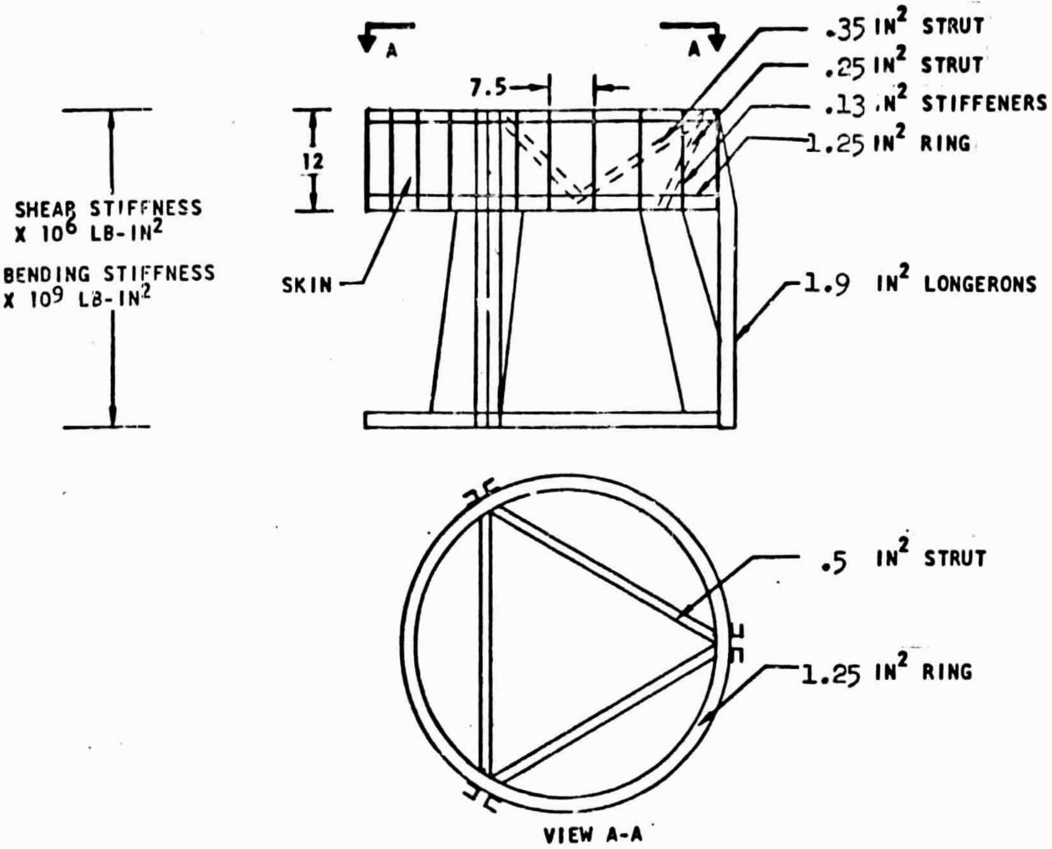
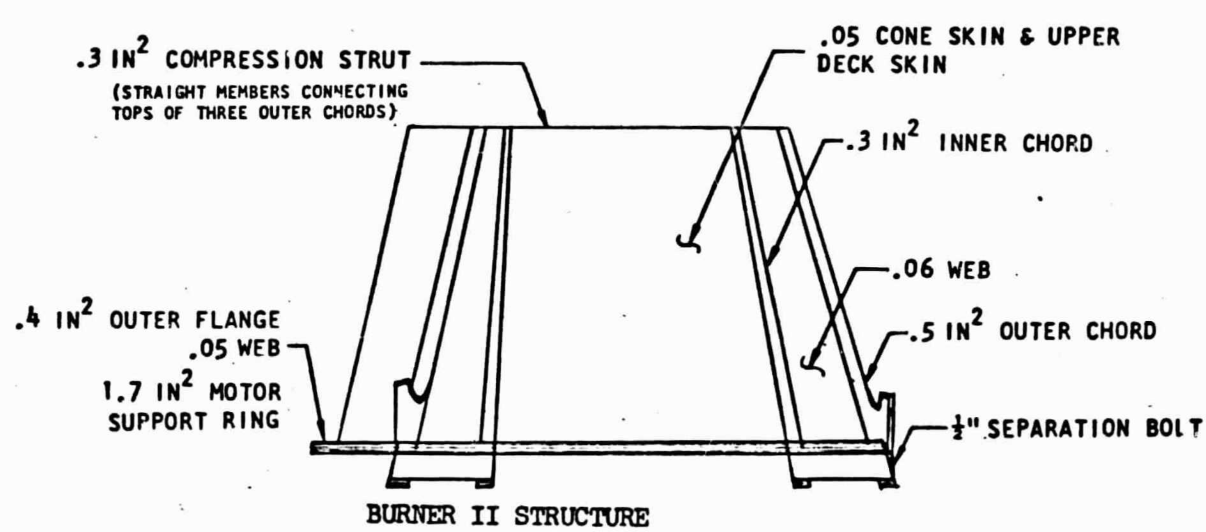


FIGURE 2.2-20

2.2.5.8 Burner II Structural Modifications

The Burner II primary structure as modified to meet the strength and stiffness requirements for this mission is defined in Figure 2.2-21. The modifications are similar to the ones designed and successfully tested for the SESP 68-1 mission.



BURNER II STRUCTURE

FIGURE 2.2-21

2.2.5.8 Continued

Primary modifications to the Burner II structure are: increasing the skin gage of the cone and forward bulkhead from .01 to .05; increasing the platform skin gage from .036 to .050; increasing compression strut area from .15 to .3 in^2; increasing the inner and outer chords of the vertical beams and modifying the lower platform to attach the motor support ring.

These modifications are required to provide adequate shear stiffness to meet the bending frequency requirements and to provide strength for supporting the large motor. In general, the modifications dictated by the large motor installation provide the necessary shear stiffness. These changes to the Burner II primary structure increase the Burner II structural weight by 46 pounds.

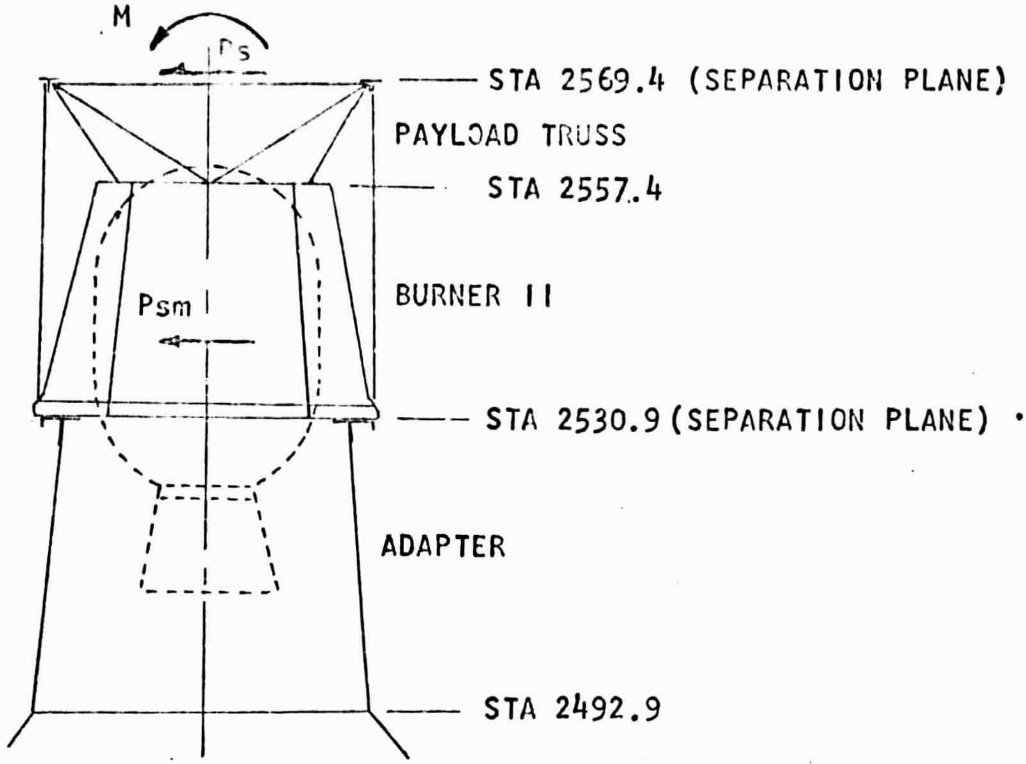
2.2.5.9 Burner II - Payload Support Structure Stiffness Analysis

A summary of the stiffness analysis of the Burner II and payload support adapter is presented in this section. The analysis defines the procedures followed in performing a stiffness analysis and verifies that the structure meets the stiffness requirements defined in Section 2.2.5.3. The structural model used for analysis assumes that the payload bending moment is reacted by three support points rather than by distributed ring loads. An analysis that adequately considers the ring redistribution structure would be considerably more complex and would require a good definition of the payload interface structure. For this study, the stiffness characteristics of both support concepts are considered to be the same.

The analysis includes the calculation of the strain energy in the structure produced by a force at the payload center of gravity. The bending stiffness and shear stiffness of an equivalent beam are then determined by matching its deflections to those calculated at the payload c.g. station for the actual configuration.

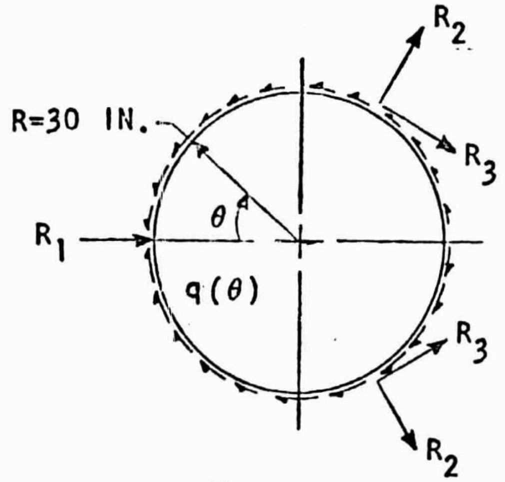
A 15% energy increase due to joint flexibility has been included in the analysis.

BURNER II - PAYLOAD SUPPORT STRUCTURE STIFFNESS ANALYSIS



SUMMARY OF ENERGY EQUATIONS

1. ADAPTER RING $I = .9\ IN^4$



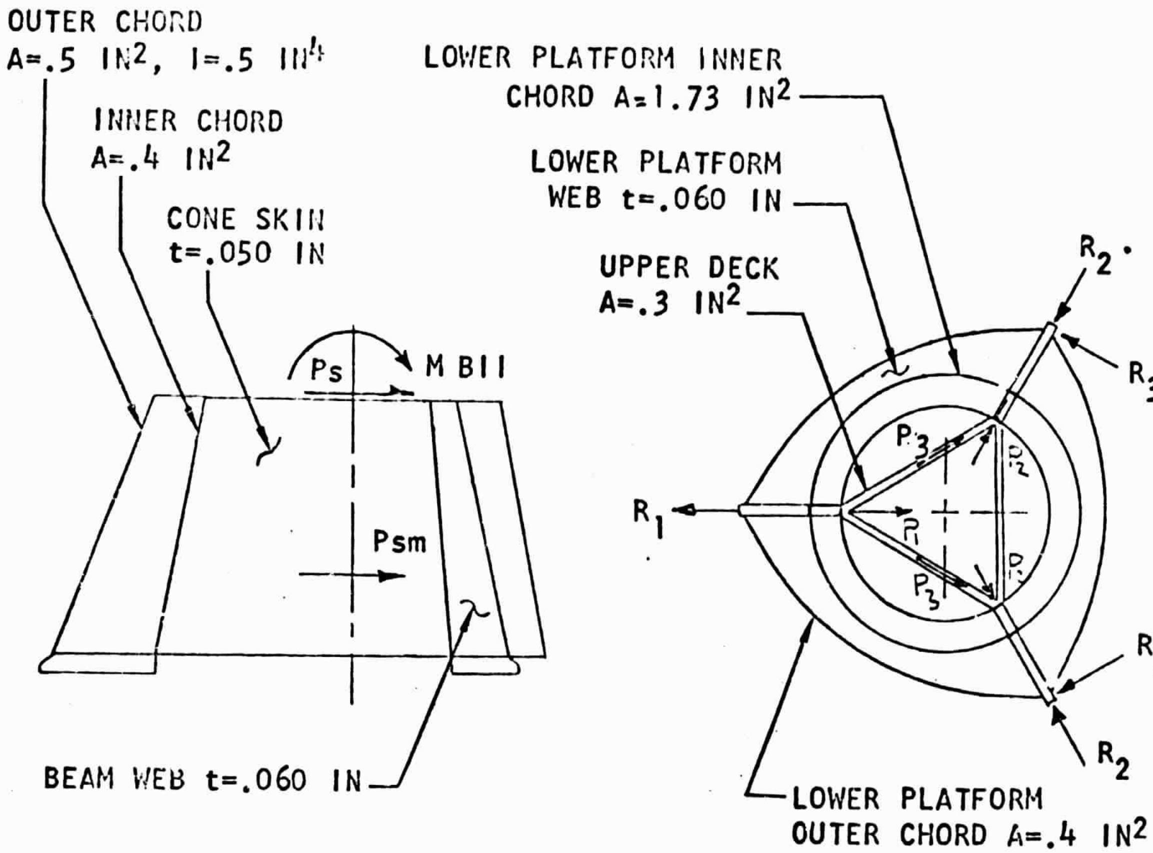
$$q(\theta) = \frac{Ps+Psm}{2} \sin(\theta)$$

(1)

$$U = 10^{-6} \begin{Bmatrix} Ps \\ Psm \\ R_2 \\ R_3 \end{Bmatrix}^T \begin{bmatrix} 63.51117 & & & \text{SYM} \\ 63.51117 & 63.51117 & & \\ -31.9165 & -31.9165 & 73.2932 & \\ -149.2413 & -149.2413 & 51.51262 & 359.80.94 \end{bmatrix} \begin{Bmatrix} Ps \\ Psm \\ R_2 \\ R_3 \end{Bmatrix}$$

2. BURNER II

CONSIDER THE LOWER PLATFORM AND BENDING IN THE OUTER CHORD AS PART OF THE ADAPTER RING



A. LOWER PLATFORM AND OUTER CHORD BENDING ENERGY

$$U=10^{-6}\begin{Bmatrix} P_s \\ M_{BII} \\ P_{sm} \\ R_2 \\ R_3 \end{Bmatrix}^T \begin{bmatrix} 24.9382 & & & & \\ .081275 & .000404 & & \text{SYM} & \\ 19.63283 & .051133 & 15.50393 & & \\ -30.91398 & -.104249 & -23.98044 & 41.72068 & \\ -33.58222 & -.098304 & -26.67873 & 41.60379 & 61.6045 \end{bmatrix} \begin{Bmatrix} P_s \\ M_{BII} \\ P_{sm} \\ R_2 \\ R_3 \end{Bmatrix} \quad (2)$$

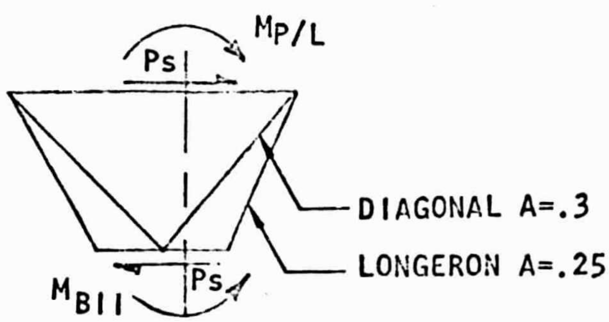
B. INNER AND OUTER CHORDS, CONE SKIN AND BEAM WEB ENERGY

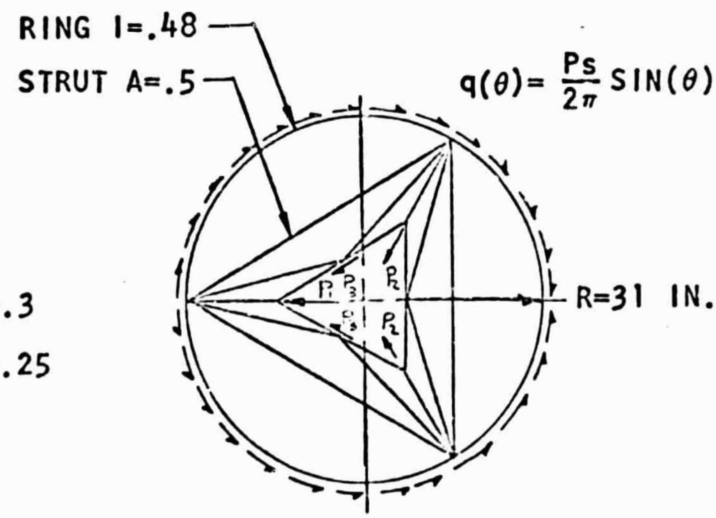
$$U=10^{-6}\begin{bmatrix} P_s & M_{B11} & P_{sm}\end{bmatrix}\begin{bmatrix} 1.45208 & & \text{SYM} \\ .012479 & .0021271 & \\ .135916 & .001159 & .0127086 \end{bmatrix}\begin{Bmatrix} P_s \\ M_{B11} \\ P_{sm}\end{Bmatrix} \quad (3)$$

C. UPPER DECK ENERGY

$$U=10^{-6}\begin{Bmatrix} P_s \\ M_{B11} \\ P_{sm} \\ M_{P/L} \\ R_2 \\ R_3 \end{Bmatrix}^T \begin{bmatrix} 1.39372 & & & & & \text{SYM} \\ .01502 & .00021 & & & & \\ .03548 & .00051 & .01095 & & & \\ .05865 & .00069 & .00145 & .00255 & & \\ -.24221 & -.00353 & -.03092 & -.01081 & .11147 & \\ -.11805 & -.001527 & -.03123 & -.00471 & .08776 & .0812 \end{bmatrix}\begin{Bmatrix} P_s \\ M_{B11} \\ P_{sm} \\ M_{P/L} \\ R_2 \\ R_3 \end{Bmatrix} \quad (4)$$

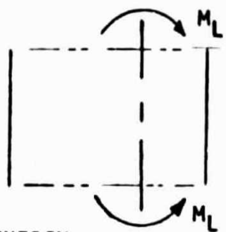
3. PAYLOAD TRUSS





$$U=10^{-6}\begin{bmatrix} P_s & M_{P/L}\end{bmatrix}\begin{bmatrix} 8.79686 & .198558 \\ .198558 & .011422 \end{bmatrix}\begin{Bmatrix} P_s \\ M_{P/L}\end{Bmatrix} \quad (5)$$

4. MAIN LONGERONS $A = 2.05\ IN^2$



$$U = 6.281 \times 10^{-10} M_L^2 \qquad (6)$$

5. TOTAL ENERGY

$$U = 10^{-6} \begin{Bmatrix} M_L \\ Ps \\ M_{B11} \\ Psm \\ M_{P/L} \\ R_2 \\ R_3 \end{Bmatrix}^T \begin{bmatrix} .0006281 & & & & & & \text{SYM} \\ 0 & 100.09203 & & & & & \\ 0 & .1087741 & .0027411 & & & & \\ 0 & 83.315396 & .0528689 & 79.038759 & & & \\ 0 & .257203 & .00069 & .00145 & .0139722 & & \\ 0 & -63.072.69 & -.107779 & -55.92786 & -.01081 & 115.12535 & \\ 0 & -182.94153 & -.099831 & -175.95122 & -.00471 & 99.20417 & 421.49764 \end{bmatrix} \begin{Bmatrix} M_L \\ Ps \\ M_{B11} \\ Psm \\ M_{P/L} \\ R_2 \\ R_3 \end{Bmatrix} \qquad (7)$$

$$\begin{Bmatrix} R_2 \\ R_3 \end{Bmatrix} = - \begin{bmatrix} 115.12535 & 99.20417 \\ 99.20417 & 421.49764 \end{bmatrix}^{-1} \begin{bmatrix} -63.07269 & -.107779 & -55.92786 & -.01081 \\ -182.94153 & -.099831 & -175.95122 & -.00471 \end{bmatrix} \begin{Bmatrix} Ps \\ M_{B11} \\ Psm \\ M_{P/L} \end{Bmatrix}$$

$$\begin{Bmatrix} R_2 \\ R_3 \end{Bmatrix} = \begin{bmatrix} .218088 & .0009184 & .1581643 & .0001057 \\ .382698 & .0000207 & .3302173 & -.0000137 \end{bmatrix} \begin{Bmatrix} Ps \\ M_{B11} \\ Psm \\ M_{P/L} \end{Bmatrix} \qquad (8)$$

SUBSTITUTING R_2 AND R_3 INTO THE TOTAL ENERGY

$$U = 10^{-6} \begin{bmatrix} M_L & Ps & M_{B11} & Psm & M_{P/L} \end{bmatrix} \begin{bmatrix} .0006281 & & & & \text{SYM} \\ 0 & 16.32528 & & & \\ 0 & .047064 & .00264 & & \\ 0 & 3.78202 & -.002135 & 3.293277 & \\ 0 & .253048 & .00068 & -.002051 & .013971 \end{bmatrix} \begin{Bmatrix} M_L \\ Ps \\ M_{B11} \\ Psm \\ M_{P/L} \end{Bmatrix} \qquad (9)$$

SUBSTITUTING

$$M_L = M - M_{P/L}$$
$$M_{BII} = M_{P/L} + 12\ Ps \qquad (10)$$

$$U = 10^{-6} \begin{Bmatrix} M \\ Ps \\ Psm \\ \hdashline M_{P/L} \end{Bmatrix} \left[\begin{array}{ccc:c} .0006281 & & & \text{SYM} \\ 0 & 17.834976 & & \\ 0 & 3.7564 & 3.29327 & \\ \hdashline -.0006281 & .339952 & -.004186 & .0185991 \end{array} \right] \begin{Bmatrix} M \\ Ps \\ Psm \\ \hdashline M_{P/L} \end{Bmatrix} \qquad (11)$$

$$M_{P/L} = .0337705\ M - 18.277874\ Ps + .225065\ Psm \qquad (12)$$

SUBSTITUTING EQTNS 8,10 AND 12 INTO THE SUM OF 1 AND 2, THE ADAPTER RING SYSTEM ENERGY IS:

$$U = 10^{-10} \begin{bmatrix} M & Ps & Psm \end{bmatrix} \begin{bmatrix} .00355 & & \\ 6.46281 & 45924.74 & \\ & & \end{bmatrix} \begin{Bmatrix} M \\ Ps \\ Psm \end{Bmatrix} \qquad (13)$$

SUBSTITUTING EQTNS 8,10 AND 12 INTO THE SUM OF 3, 4, 5 AND 6, THE STAGE ENERGY IS:

$$U = 10^{-10} \begin{bmatrix} M & Ps & Psm \end{bmatrix} \begin{bmatrix} 6.06534 & & \\ 108.3364 & 70289.46 & \\ & & \end{bmatrix} \begin{Bmatrix} M \\ Ps \\ Psm \end{Bmatrix} \qquad (14)$$

STIFFNESS CALCULATION

$M = 83.15 \qquad Psm = 0 \qquad h = 38.5$ IN.

ADAPTER RING SYSTEM

$$U = 10^{-10}\,(.00355\ M^2 + 12.92562\ MPs + 45924.74\ Ps^2)$$
$$= 4.7024 \times 10^{-6}\ Ps^2$$

$$S.R. = \frac{Ps^2}{2U} = 106{,}300\ \#/IN \qquad (15)$$

BURNER II STAGE AND PAYLOAD ADAPTER

$$U = (6.06534\ M^2 + 216.6761\ PsM + 70289.46\ Ps^2)10^{-10}$$

$$EI = \frac{h\ 10^{10}}{2(6.06534)} = 3.17 \times 10^{10} \quad (16)$$

$$GA = \frac{h\ 10^{10}}{2(70289.46) - \frac{h^3}{3EI}} = 2.86 \times 10^{6} \quad (17)$$

ASSUMING A 15% INCREASE IN ENERGY DUE TO JOINTS

S.R. = 92,500 #/IN
EI = 27.9×10^9 # IN^2 50% C.G. (18)
GA = 2.51×10^6 #

FOR A C.G. HEIGHT OF 41.6 INCHES (25%) AND CHANGING THE MAIN LONGERON AREA TO .95 IN^2, THE STIFFNESS CORRESPONDING TO EQTN (18) IS:

S.R. = 93,600 #/IN
EI = 13.3×10^9 # IN^2 25% C.G.
GA = 2.55×10^6 #

THE STIFFNESS REQUIRED TO MEET THE REQUIREMENTS OF SECTION 2.2.5.3 IS:

EI = 26×10^9 LB-IN^2
GA = 2.5×10^6 LB
} 50% C.G.

EI = 12×10^9 LB-IN^2
GA = 2.5×10^6 LB
} 25% C.G.

2.2.6 Weight Analysis

Weight data are presented in Tables 2.2-2 and 2.2-3 for the payload adapter, Burner II primary structure modification, and the Burner II/Centaur adapter. All the weights are based on designs using the TE-M-364-4 rocket motor. Separate weights are shown for designs that will accommodate a 2800 pound and 1200 pound payload. The 46 pound weight increase noted for the basic Burner II is made up of changes to accommodate the TE-M-364-4 motor and the payload support system.

The tabulation shows the Burner II structure weight data for a 2800 pound payload with the Cg located at either 25 percent (41.6 inches from the base) or 50 percent of the length from the base. The weight derivation for the 2800 pound payload configurations is substantitated by the structural analysis presented in Section 2.2.5.

The tabulation also shows the structure weight data for a 1200 pound payload with a Cg 20 inches from the base. The weight of the payload adapter and Burner II primary structure modifications are obtained from analysis of previous Burner II payload support studies for this size payload. The weight of the Burner II/Centaur adapter for the 1200 pound payload is extrapolated from the stage adapter analysis for the 2800 pound payload.

TABLE 2.2-2

PRELIMINARY WEIGHT BURNER II/CENTAUR ADAPTER

	2800 LB PAYLOAD 50% CG	2800 LB PAYLOAD 25% CG	~1200 LB PAYLOAD CG 20" FROM BASE
SKINS - ALUMINUM	64.3	36.4	33.8
- MAGNESIUM	26.9	26.9	21.5
LONGERONS	12.7	7.4	6.9
SKIN SPLICE/STIFFENERS	7.7	10.1	4.2
FORWARD RING	21.4	21.4	19.0
CENTER RINGS	14.2	14.2	10.2
AFT RING	8.1	8.1	6.1
DESTRUCT - ACCESS & SUPPORT	1.5	1.5	1.5
DEBRIS SHIELD	7.0	7.0	7.0
SEPARATION HARDWARE	10.0	10.0	8.0
FASTENERS	7.3	7.5	6.5
TOTAL STRUCTURE	181.1	150.5	124.7
DESTRUCT & PSS COMPONENTS & INSTALLATION	14.0	14.0	14.0
CABLING	14.0	14.0	14.0
TOTAL	209.1	178.5	152.7

This weight statement summarizes the Burner II/Centaur adapter weights and illustrates the weight reduction achieved by lowering the payload c.g. from 50% to 25% of the payload length.

Significant weight reductions occur in the aluminum skins and the longerons. A slight increase in the stiffening weight is caused by adding stiffeners to each side of the longerons to prevent buckling of the reduced gage skin panels.

A weight reduction of 30.6 pounds is produced by lowering the c.g. to 25%.

TABLE 2.2-3

WEIGHT SUMMARY - PAYLOAD ADAPTER AND BURNER II PRIMARY STRUCTURE

	2800 LB PAYLOAD		~1200 LB PAYLOAD
	50% CG WEIGHT LB	25% CG WEIGHT LB	CG 20" FROM BASE WEIGHT LB
MODIFIED BURNER II			
STRUCTURAL SHELL	21.4	21.4	17.9
BEAMS	20.7	20.7	18.5
LOWER DECK	11.0	11.0	8.5
UPPER DECK	8.2	8.2	6.8
ROCKET MOTOR SUPPORT	16.9	16.9	16.9
CONTINGENCY	3.8	3.8	3.4
SUBTOTAL	82.0*	82.0	72.0
PAYLOAD ADAPTER			
LONGERONS	17.3	8.2	•
LOWER RING	24.6	21.6	•
SKIN	13.9	12.4	•
SKIN STIFFENERS	4.4	4.0	•
UPPER RING	25.8	22.7	•
STRUTS	15.3	15.3	17.5
GUSSETS, FILLER, FASTENERS, DOUBLERS, CLIPS, ETC.	16.2	13.5	3.5
CONTINGENCY (Payload wire bundles, etc)	12.5	10.4	3.0
SUBTOTAL	130.0	108.1	24.0**
TOTAL	212.0	190.1	96.0

*WEIGHT INCREASE OF 46 LB OVER BURNER II (LESS PAYLOAD SUPPORT)

**THREE POINT PAYLOAD SUPPORT SYSTEM INCLUDES BURNER II TYPE PAYLOAD SEPARATION SYSTEM

2.3 TASK 3 - ELECTRICAL DEFINITION

The purpose of this task is to define the Burner II electrical subsystem configuration and performance requirements for integration with the Centaur and Payload systems and to identify the electrical subsystem interfaces.

2.3.1 Burner II Electrical Subsystem

Figure 2.3-1 shows the baseline Burner II electrical subsystem components and the primary power distribution. The Burner II electrical subsystem changes required to integrate with the Centaur electrical subsystem for the mission specified in Task 1 include the following areas:

a. Add signal relays in the Burner II Relay Box for the Centaur Guidance and Control interface as defined by Task 5.

b. Replace S-Band Transmitter with a unit having higher RF output power as determined by the R.F. Link Analysis.

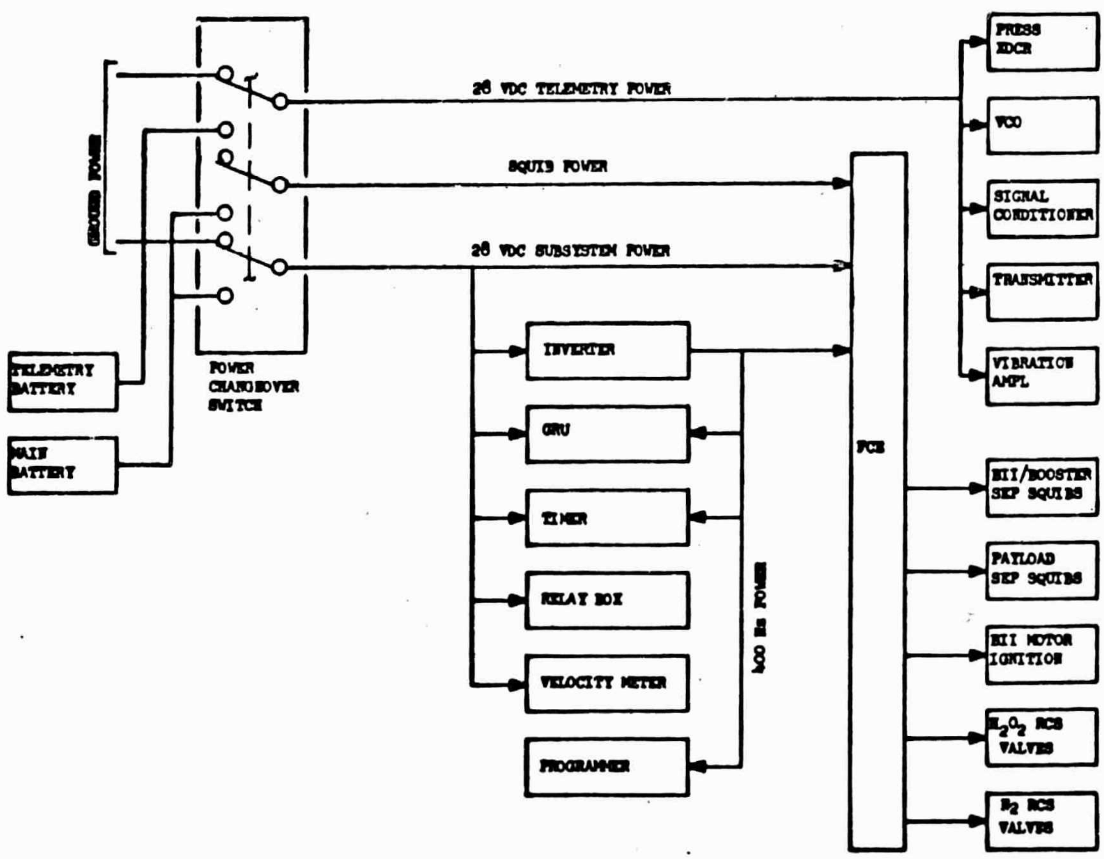


FIGURE 2.3-1 ELECTRICAL POWER AND DISTRIBUTION

c. Revise Burner II Timer program to control the event sequence for the synchronous orbit mission.

d. Increase battery capacity as determined by the Electrical Load Analysis.

e. Revise Burner II wiring installation to provide electrical interfaces with Centaur and Payload.

The Burner II electrical power and distribution system utilizes separate batteries for the Guidance and Control and Telemetry systems to provide assurance of data recovery in the event of a Burner II malfunction. A single Ground Power Changeover Switch controls transfer from ground to airborne power and also provides electrical isolation of the pyrotechnic circuits when Burner II is operating on ground power. All pyrotechnic circuits are shielded-twisted pair in compliance with applicable safety requirements.

The separation circuits for the shroud, stage and payload are initiated by relays located in the Burner II Flight Control Electronics (FCE) which are programmed either by signals from Centaur or from Burner II Timer. Safe-Arm status of Burner II is monitored by the Launch Control Console.

The Burner II Timer will be reprogrammed to control the sequence of events for the synchronous orbit mission. Relay Box modifications will be required to control added events, e.g., Transmitter On-Off.

2.3.2 Burner II/Centaur Electrical Interface

The Burner II electrical subsystem is independent of the Centaur electrical subsystem. Centaur guidance signals to Burner II are electrically isolated by switching relays in the Burner II Relay Box. This approach maintains interface compatibility between the Burner II single point grounding system and the Centaur multiple point grounding system.

The electrical input characteristics of the Burner II relay circuits that interface with the Centaur subsystems are specified in Section 2.4, Task 4 - Destruct System, and Section 2.5, Task 5 - Guidance System. Figure 2.3-2 shows the electrical interface connections between Burner II and Centaur and specifies the electrical connector configuration for interconnection of the Centaur guidance and destruct signals to Burner II. The Burner II umbilical connector is located on the Centaur Umbilical Island and is described by Gray and Hulegard Part No. 693-200-001. The mounting area required for the umbilical connector is approximately 4.94 inches diameter.

2.3.3 Burner II/Payload Electrical Interface

The routing of the payload umbilical wiring has been analyzed by a trade study summarized in Figure 2.3-3. This evaluation of the alternate methods for payload umbilical routing concludes that the best approach is to route the wiring through the Burner II stage to the Centaur Umbilical Island and to provide staging connectors on the Burner II for in-flight separation. Since the payload umbilical wiring will be superimposed on the Burner II cabling with separate staging connectors, then it is not critical to constrain the number of payload umbilical circuits to 50. The primary constraint is the size of the umbilical connector that can be mounted on the Centaur Umbilical Island.

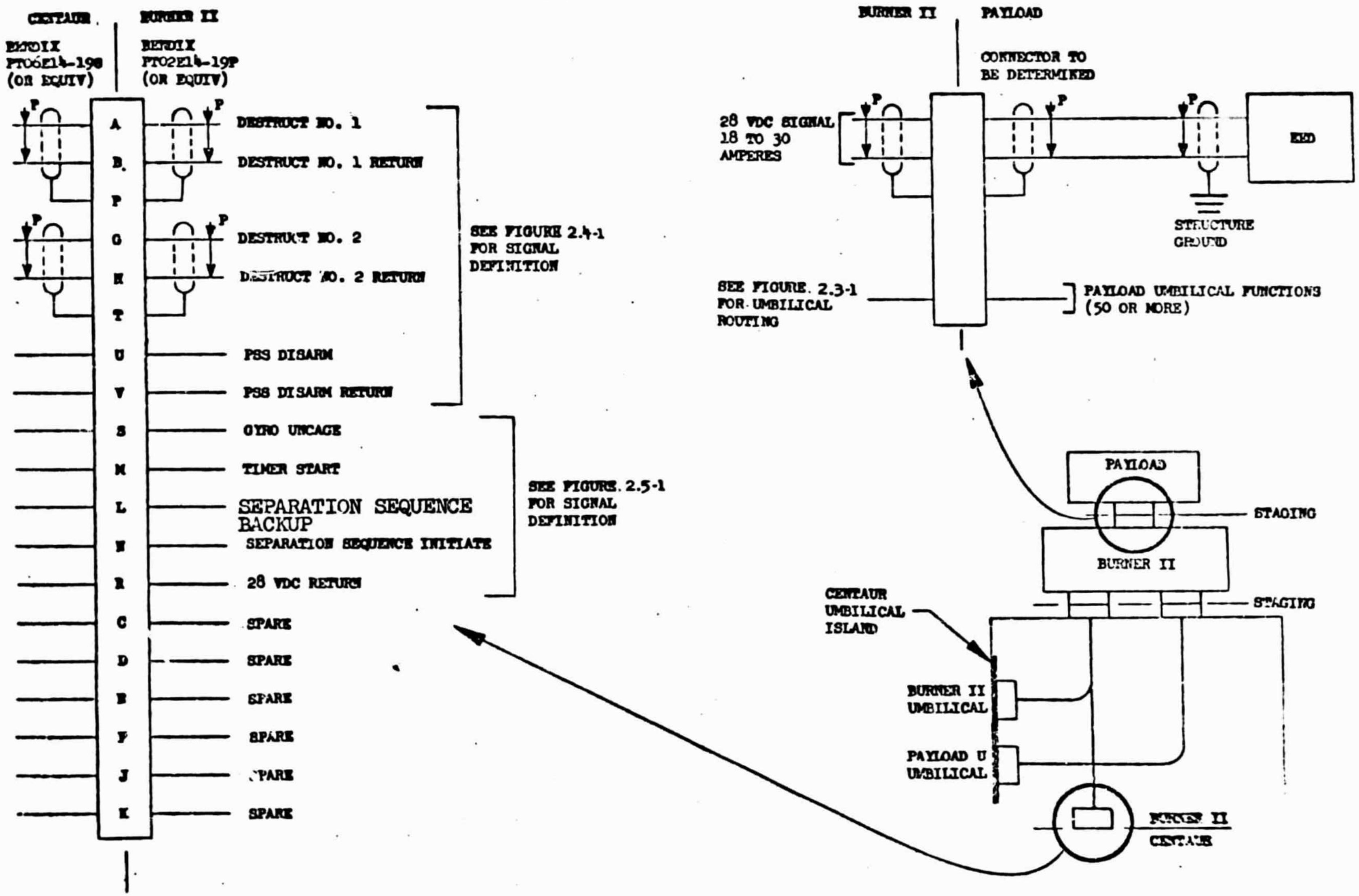
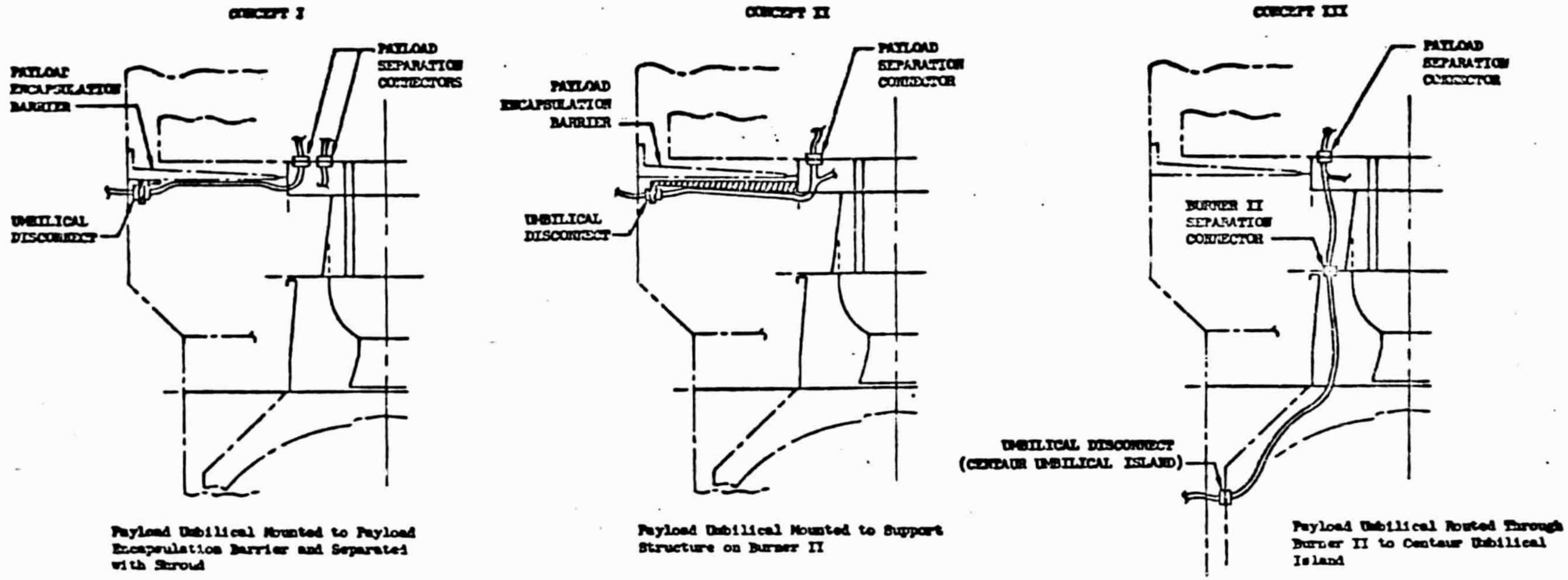


FIGURE 2.3-2 ELECTRICAL INTERFACE



Concept I: Payload Umbilical Mounted to Payload Encapsulation Barrier and Separated with Shroud

ADVANTAGES
1. LESS WEIGHT
2. CABLE BETWEEN SHROUD AND PAYLOAD IS STAGED AT TIME OF SHROUD SEPARATION.

DISADVANTAGES
1. ADDITIONAL ACCESS DOOR IN SHROUD
2. ADDITIONAL PAYLOAD INTERFACE CONNECTOR
3. REWORK TO TOWER TO PROVIDE FOR UMBILICAL DISCONNECT

Concept II: Payload Umbilical Mounted to Support Structure on Burner II

ADVANTAGES
1. ELIMINATES ONE (1) STAGING CONNECTOR

DISADVANTAGES
1. DECREASE IN PAYLOAD WEIGHT DUE TO BALLAST REQUIRED TO OFFSET MOMENT CAUSED BY UMBILICAL SUPPORT STRUCTURE.
2. ADDITIONAL ACCESS DOOR IN SHROUD
3. REWORK TO TOWER TO PROVIDE FOR UMBILICAL DISCONNECT

Concept III: Payload Umbilical Routed Through Burner II to Centaur Umbilical Island

ADVANTAGES
1. DOES NOT REQUIRE ACCESS DOOR IN SHROUD
2. DOES NOT REQUIRE MAST REWORK FOR UMBILICAL DISCONNECT MECHANISM
3. SIMPLIFIES CHECKOUT OF UMBILICAL CABLE
4. ROUTED WITH BURNER II UMBILICAL CABLE AND IS INSTALLED CONCURRENT WITH BURNER II CABLING PRIOR TO FIELD DELIVERY

DISADVANTAGES
1. ADDITIONAL STAGING CONNECTOR
2. ADDITIONAL WIRE WEIGHT

RECOMMENDATION:

USE CONCEPT III FOR FOLLOWING REASONS:

1. NO SHROUD MODIFICATION
2. MINIMUM IMPACT ON TOWER INTERFACE.
3. ELIMINATES INSTALLATION IN FIELD.

FIGURE 2.3-3 **PAYLOAD UMBILICAL TRADE STUDY**

Burner II will provide a 2-wire ordnance firing circuit capable of supplying 18-30 amperes for 20 milliseconds at 28 VDC to the payload for separation initiation.

The Burner II/Payload electrical interface is further defined by Figure 2.3-2.

2.3.4 R.F. Link Analysis

The following assumptions have been made to provide a baseline for the Burner II R.F. Link Analysis:

a. Burner II attitude is not constrained for telemetry transmission.

b. Telemetry carrier tracking is adequate.

c. Continuous telemetry is not required.

d. Burner II R.F. performance is based on a fixed antenna gain for 80% spherical coverage and referenced to a 12 DB signal-to-noise ratio in the MSFN Receiver IF bandwidth.

e. MSFN Receiver IF bandwidth can be equated to vehicle RF bandwidth.

f. MSFN can demodulate and process the Burner II telemetry signal.

g. MSFN and Burner II RF characteristics are tabulated in Table 2.3-1.

The Burner II RF Performance Analysis is summarized on Table 2.3-2. The first column shows that the existing Burner II system for the synchronous orbit mission, using the MSFN 85 foot antenna, is inadequate (Negative IF SNR Margin). The second column shows that by increasing the Telemetry Transmitter RF Power to 12 watts and decreasing the bandwidth requirement, it is possible to improve the IF SNR margin and meet RF performance requirements.

The Burner II Telemetry System, as modified to provide adequate performance for the Centaur/Burner II synchronous orbit mission, is shown on Figure 2.3-4. Equipment changes are noted for comparison with the existing Burner II Telemetry System. For the current Burner II operations, the telemetry system is on continuously. However, for the synchronous orbit mission, it is assumed that the Telemetry System will be programmed ON 50% of the time. The Burner II Telemetry System, when integrated with Centaur, will require the following modifications:

a. Elimination of the vibration channels after separation from Centaur.

b. Increase transmitter RF power output.

c. Increase battery capacity for higher electrical load and longer mission time.

d. Add programming for Transmitter ON-OFF control.

MSFN RF CHARACTERICTICS		
RF CHARACTERISTICS	VALUE	REMARK
ANTENNA - 85 FOOT DISH		
RECEIVING GAIN (MIN.)	+ 50.0 dB	SPECIFICATION
POLARIZATION	RHCP OR LHCP	SPECIFICATION
RECEIVING CIRCUIT LOSS (MAX.)	- 0.5 dB	SPECIFICATION
SYSTEM NOISE TEMPERATURE	+ 200 °K	ASSUMED
RECEIVER	FM	ASSIGNED
IF BANDWIDTH	150 & 500 KHz	ASSIGNED
THRESHOLD SNR	+ 12.0 dB	ASSUMED
BURNER II RF CHARACTERISTICS		
ANTENNA SUBSYSTEM		
TRANSMITTING GAIN	- 9.0 dB	MEASURED [1]
POLARIZATION	RHCP	
TRANSMITTING CIRCUIT LOSS (MAX.)	- 1.5 dB	
RF BANDWIDTH	500 KHz	

[1] MEASURED (RHCP) BURNER II ANTENNA GAIN FOR 80-PERCENT SPHERICAL COVERAGE

TABLE 2.3-1

MSFN AND VEHICLE RF CHARACTERISTICS

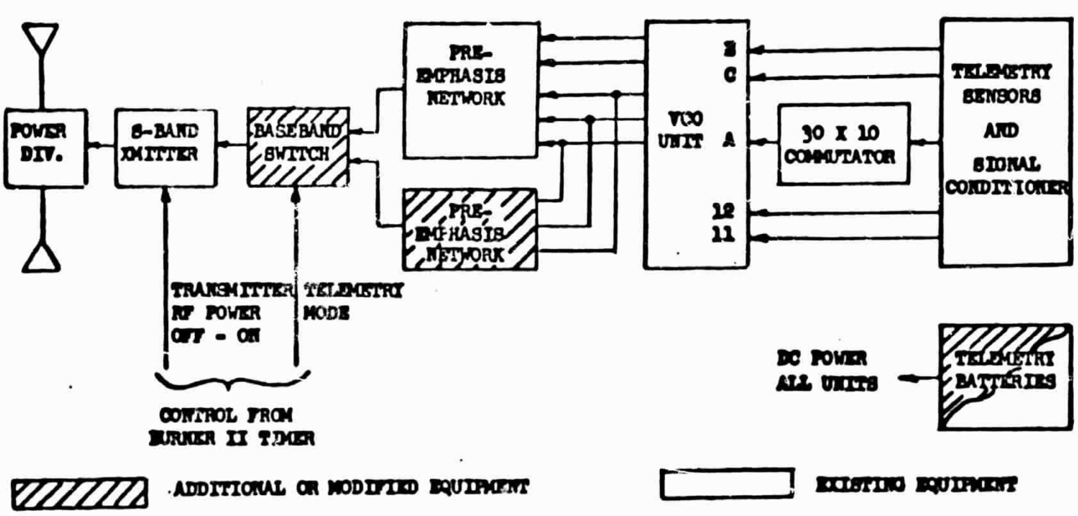
BURNER TELEMETRY SYSTEM				BURNER II/ CENTAUR TELEMETRY BASELINE	
+	37.0 dBm*	TRANSMITTER RF POWER	+	40.9	dBm*
-	1.5 dB	TRANSMITTING CIRCUIT LOSSES	-	1.5	dB
-	9.0 dB	TRANSMITTING ANTENNA GAIN	-	9.0	dB
-	191.7 dB	SPACE LOSS	-	191.7	dB
+	50.0 dB	RECEIVING ANTENNA GAIN	+	50.0	dB
-	0.5 dB	RECEIVING CIRCUIT LOSSES	-	0.5	dB
-	115.7 dBm	RECEIVED RF POWER	-	111.8	dBm
-	175.6 dBm/Hz	RECEIVER NOISE DENSITY	-	175.6	dBm/Hz
+	57.0 dBHz	RECEIVER IF NOISE BANDWIDTH	+	51.8	dBHz
+	2.9 dB	RECEIVER IF SNR	+	12.0	dB
+	12.0 dB	REQUIRED IF SNR	+	12.0	dB
-	9.1 dB	IF SNR MARGIN	+	0.0	dB

INADEQUATE RF PERFORMANCE
* 5 WATTS

{ BANDWIDTH REDUCTION AND INCREASED TRANSMITTER POWER }

ADEQUATE RF PERFORMANCE
* 12 WATTS

TABLE 2.3-2
RF PERFORMANCE ANALYSIS



TELEMETRY SYSTEM*	EST. WEIGHT (POUNDS)	EST. DC POWER (WATTS)
EXISTING BURNER II	6.5	78.0
BURNER II/CENTAUR+	23.0	128.0

* INCLUDES TELEMETRY BATTERIES (50% TRANSMISSION CYCLE)
+ BURNER-II/CENTAUR TELEMETRY BASELINE

FIGURE 2.3-4

The elimination of the vibration channels after Burner II separation from Centaur results in a reduction of the RF bandwidth or required ground receiver IF noise bandwidth. This bandwidth reduction improves the performance margin +5.2 db. Programming the transmitter for 50% operating time will reduce battery capacity required for TM operation.

Further improvement in TM performance can be achieved by iteration of the following areas:

a. Antenna gain vs. RF Link Geometry

b. Ground Station Modulation and Demodulation Requirements.

c. Data Signal-To-Noise Ratios

d. Ground Station Antenna Performance and Size

e. Tracking Requirements

2.3.5 Burner II Electrical Load Analysis

The Electrical Load Analysis of the Burner II System for the mission specified in Task 1 is summarized on Table 2.3-3. For purpose of this analysis, the Burner II operating time was assumed to be 6 hours with separate batteries provided for the Guidance & Control and Telemetry Subsystems. Refinement of the Burner II operating time for a specific mission will directly affect final battery selection.

Space qualified batteries are available from other programs that will meet the voltage and capacity requirements for the Burner II electrical load. Typical batteries are summarized on Table 2.3-4. Final battery selection is dependent upon specific Burner II requirements to be defined for a particular application. The load analysis made for this task requires a main battery for 28 VDC with a minimum capacity of 25.3 ampere-hours and a Telemetry Battery for 28 VDC with a minimum capacity of 14.7 ampere-hours. By combining the Burner II electrical power requirements, a single battery for 28 VDC with a minimum capacity of 40 ampere hours may be selected.

COMPONENT	POWER WATTS	ENERGY * WATT-HOURS
INVERTER	38.0	228.0
GYRO REFERENCE UNIT	45.0	270.0
TIMER	3.5	21.0
PROGRAMMER	6.3	37.8
VELOCITY METER	6.5	39.0
FLIGHT CONTROL ELECTRONICS	13.0	78.0
REACTION CONTROL SUBSYSTEM	2.0	12.0
SUBSYSTEM TOTAL	114.3	685.8
DISTRIBUTION LOSSES		21.6
TOTAL		707.4
TELEMETRY SUBSYSTEM		
TRANSMITTER	120.0	360.0**
VCO	3.0	18.0
COMMUTATOR	3.0	18.0
INSTRUMENTATION	2.0	12.0
SUBSYSTEM TOTAL	128.0	408.0
DISTRIBUTION LOSSES		4.0
TOTAL		412.0

*MISSION TIME - 6 HRS. **ASSUMES 50% DUTY CYCLE AS BASELINE

TABLE 2.3-3
ELECTRICAL LOAD ANALYSIS

MODEL NO.	CAPACITY AMP-HOUR	NO. CELLS	VOLTAGE NL PLATEAU	WEIGHT LBS.	SIZE CU. IN.	PROGRAM USED ON
Yardney 19 x PM 30	23	19	33.0 - 29.0	37.0	766	Atlas
Yardney 20 x HE 20	20	20	34.0 - 30.0	25.0	594	Vanguard
Yardney 19 x PML 21 (30)	30	19	33.0 - 29.0	24.6	555	Philco-Ford Contract
Eagle Picher MAP 4202 Cells in new case	15	20	24.0 - 30.6	22.0	330	Saturn IVB
Eagle Picher MAP 4265-5	40	20	34.0 - 30.6	28.5	466	Apollo CM
Eagle Picher MAP 4062-3	50	18	30.6 - 27.6	29.0	378	Agena

NOTE: 18 Cells are required in a Ag-Zn battery to provide 28 VDC output. Dummy cells can be installed in batteries having more than the required cells to meet voltage requirements.

TABLE 2.3-4
TYPICAL SPACE QUALIFIED BATTERIES

2.4 TASK 4 - DESTRUCT SYSTEM

The purpose of this task is to examine the Destruct Systems on both the Improved Centaur and the Burner II and determine the integration details. The Burner II destruct system described complies with AFETR 127-1, Section D. Integration with the Centaur destruct system is shown on Figure 2.4-1. The destruction of Burner II in flight can be achieved by ground command by way of the Centaur command destruct receivers or by premature separation of the Burner II from the Centaur adapter. The destruct signal from the Centaur must be $28 \, {}^{+2}_{-0}$ VDC, 4.5 amp minimum for 20 milliseconds.

2.4.1 Burner II Destruct System

The Burner II Destruct System is composed of a Safe and Arm Device, containing detonators, an Interconnect Train, with dual mild-detonating fuzes, and a shaped charge. The complete Destruct System, illustrated schematically in Figure 2.4-1 is installed in the Burner II adapter section and remains with the booster at normal stage separation. Destruction of the Burner II, in the event of malfunction, will be provided during boost phase by detonation of the shaped charge which will penetrate the side of the rocket motor. The destruct initiate signal will come from the booster command destruct receivers.

2.4.2 Burner II Premature Separation System (PSS).

The Burner II will be destructed automatically in the case of a premature separation of the Burner II from the Centaur. The PSS is composed of dual 1.5 ampere-minute batteries, three plunger type switches, and two arm-inhibit relays. The batteries provide a dual path through the PSS switches and arm-inhibit relays to the detonators on the safe and arm device. The plunger switches are held open mechanically by the mating surfaces of the Burner II and the booster adapter section. Upon premature separation, the closing of any switch will connect both batteries to the detonators through the arm-inhibit relays. After normal boost, the arm-inhibit relay is disabled by a signal from the Centaur indicating main engine cutoff. Disabling of this relay disconnects the batteries from the detonators and allows normal stage separation.

2.4.3 Safe and Arm Control

The safe and arm device, and the latching type arm-inhibit relays, are remotely armed or disarmed from the Launch Control Console in the VIB through ground umbilical actuation circuits. The position status of both devices is displayed on the Launch Control Console in the VIB.

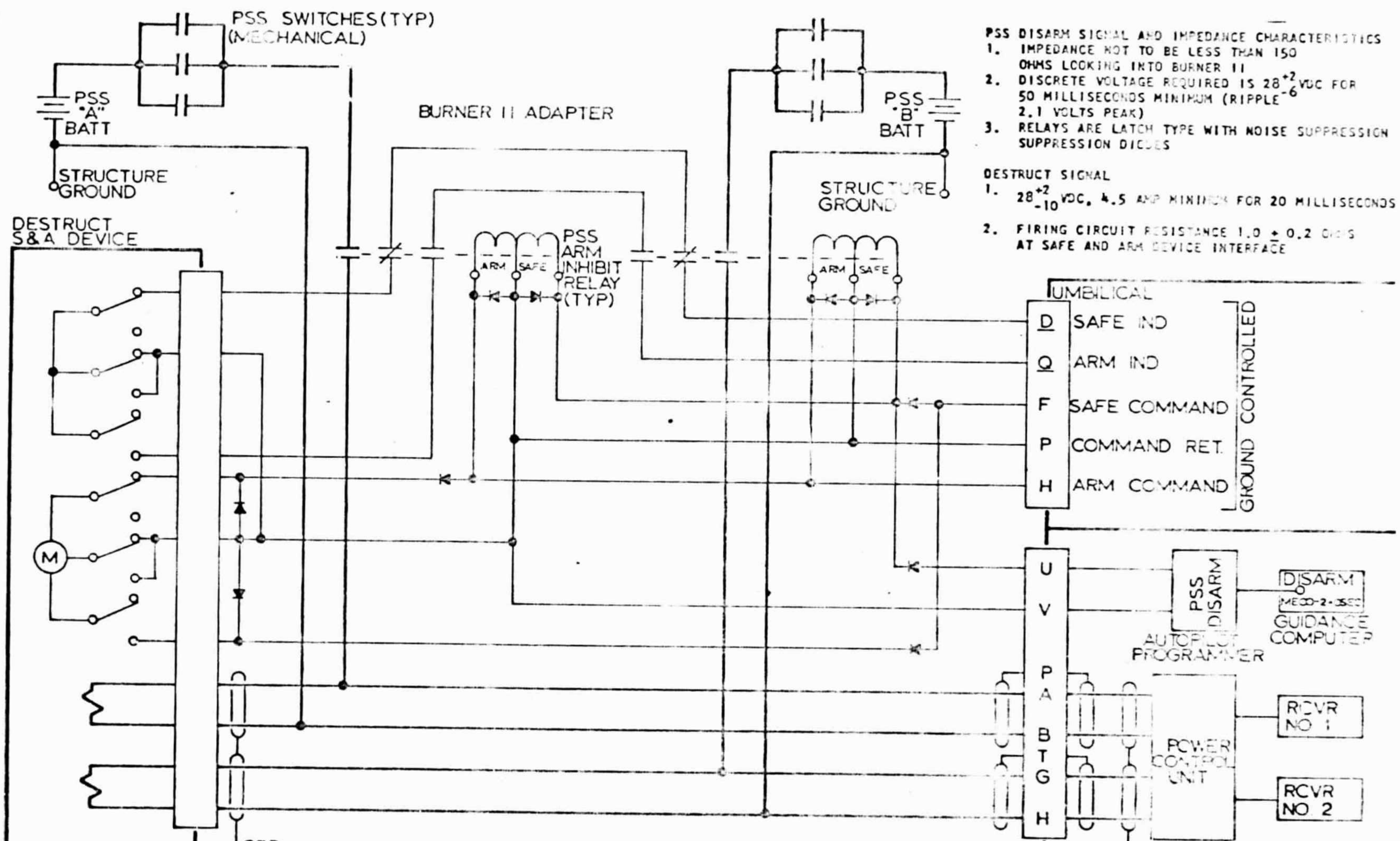


FIGURE 2.4-1 DESTRUCT & PREMATURE SEPARATION SYSTEM (PSS)

2.5 TASK 5 - GUIDANCE SYSTEM

The integration of the Burner II with the Improved Centaur combines two different guidance systems to achieve the prescribed terminal conditions of the powered portion of the mission trajectory. The integration of the Burner II preprogrammed strapped down inertial system with the Centaur closed loop inertial platform system is discussed in this section. The material presented discusses the guidance interface details and some guidance options to improve the Centaur-to-Burner II attitude transfer errors. The attitude transfer error is the predominant guidance error associated with adding Burner II to Centaur.

2.5.1 Burner II/Centaur Guidance System Interface

Figure 2.5-1 is a functional block diagram of the Burner II/Centaur guidance interface. Four discrete signals are required from Centaur to initialize the Burner II guidance system: Gyro Uncage; Timer Start; Separation Sequence Initiate; and Back-up Separation Sequence Initiate.

Gyro Uncage is a separate time discrete providing flexibility in uncaging the gyros at a time which minimizes attitude transfer errors.

Timer Start is a command computed by Centaur to provide compensation for boost dispersion by controlling the time of Burner II ignition. Since Burner II is programmed for a fixed interval between Timer Start and ignition, the desired compensation is achieved by adjusting Timer Start. A hydrogen peroxide warm-up pulse is required 2 to 40 seconds before separation. This permits a tolerance of $\pm$ 19 seconds on Timer Start by programming warm-up to occur 21 seconds before the nominal separation time.

If analysis should show that additional compensation is required, then added commands would be needed for the warm-up pulse. Either two timed discretes from Centaur could start and stop the pulse or the pulse could be generated by the time delay circuits in Burner II.

Burner II Separation Sequence Initiate is a time discrete following Centaur cutoff (MECO-2). The command also provides a back-up for Gyro Uncage and Timer Start.

A separation sequence initiate back-up is provided by an additional command from the Centaur computer initiating a back-up discrete in the autopilot-programmer which goes through separate pins of the connectors to a summing junction in Burner II.

Figure 2.5-2 shows the electrical interface for guidance and control. The input impedance for signals from Centaur to Burner II is greater than 150 ohms, the coil impedance for a latching relay in Burner II. Pulses for actuating the relays are 28^{+2}_{-6} volts dc and of 50 milliseconds minimum duration. The latching relays in the figure will be reset for ground testing and preflight set-up by the same reset signal as used for all other relays in Burner II using the same reset indicator circuitry. All Burner II relay coils are protected by back-EMF suppression diodes to reduce EMI.

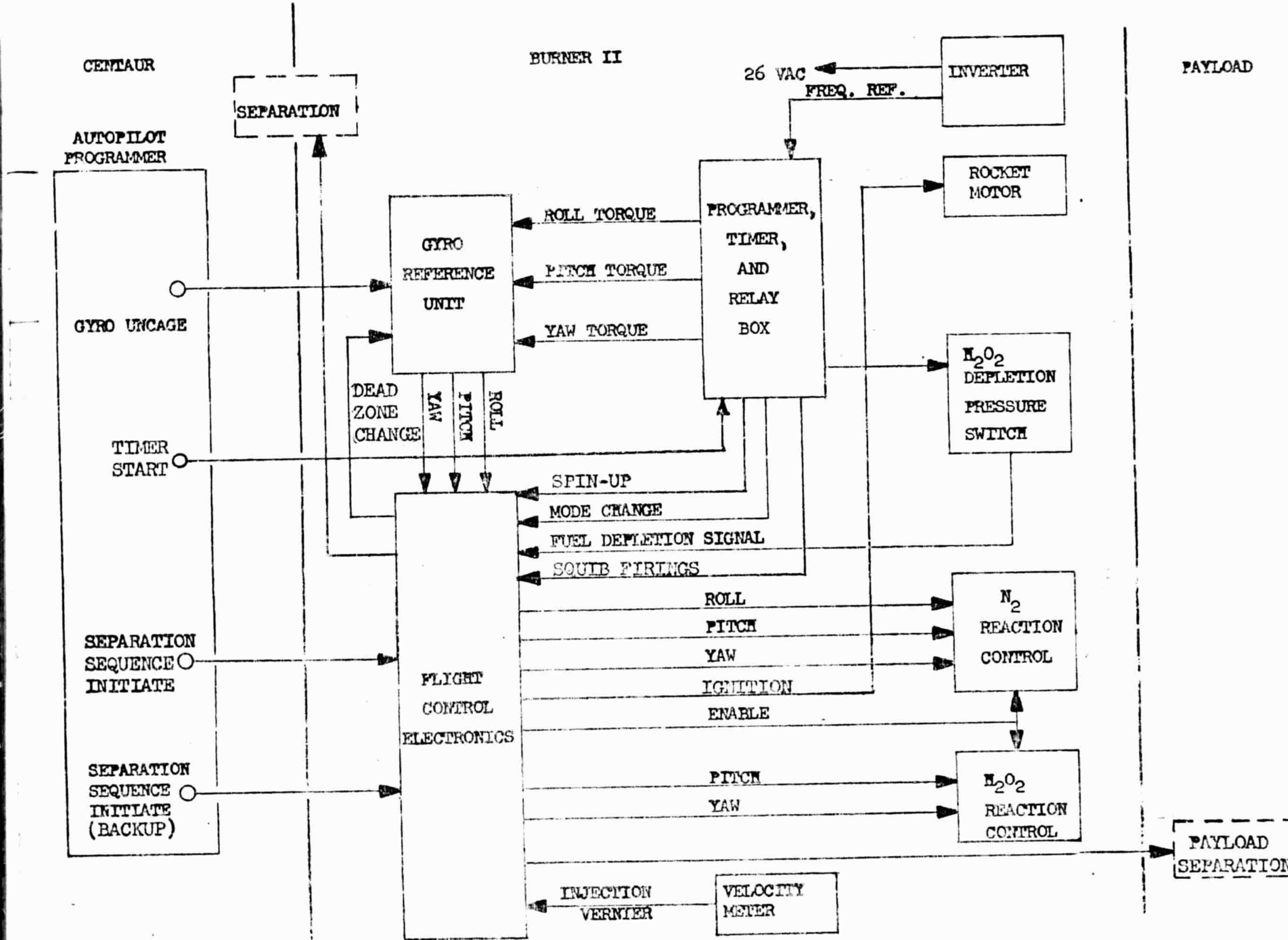
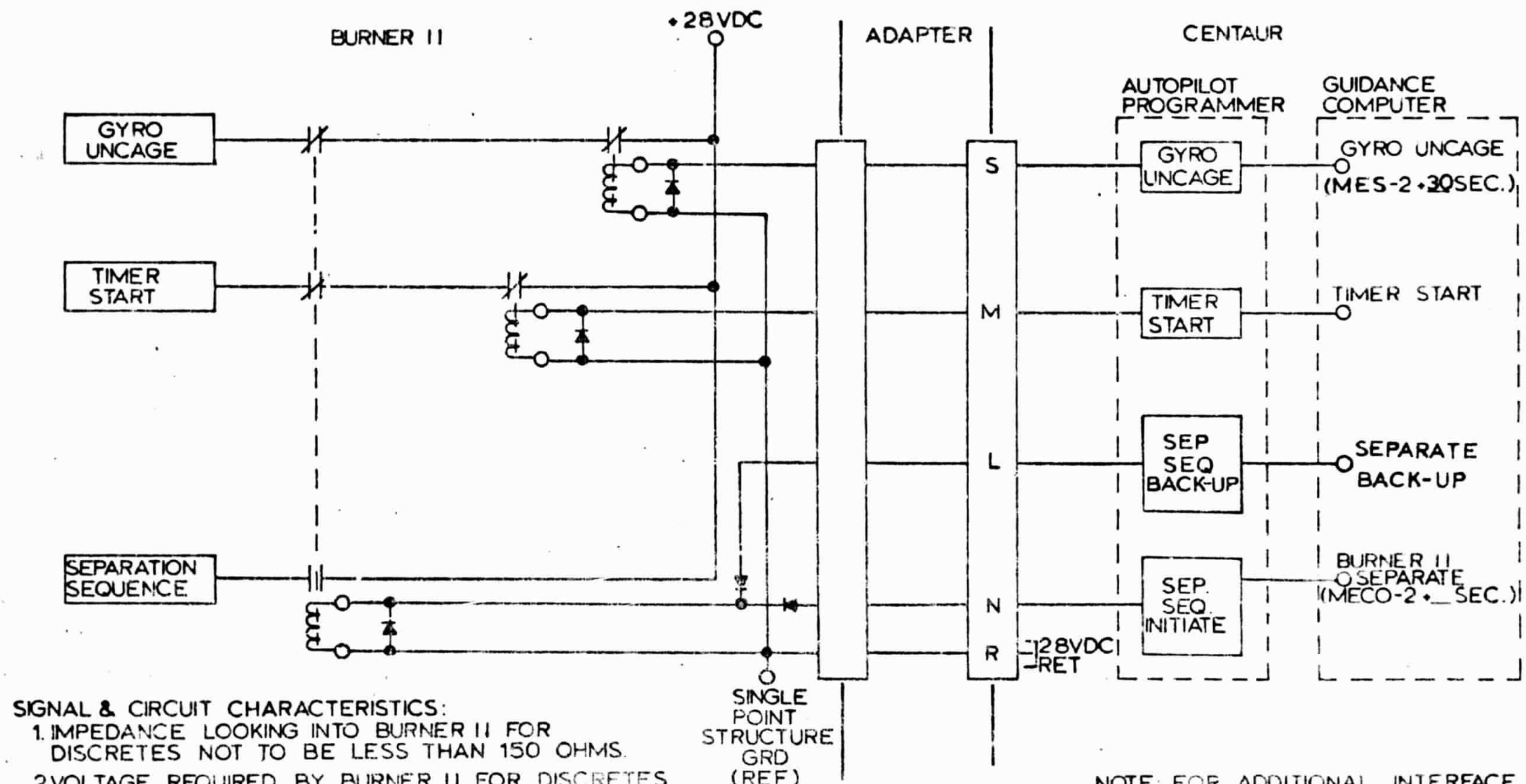


FIGURE 2.5-1: GUIDANCE & CONTROL - BURNER II/CENTAUR FUNCTIONAL INTERFACE



SIGNAL & CIRCUIT CHARACTERISTICS:

1. IMPEDANCE LOOKING INTO BURNER II FOR DISCRETES NOT TO BE LESS THAN 150 OHMS.
2. VOLTAGE REQUIRED BY BURNER II FOR DISCRETES IS 28^{+2}_{-6} VDC FOR 50 MILLISECONDS MINIMUM. (RIPPLE 2.1 VOLTS PEAK.)
3. ALL BURNER II RELAYS SHOWN ARE LATCH TYPE WITH NOISE SUPPRESSION DIODES.

NOTE: FOR ADDITIONAL INTERFACE SIGNAL DEFINITION SEE FIGURE 4-1.

FIGURE 2.5-2 BURNER II/CENTAUR GUIDANCE ELECTRICAL INTERFACE

2.5.2 Guidance System Options

2.5.2.1 Summary

Several techniques for reducing Centaur/Burner II attitude transfer errors have been evaluated and the results are summarized in Table 2.5-1. Option 2.A, the recommended baseline using cross-axis accelerometers in Burner II with the gyros uncaged during Centaur second burn, results in a transfer error of 26.5 arc-minutes compared to the 1.0 degrees goal for Improved Centaur.

The use of improved gyros on Burner II uncaged at liftoff is more accurate than the baseline, but imposes complex interfaces or constraints on Centaur. There are two alternatives possible with this option: (1) Burner II could guide the booster, but the interface would be out of scope* and more complex; (2) Burner II could be pre-programmed to follow the booster, but this would impose a constraint on the Titan and Centaur not to exceed an attitude of 10 degrees from nominal. It is questionable whether the 10 degree constraint can be met.

The use of zero crossing or soft uncaging does not offer a significant improvement in attitude transfer accuracy compared to an ATS Pointing Accuracy study attached to NASA Letter 93061 dated 4 June 1969. Neither does uncaging at liftoff if the present Burner II gyros are used.

A horizon sensor on Burner II is estimated to provide the same degree of accuracy as the baseline concept and would be recommended if on-orbit correction capability were desired.

2.5.2.2 Gyro Uncage after MECO-2

An analysis, based on data from the ATS study, was made of the Centaur/Burner II attitude transfer error if the Burner II gyros are uncaged after Centaur second burn cutoff. The individual error sources of the ATS study and the error due to misalignment of the Burner II gyros to the Centaur are shown in Table 2.5-2. These errors do not accurately represent the Titan/Centaur/Burner II mission nor the Improved Centaur guidance, but they provide a basis for comparing the other options considered. An attitude transfer error of one degree, the goal of the Improved Centaur guidance, was used for the error analysis in Task 1.

2.5.2.3 Gyro Uncage During Centaur Second Burn

In this concept, the Centaur is maintained at a constant attitude for a short time during the thrusting period; i.e., guidance steering corrections are inhibited. Cross-axis accelerometers on Burner II sense lateral components of acceleration which are proportional to the mechanical misalignments of Burner II to the Centaur thrust vector. The gyros are uncaged and the pitch and yaw gyros are then torqued to place them in a plane normal to the thrust vector. After Centaur/Burner II separation, the Burner II rotates to eliminate the gyro error signals. Since the inertial orientation of the thrust vector is very well known, this establishes a highly accurate attitude transfer.

*A ground rule of the study was that Centaur provides guidance through Centaur burnout.

TABLE 2.5-1

SUMMARY OF ATTITUDE TRANSFER OPTIONS

METHOD	RELATIVE ACCURACY (ARC-MIN)	CONCLUSION
1. UNCAGE AFTER MECO-2	54.0	BASED ON ATS STUDY
2. TRANSFER DURING CENTAUR THRUSTING AT PREPROGRAMMED ΔV VECTOR	A. WITH BII CROSS-AXIS ACCELEROMETERS - 26.5	-RECOMMENDED METHOD -SLIGHT PERFORMANCE PENALTY -ADDITIONAL CENTAUR PROGRAMMING
	B. W/O CROSS-AXIS ACCELEROMETERS - 54.0	-NO IMPROVEMENT
3. UNCAGE GYROS AT LIFTOFF	A. GG-334 GYROS - 16.1 B. GG-87 (H-419) - 19.9	-MOST ACCURATE METHOD -COMPLEX INTERFACE TO GUIDE BOOSTER -INADEQUATE GIMBAL FREEDOM TO FOLLOW BOOSTER
	C. GG-87 (BII) - 50.0	-SMALL IMPROVEMENT
4. ZERO CROSSING	52.2	-SMALL IMPROVEMENT -REQUIRES UNDISTURBED LIMIT CYCLE -COMPLEX INTERFACE
5. SOFT UNCAGING	52.2	-SAME AS 4 ABOVE
6. HORIZON SENSOR ON BURNER II	< 24 SYNC < 30 ESCAPE	-ESTIMATE BASED ON BURNER II ANALYSIS FOR SESP 68-1 -SLIGHT PERFORMANCE PENALTY

TABLE 2.5-2

CENTAUR/BURNER II ATTITUDE TRANSFER ERROR
FOR GYRO UNCAGE AFTER MECO-2 [1]

ERROR SOURCE		3σ ERROR (ARC-MIN)
INTERFACE PLANE ERROR		27.4
• FABRICATION & INSTALLATION	4.5	
• FLIGHT EFFECTS [2]	27.0	
GUIDANCE STEERING ERROR		43.5
• GYRO DRIFT	24.5	
• STEERING MODULE	14.9	
• FOURTH GIMBAL AXIS TO PLATFORM CASE	11.0	
• INNER BLOCK BOLT HOLE ALIGNMENT	7.6	
• RESOLVER CHAIN [3]	29.0	
• INPUT AMPLIFIER GAIN	3.4	
• EXCITATION TRANSFORMER ASSYMMETRY	6.0	
SOFTWARE ERROR		7.5
FLIGHT CONTROL SYSTEM		13.6
BII GYRO ALIGNMENT TO CENTAUR		5.2
• GYRO TO CASE	3.0	
CASE TO BII MOUNT	3.0	
• BII MOUNT TO CENTAUR BASE	3.0	
RSS		54.0

[1] REFERENCE: ATS POINTING ACCURACY STUDY, NASA LETTER 93061, 4 JUNE 1969

[2] SHELF ROTATION DURING TANKING AND COUNTDOWN

[3] CALIBRATED WITHIN 90 DAYS

The gyros are torqued through angles given by:

$$\delta\theta = \frac{a_z}{\Delta V_x} \Delta t \qquad \delta\psi = \frac{a_y}{\Delta V_x} \Delta t$$

where $\delta\theta$ and $\delta\psi$ are the pitch and yaw torquing commands a_y and a_z are lateral accelerations along the y and z - axes, and ΔV_x is the incremental velocity measured by the Burner II velocity meter in the time Δt that the lateral accelerometers are sampled.

These equations are mechanized by counting the number of pulses from the lateral accelerometers in the time it takes to accumulate a predetermined number of pulses from the velocity meter. Figure 2.5-3 is a functional block diagram of the modification to Burner II required to implement this technique. Two integrating lateral accelerometers and a gyro uncage adapter are added to Burner II. (The functional interface shown in Figure 2.5-1 is unaffected by this change.) The uncage adapter is enabled and the gyros uncaged by the same discrete command from Centaur. Pulses from the velocity meter and the lateral accelerometers are then accumulated in separate registers of the adapter. When ten pulses from the velocity meter have been counted, a timing signal from the gyro uncage adapter initiates the pitch torquing rate. This rate is applied to the gyro until the number of pulses from the z-axis accelerometer is matched by an equal number of properly scaled pulses from the inverter. A second timing signal then terminates the pitch torque rate and starts the yaw torque rate, the duration being determined by the pulses accumulated by the y-axis accelerometer.

An accuracy analysis of this method is summarized in Table 2.5-3. The attitude transfer error is a function of the accuracy of the Centaur inertial reference, the alignment of the Centaur thrust vector to the inertial reference, and the alignment of the Burner II gyros to the Burner II accelerometers. The inertial reference depends on initial platform alignment to the pad reference, which is assumed to be a negligible source of error, and gyro drift. Orientation of the thrust vector depends on software errors and misalignment of the Centaur gyros to the Centaur accelerometers. Scale factor errors in the Burner II accelerometers contribute to errors in gyro torquing commands. For example, if the accelerometer pulse weight is 0.05 ft/sec and ΔV_x is 80 ft/sec (10 pulses in the velocity meter), an error of one pulse will result in a torquing command error of 2.1 arc-minutes.

This uncaging technique is recommended for Centaur/Burner II integration. The attitude transfer accuracy is a significant improvement over that in Table 2.5-2. There is a slight performance penalty because Centaur guidance is inhibited. Also, additional programming is required. However, the physical and electrical interfaces between Centaur and Burner II are unchanged.

For comparison, gyro uncage during Centaur burn was also evaluated for the case in which no lateral accelerometers are added to Burner II. These results, also shown in Table 2.5-3 are no improvement over those in Table 2.5-2. The limit cycle error after MECO is replaced by an error due to C.G. offset during thrust. Other error sources are the same.

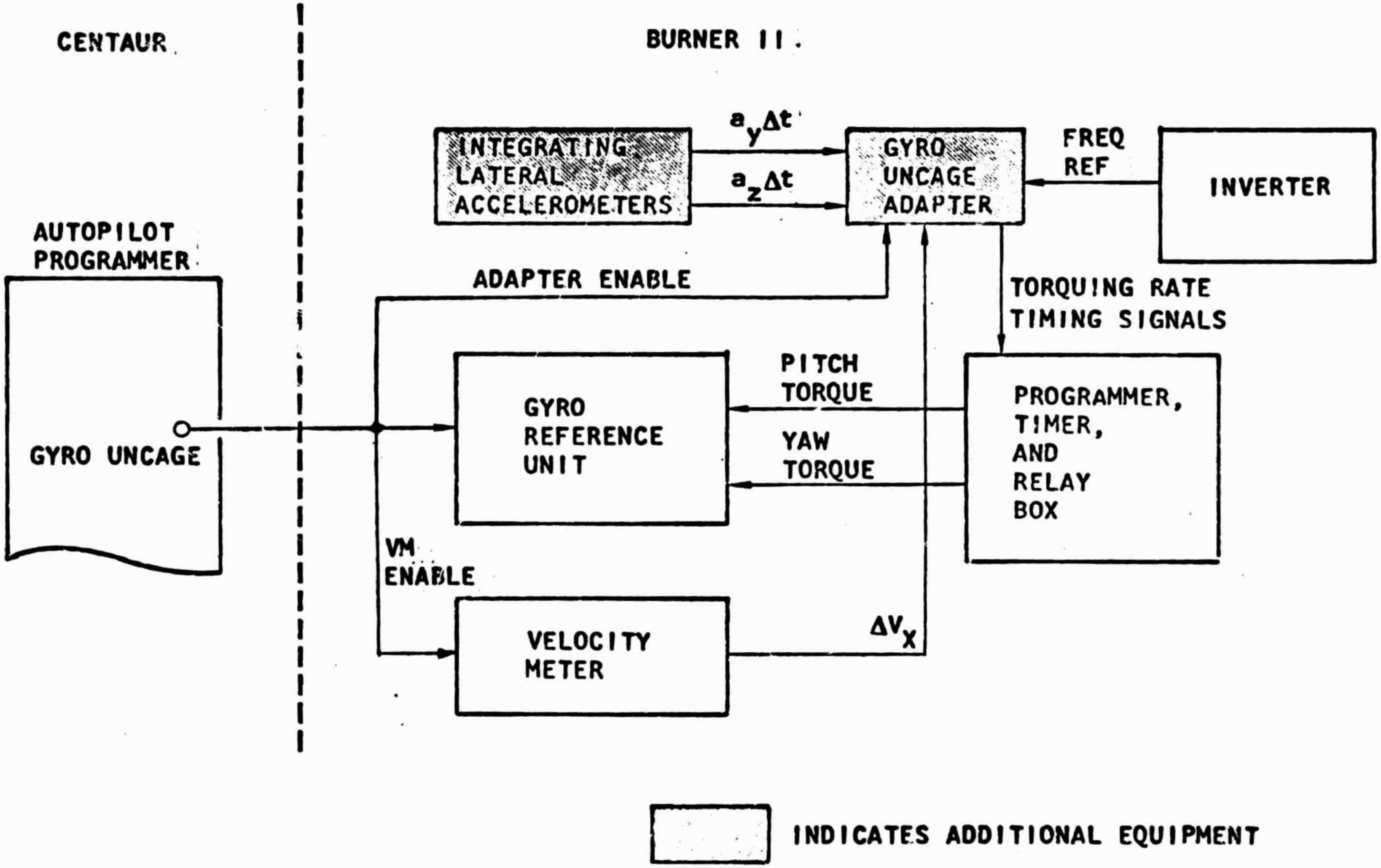


FIGURE 2.5-3: FUNCTIONAL INTERFACE FOR GYRO UNCAGE DURING CENTAUR BURN

TABLE 2.5-3

ATTITUDE TRANSFER ACCURACY FOR GYRO UNCAGE DURING CENTAUR BURN

	WITH BII CROSS- AXIS ACCELEROMETERS (ARC-MIN) 3σ	W/O BII CROSS - AXIS ACCELEROMETERS (ARC-MIN) 3σ
CENTAUR GUIDANCE ERRORS		
. GYRO DRIFT	24.5	24.5
. STEERING MODULE	-	14.9
. GAIN AND EXCITATION	-	6.9
. INNER BLOCK AND GIMBAL MOUNTING	-	13.4
. RESOLVER CHAIN	-	29.0
. ACCELEROMETER BIAS AND SCALE FACTOR	Negligible	Negligible
SOFTWARE ERRORS (CENTAUR)	7.5	7.5
ALIGNMENT ERRORS		
MISALIGNMENT OF BII GYROS TO BII ACCELEROMETERS		
. GYRO TO GYRO CASE	3.0	-
. GYRO CASE TO BII MOUNT	3.0	-
. ACCELEROMETER TO ACCELEROMETER CASE	3.0	-
. ACCELEROMETER CASE TO BII MOUNT	3.0	-
MISALIGNMENT OF CENTAUR GYROS TO ACCELEROMETERS	3.0	-
MISALIGNMENT OF BII GYROS TO CENTAUR REFERENCE		
. INTERFACE PLANE ERROR	-	27.4
. BII GYRO ALIGNMENT TO CENTAUR	-	5.2
BII ACCELEROMETER ERROR	2.1 [1]	-
CENTAUR C. G. OFFSET	-	14.3 [2]
RSS ERROR	26.5	54.1

[1] BASED ON 0.05 FT/SEC ERROR (1 PULSE) IN ΔV_X INCREMENT OF 80 FT/SEC.

[2] BASED ON 1-INCH C. G. OFFSET AT 20 FEET FROM ENGINE NOZZLES.

2.5.2.4 Gyro Uncage at Liftoff

Two methods of uncaging the Burner II gyros at liftoff were considered: Burner II guiding the booster; Burner II pre-programmed to follow the nominal trajectory of the Booster.

Burner II guidance of the booster could be accomplished by adding a computer and cross-axis accelerometers to Burner II. Guidance corrections would be transmitted to the Titan and Centaur autopilots. Alternatively, signals from the Burner gyros could go to the Centaur computer to generate the guidance corrections, but this would require added software because Burner II uses strapdown gyros and Centaur has an inertial platform. Either approach would require a complex interface.

Burner II can be mechanized to follow the booster by using pre-programmed gyro torquing rates which match the nominal boost trajectory. This approach results in a much simpler interface. However, it imposes a constraint on guidance corrections and attitude transients due to engine starts and staging. The GG-87 gyro has a gimbal freedom of 10° and the GG-334 has only 5°. Any attitude dispersions exceeding these limits will cause errors due to the gyros hitting their stops. It is questionable that these constraints can be met.

The attitude transfer accuracy for gyro uncage at liftoff of a representative synchronous equatorial mission was evaluated for three cases: Burner II gyros (GG-87); Honeywell SIGN III H-419 gyros (improved GG-87); and SIGN III H-429/H-448 gyros (GG-334 gas-bearing). The error parameters for these three gyros are shown in Table 2.5-4.

It was assumed that the Burner II mount was used for all three models of gyros so that the misalignment errors would be the same in all cases. In practice, the Burner II mount would require additional machining to accommodate the GG-334.

Table 2.5-5 shows the attitude errors at Centaur second cutoff (MECO-2) for each of the gyros. The component of error for each error source is shown. There is a significant accuracy improvement in going from the Burner II gyro to the H-419 gyro primarily because of the reduced drift. There is not much difference between the H-419 and the H-429/H-448 gyros because the misalignment errors dominate the lower drift rates.

This option, using either of the SIGN III gyros, is the most accurate considered. However, the interface complexity and operational constraints discussed above make this concept less attractive than the technique of the preceding section.

2.5.2.5 Zero Crossing

Zero crossing uncage consists of uncaging the Burner II gyros at zero crossing of the Centaur gyros to eliminate attitude transfer errors due to limit cycling. This requires that the Centaur autopilot provide three gyro output signals with zero voltage detection and that the Burner II gyros are uncaged individually after an uncage enable command from the guidance computer.

TABLE 2.5-4

GYRO ERROR PARAMETERS

ITEM	ERROR SOURCE	DEVIATION (3 σ) BURNER II GYROS	H-419 GYROS	H-429/H-448 GYROS
	INITIAL MISALIGNMENT OF BODY AXES TO LCI COORDINATES			
1.	ROLL MISALIGNMENT (deg)	0.1	0.1	0.1
2.	PITCH MISALIGNMENT (deg)	0.0806	0.0806	0.0806
3.	YAW MISALIGNMENT (deg)	0.0806	0.0806	0.0806
	GYRO ERRORS			
4.	RANDOM DRIFT (deg/hr)	1.0	0.25	0.1
5.	SCALE FACTOR (%)	0.11	0.02	0.01
6.	MISALIGNMENT ABOUT SPIN AXIS (arc-sec)	292.5	292.5	292.5
7.	MISALIGNMENT ABOUT OUTPUT AXIS (arc-sec)			
	a. ROLL GYRO	292.5	292.5	292.5
	b. PITCH & YAW GYROS	230.5	230.5	230.5
8.	MASS UNBALANCE-SPIN AXIS (deg/hr/g)	0.5	0.4	0.12

TABLE 2.5-5

3σ ATTITUDE ERRORS FOR GYRO UNCAGE AT LIFTOFF

ERROR SOURCE	BURNER II GYROS Roll (arc-min)	BURNER II GYROS Pitch (arc-min)	BURNER II GYROS Yaw (arc-min)	H-419 GYROS Roll (arc-min)	H-419 GYROS Pitch (arc-min)	H-419 GYROS Yaw (arc-min)	H-429/H-448 GYROS Roll (arc-min)	H-429/H-448 GYROS Pitch (arc-min)	H-429/H-448 GYROS Yaw (arc-min)
Body Misalignments									
Roll	-5.9639		0.6418	-5.9639		0.6418	-5.9639		0.6418
Pitch		4.8333			4.8333			4.8333	
Yaw	-0.5173		-4.8069	-0.5173		-4.8069	-0.5173		-4.8069
Gyro Roll									
Drift	-12.8879		17.7576	-3.2220		4.4394	-1.2888		1.7758
Output-Axis Misalign	0.5214		9.7179	0.5214		9.7179	0.5214		9.7179
MUSA	-0.6950		-6.2532	-0.5560		-5.0026	-0.1668		-1.5008
Pitch Gyro									
Drift		33.2802			8.3201			3.3280	
Scale Factor		12.2788			2.2325			1.1163	
Yaw Gyro									
Drift	-17.7673		-12.8800	-4.4418		-3.2200	-1.7767		-1.2880
Output-Axis Misalign	7.6602		-0.4109	7.6602		-0.4109	7.6602		-0.4109
MUSA	0.0226		-0.1489	0.0181		-0.1191	0.0054		-0.0357
RSS	24.0218	35.8009	25.2681	11.1896	9.8777	13.1621	9.9816	5.9735	11.1889
Total Att. Error		49.97			19.90			16.14	

Referring to Table 2.5-2, zero crossing eliminates the flight control system error so that the attitude transfer error is reduced from 54.0 arc-minutes to 52.2. This method was ruled out because the gain is insignificant and there is no assurance of having the disturbance-free limit-cycle required for a zero crossing.

2.5.2.6 Soft Uncaging

Soft uncaging is another method of reducing attitude transfer errors caused by Centaur limit cycling. Soft uncaging consists of using a very low feedback gain between the gyro output and its torquer. The low gain allows the Burner II gyros to follow the limit cycle motion of the booster and simultaneously produce a gradual decay in the attitude error. This technique requires the use of two caging gains on the Burner II gyros. At liftoff, the hard cage mode is used. Several minutes before uncage, the gyros are switched to the soft uncage mode.

The effect of soft uncaging is the same as zero crossing in that it eliminates only the flight control system error shown in Table 2.5-2. This method was also ruled out for the same reasons given above.

2.5.2.7 Horizon Sensor on Burner II

An estimate of attitude transfer accuracy using a horizon sensor on Burner II was made on the basis of detailed analysis done for the Atlas/Burner II SESP 68-1 Mission. The error is not expected to exceed 24 arc-minutes for the synchronous mission or 30 arc-minutes for the escape mission. This accuracy is comparable to that for the recommended method of gyro uncage during Centaur burn. Furthermore, the gyro torquing signal conditioner electronics is already developed and qualified. Despite these advantages, however, this method is not the recommended baseline because of the performance penalty (approximately 10 pounds) that is incurred if the sensor is used only for attitude transfer.

This method would be recommended if Burner II were also to provide on-orbit ΔV corrections of boost phase errors, using the continuous attitude update capability of the horizon sensor. Velocity corrections would be made using the Burner II vernier control capability, a concept proven feasible by several past Burner II program studies. On-orbit correction capability can result in net payload improvement and cost saving by reducing boost dispersion errors to a level within the capability of a spacecraft station-keeping system, thus eliminating the need for high-thrust propulsion on the spacecraft.

2.6 TASK 6 - ELECTROMAGNETIC ENVIRONMENT

Burner II is required to function properly while in the presence of the electromagnetic environment generated by Centaur. The purpose of this task was to determine by analysis if Burner II is electromagnetically compatible with the Centaur. The hardwire interfaces between Burner II and Centaur including the respective types of grounding used were evaluated to determine potential problem areas. RF coupling between Centaur transmitting antennas and Burner II electronic subsystems was determined. The coupling information was used to establish the RF signal strength present at Burner II. The desired signal strengths were compared with previous Burner II EMI sensitivity data to determine relative sensitivity to the Centaur environment and resulting potential problem areas. No electromagnetic interference problems are anticipated with the integration of Burner II with Centaur.

2.6.1 Burner II/Centaur Interface Signals

The following functions comprise the Burner II/Centaur electrical interface:

1) Premature Separation Switch Disarm;
2) Destruct Ordnance No. 1 and 2 Initiate;
3) Separation Sequence Start;
4) Timer Start;
5) Gyro Uncage.

A schematic of the interface functions is shown in Figures 2.4-1 and 2.5-1.

The premature Separation Switch Disarm signal is issued from the Centaur immediately prior to Burner II/Centaur separation. The disarm signal operates two Burner II latching-type relays which prevent destruct ordnance from firing during the normal separation sequence. The relays are shielded and are considered non-sensitive to EMI. Isolation of the circuitry is provided through the use of two-wire signal distribution to the relays. Additional isolation of the circuitry is provided by the use of twisted pair leads and closely-controlled wire routing for these leads within Burner II. Diode suppressors are installed on the relays to provide transient kickback voltage reduction, thus limiting the transient voltage that can be induced into adjacent wiring or be developed at the Burner II/Centaur interface terminals. As a result of the inherent non-sensitivity of the relays and the isolation precautions incorporated into the circuit design, no EMI problems are anticipated in the PSS Disarm Interface.

The Destruct Ordnance No's 1 and 2 Initiation is commanded from the Centaur as a result of confirmed mission failure. Maximum protection for these ordnance leads is provided in Burner II. A two-wire signal distribution system is used which incorporates shielded twisted-pair wiring and separate wire bundle routing from the ordnance to the Centaur interface. Squibs selected for the destruct function are rated at one ampere no-fire, thus providing a high tolerance to extraneous currents that may be induced into the ordnance wiring. It is concluded that the ordnance circuitry will not present an EMI problem providing that adequate precautions are taken to preclude the introduction of stray currents into the ordnance circuitry within the Centaur vehicle. This conclusion is further reinforced by the results of previous Burner II EMI tests which show there have been no EMI problems associated with the destruct ordnance.

The signals issued from Centaur to uncage Burner II gyros, to start the Timer and to initiate separation operate individual latching-type relays to accomplish the respective functions. The relays are shielded and are considered non-sensitive to EMI. Diode suppressors are used to reduce the transient kickback voltage caused by relay operation. The results of EMI tests performed on previous Burner II configurations show that existing wire-routing techniques are adequate to prevent EMI coupling from the relay circuits into adjacent circuits. The Burner II/Centaur timing sequence differs slightly from previous Burner II sequencing in that both gyro uncage and timer start events occur during flight rather than at launch. This difference, however, is not considered to be a problem since the events and subsequent operations have been satisfactorily performed in all phases of the Burner II flight program during previous EMI tests. Considering the lack of EMI sensitivity in the relay circuitry and the consistently satsifactory results achieved in previous Burner II tests, no EMI problems are anticipated in the Gyro Uncage, Timer Start and Burner II Separation interface circuitry.

2.6.2 Grounding

A single-point grounding philosophy is used in the Burner II system. (Figure 2.6-1) A single structural area within the airborne vehicle provides ground referencing for main power, signals and premature separation ordnance power. Single-point grounding is also provided for individual-circuit shields. Overall shields installed on airborne cabling to provide RF protection are multiple grounded. Since Centaur uses a single point ground except for igniters and the recirculating pump, the two-grounding philosophies are examined at the interface to determine possible effects on system operation and to identify potential problem areas.

The addition of another ground on the Disarm, Gyro Uncage, Timer Start and Separation Interface Signal lines will violate the single point ground philosophy used in Burner II. The additional ground will allow currents to flow through Burner II/Centaur structure with two possible results:

1) The differential transient voltage generated by operation of the respective interface circuit will be reduced at the Burner II/Centaur interfaces.

2) The common-mode voltage developed by operation of the respective interface circuit will be increased within both Burner II and Centaur. The additional ground will also have a tendency to increase the overall common-mode EMI within Burner II as a result of Centaur operation. and within Centaur as a result of Burner II operation. The amount of voltage developed will depend on the characteristics of the EMI source and the amount of the common impedance in the respective ground reference lines.

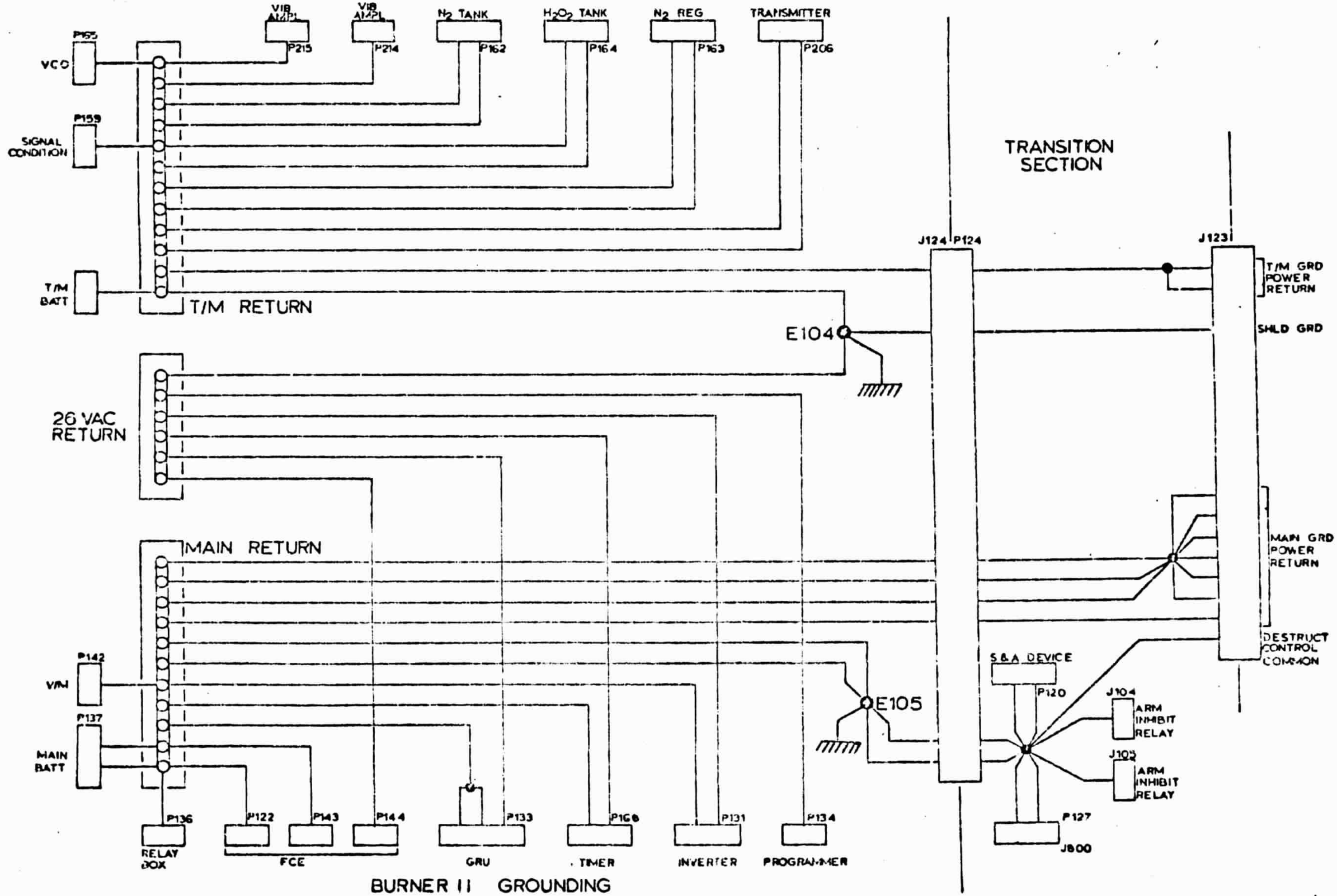

VIB AMPL
VIB AMPL
N2 TANK
H2O2 TANK
N2 REG
TRANSMITTER
P215
P214
P162
P164
P163
P206
P165
VCO
P159
SIGNAL CONDITION
T/M BATT
T/M RETURN
TRANSITION SECTION
J124
P124
J123
T/M GRD POWER RETURN
SHLD GRD
E104
26 VAC RETURN
MAIN RETURN
MAIN GRD POWER RETURN
DESTRUCT CONTROL COMMON
S&A DEVICE
P120
E105
J104
ARM INHIBIT RELAY
J105
ARM INHIBIT RELAY
P127
J800
P142
V/M
P137
MAIN BATT
P136
P122
P143
P144
P133
P166
P131
P134
RELAY BOX
FCE
GRU
TIMER
INVERTER
PROGRAMMER
BURNER II GROUNDING

Figure 2.6-1

The additional ground will not affect the interface circuits within Burner II because of the insensitivity of the latching relays to EMI. The ground will allow relay currents and extraneous EMI currents to flow through the main ground-reference lead in Burner II (Figure 2.6-2). This ground connection however, has been present during previous EMI tests and Burner II-Thor flights and has caused no problems. It is concluded therefore that only a remote chance exists that an EMI problem in Burner II will be caused by the additional grounds.

The Destruct Ordnance Initiate circuit is ungrounded in Burner II. No grounding problems associated with this interface are anticipated.

2.6.3 RF Coupling

The major RF sources aboard Centaur which could affect Burner II operations are:

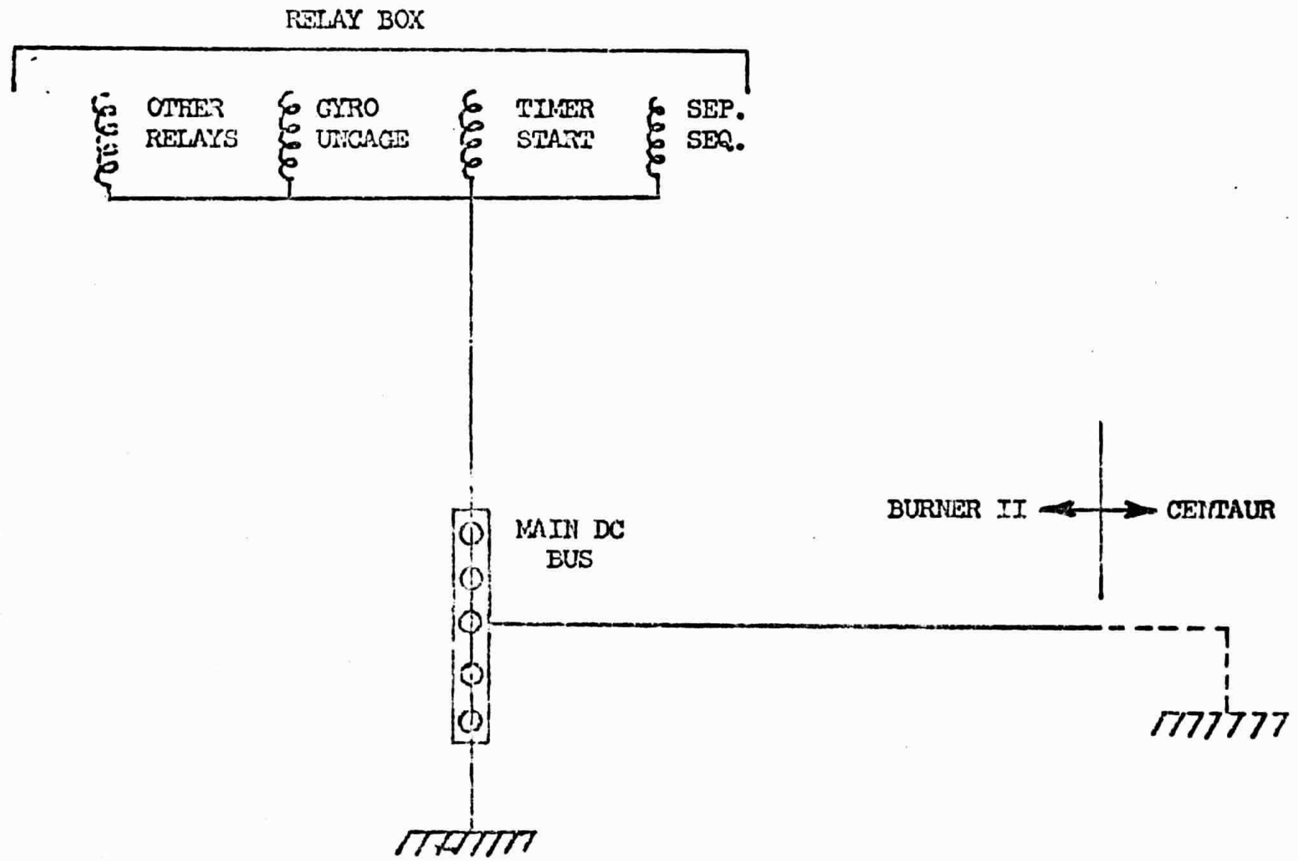
1) S-Band telemetry transmitter;

2) C-Band Transponder.

The radiated power levels from these RF sources anticipated to exist at Burner II were calculated using the data and techniques described in MCR-67-332 Titan III/Centaur Integration Study and antenna spacing information derived from Burner II and NASA drawings (See Figures 2.6-3 and 2.6-4). The results of calculations and anticipated EMI safety margins are shown in Table 2.6-1 and are applicable to the vehicle configuration without a metal heat shield.

Table 2.6-1 shows that an adequate margin of safety exists based on the results of previous RF radiated susceptibility tests performed on Burner II at 2100 MH_z. No burnout or cross-modulation problems are anticipated within the Burner II S-Band telemetry transmitter because of the rejection capability inherent in the transmitter and the relatively low levels of RF power from Centaur.

Operation of the RF subsystems within a metal heat shield will change the antenna coupling factors and will present a changeable power density pattern in the vicinity of Burner II equipment. The probable reaction would be spurious resulting from the presence of overly-high RF levels or mixing of the two S-band frequencies to produce a frequency within the bandwidth of Burner II equipment. RF shielding installed on all Burner II wiring will reduce the probability of a spurious reaction. However, it is anticipated that installation of RF absorbing material within the heat shield in high field regions will completely eliminate the problem.



INTERFACE SIGNAL GROUNDING

Figure 2.6-2

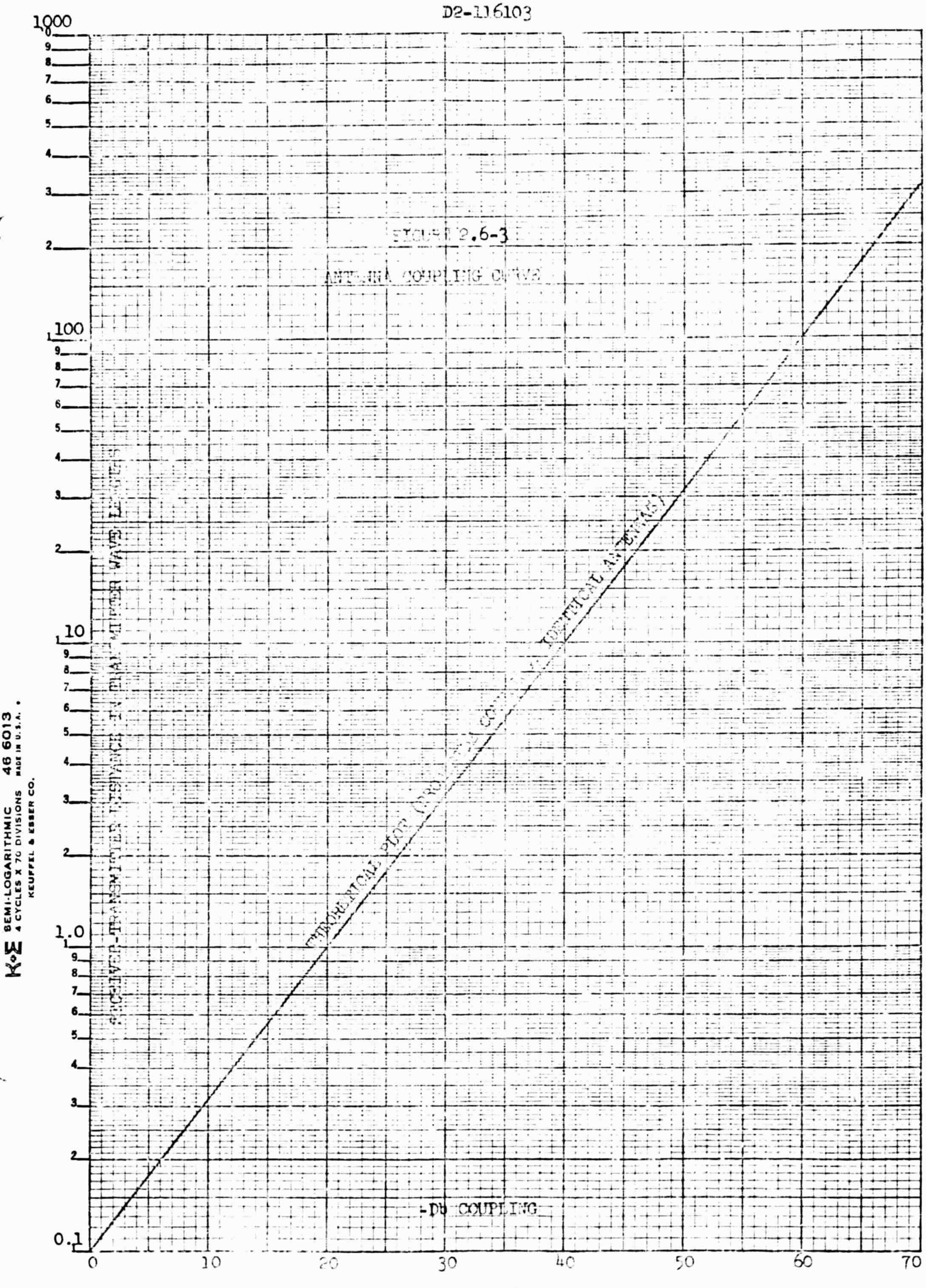


FIGURE 2.6-3
ANTENNA COUPLING CURVE
1000
100
10
1.0
0.1
-Db COUPLING
0
10
20
30
40
50
60
70
K+E SEMI-LOGARITHMIC 46 6013
4 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

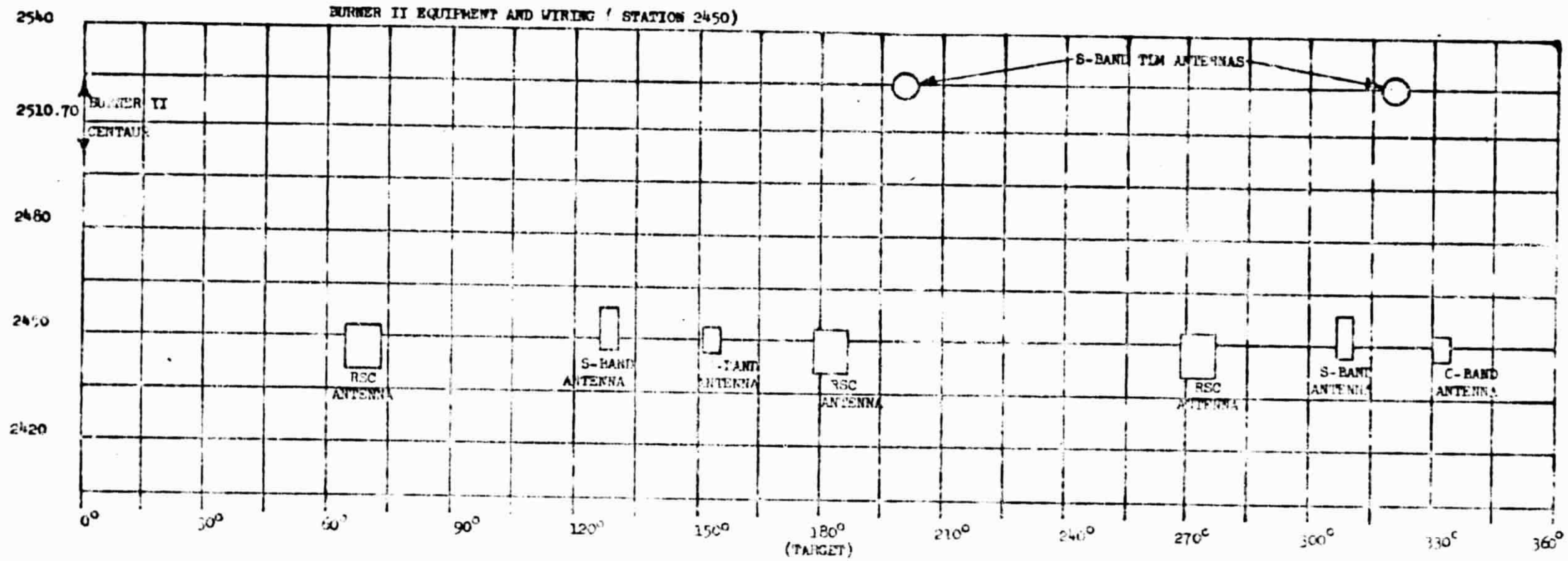


Figure 2.6-4

BURNER II/CENTAUR ROLLOUT DIAGRAM

REFERENCE: NASA DRAWING CR-600334 DATED 7-11-69

TABLE 2.6-1

SUBSYSTEM	CENTAUR XMTR PWR OUPPUT (dBW)	XMTR LINE LOSS (dB)	SEF IN WAVE-LENGTHS	COUPLING (dB)	BII RCVR/XMTR LINE LOSS (dB)	INPUT TO BII	BII RCVR/XMTR SENSITIVITY (dBW)	APPROX SAFETY MARGIN (dB)
S-BAND TLM XMTR TO BII WIRING	13	-	16.2	-24	-	-11	+17*	+28
C-BAND BEACON XMTR TO BII WIRING	27	-	43.9	-33	-	-6	+17*	+23
S-BAND TLM XMTR TO BII S-BAND TLM XMTR	13	-	13.7	-23	-	-10		
C-BAND BEACON XMTR TO BII S-BAND TLM XMTR	27	-	36.1	-31	-	-4		

*2100 MHz INTERFERENCE GENERATOR SPACED ONE METER AWAY

2.7 TASK 7 BURNER II GROUND SUPPORT EQUIPMENT INTEGRATION

This section describes the results of studies conducted under Task No. 7, Ground Support Equipment (GSE) Integration and Task No. 8, Burner II Ground Facilities. These tasks are closely interrelated and have been combined in one section to provide continuity.

The objectives of the studies were:

1. To establish requirements for equipment, facilities, services and software for ETR processing.

2. To determine which requirements can be met by existing equipment designs and ETR facilities.

3. To identify modification requirements to existing equipment designs and facilities.

4. To establish conceptual designs for new GSE.

Emphasis has been placed on the maximum use of existing GSE design and ETR facilities and minimum interference with Improved Centaur/Titan IIID processing. Other basic considerations were the requirements for payload cleanliness and continuous payload environmental control during field processing.

2.7.1 Functional Flow Diagrams.

In order to identify the field tasks necessary to integrate the Burner II with the Centaur/Titan IIID launch vehicle at the ETR, functional flow diagrams covering all field operations to be performed were prepared. First, an overall field processing sequence flow diagram (Figure 2.7-1) was prepared to identify the major tasks and the ETR locations at which they will be performed. Then, based on the overall flow diagram, detailed processing flow diagrams (Figure 2.7-2 through 2.7-13) were prepared to identify all operations which must be performed at the ETR. These flow diagrams were used as a basis for establishing the requirements specified in Section 2.7.2.

2.7.1.1 Overall Field Processing Sequence.

Figure 2.7-1 presents the overal field processing sequence for Burner II ground and airborne equipment at the ETR. The Airborne Vehicle Equipment (AVE) and Aerospace Ground Equipment (AGE) will be received and inspected at an ETR receiving area and transported to usage areas such as the Explosive Safe Area (ESA) or launch pad when needed. The receiving area for the Burner II solid rocket motor and ordnance devices will be the ETR Solid Propellants Area.

Two complete sets of non-portable Launch Control and Checkout Equipment (LCCE) will be installed at the ETR. One set will be installed at the Burner II checkout area for initial testing of the Burner II before rocket motor installation and payload mating. The other LCCE installation will consist of a Launch Control Console installed in the Vertical Integration Building (VIB) and a Launch Support Rack (LSR) and Guidance

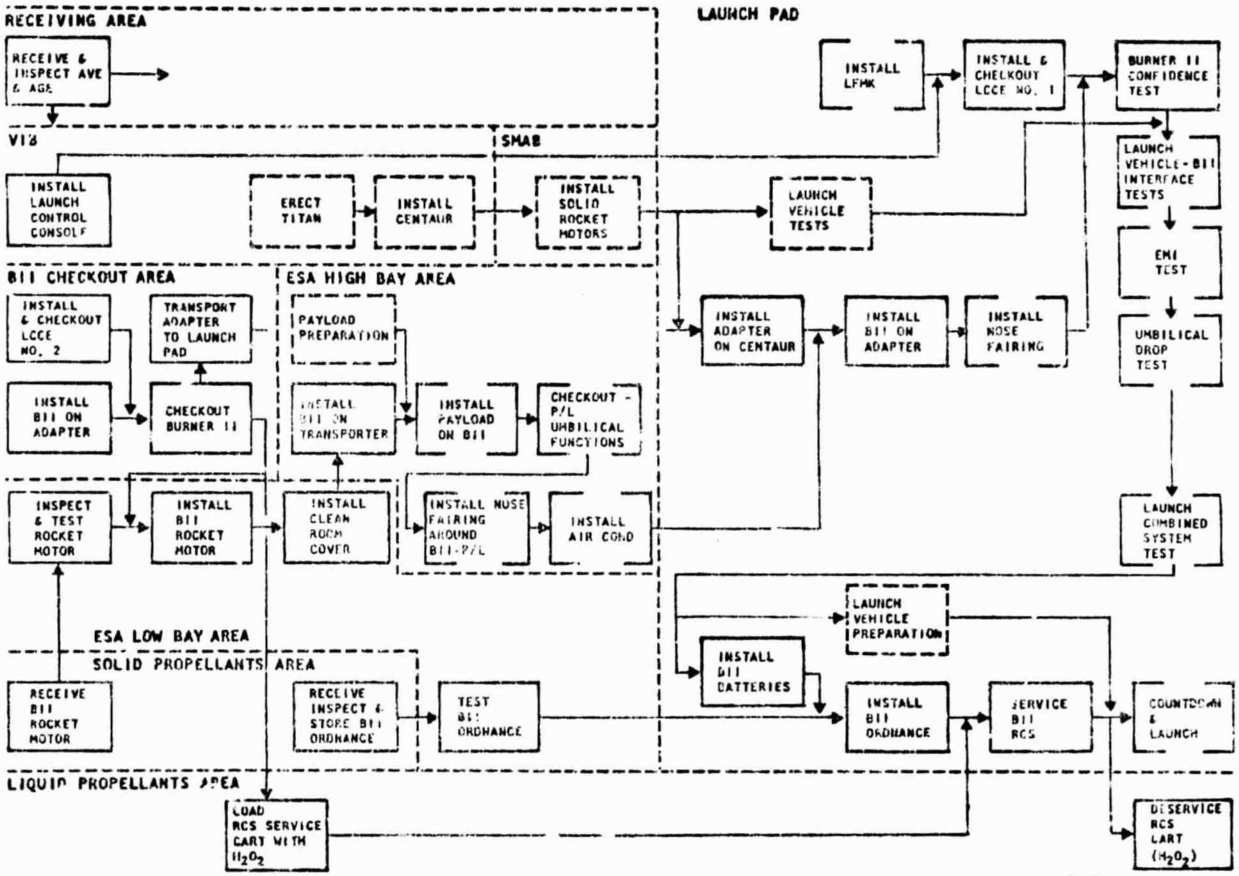


FIGURE 2.7-1: FIELD PROCESSING FLOW DIAGRAM

and Control Test Set (G&C T/S) installed in the AGE Building at the Launch pad. After necessary launch facility modification and LCCE installation are completed, the LCCE will be calibrated and checked out prior to first usage with the Burner II vehicle.

The Burner II Structure and Equipment Assembly (S&EA) and Burner II/Centaur adapter will be transported to the Burner II checkout area where they will be mated and checked out together. Burner II checkout will consist of the following tests:

1. Power and Distribution:

   Verification and adjustment of ground power supply voltages. Verification of LCC indicators and switching capability and verification of vehicle power transfer function and subsystem activation.

2. Guidance and Control (G&C) Subsystem

   Gyro Drift Test, Slew Phasing Test, Reaction Control Subsystem Phasing Test, Torquing Voltage Test. Flight Timer Timing Test and Flight Mode Switching Test.

3. Reaction Control Subsystem (RCS)

   RCS Phasing Test (combined with G&C Test) and RCS Leak Test (3200 PSIG)

4. Telemetry Subsystem:

   Closed loop Channel by channel verification test with S-Band Telemetry Station.

5. Interfaces:

   Burner II/Centaur Interface Test and Burner II/Payload Interface Test using simulators.

After completion of Burner II checkout, Burner II/Centaur adapter will be removed and transported to the launch pad for installation on the launch vehicle and the S&EA will be transported to the ESA low bay area for rocket motor installation. After rocket motor installation, the Burner II will be enclosed in a clean cover, moved to the ESA high bay clean room and installed on an assembly fixture/transporter. The payload will then be installed on the Burner II and the umbilical functions which pass through the Burner II will be verified by the payload contractor. Next, the nose shroud and payload encapsulation barrier will be installed around the Burner II and payload and the assembly transported to the launch pad. After the Burner II/Centaur adapter has been installed on the Centaur, the Burner II and nose shroud will be mated to the Burner II/Centaur adapter and lower shroud section respectively. Burner II confidence tests (abbreviated Burner II checkout) will then be performed followed by verification of Burner II/Centaur interface compatibility.

For the first launch, the Burner II will then be subjected to an EMI test, umbilical drop test, and Combined System Test in conjunction with the launch vehicle. For second and on launches the Burner II will only be subjected to a Combined System Test with the launch vehicle after the interfaces have been verified. After the Combined System Tests the Burner II vehicle will be serviced for launch which includes battery and ordnance installations and reaction control system srrvicing.

2.7.1.2 Detailed Functional Flow Diagrams.

Figures 2.7-2 and 2.7-3 presnt the detailed processing flow diagrams which were developed from the overall processing sequence (Figure 2.7-1). The processing operations identified in the detailed flow diagrams were used to establish the requirements presented in Section 2.7.2 for equipment, services, facilities and launch pad modifications at the ETR.

Figure 2.7-2 presents the category numbering system, 1.0 through 4.0, which is used for organization of the following detailed diagrams. Categories 3.0 and 4.0 are the areas of primary concern and are therefore the ones for which processing diagrams have been prepared. Blocks with interrupted sides indicate reference operations which are part of other diagrams. An asterisk (*) after a block number indicates that a separate, more detailed flow diagram is provided.

2.7.2 Requirements.

Based on the functional flow diagrams presented in Section 2.7.1, requirements for Equipment, Expendables, Services, Facilities, and Launch Facility Modifications for ETR operations have been identified and are presented separately in this section. Also, identified is the software data required for Burner II operations at the ETR. The requirements identified were compared against existing equipment designs, facilities and documentation and new designs were specified only where existing designs could not be used as-is or modified to meet established requirements. Existing equipment which will be used as-is or modified is described in this section. Conceptual designs for new equipment are presented in Section 2.7.3.

2.7.2.1 Mechanical Ground Support Equipment.

The mechanical GSE required for ETR operations is listed in Table 2.7-1. It includes handling and transportation equipment, special tools, work platforms, miscellaneous fixtures and Reaction Control Subsystem Servicing Equipment. The major items for existing design equipment which will be used with little or no modifications are:

1. Pneumagrip - A device for handling and rotating the Burner II Solid Rocket Motor by pneumatically gripping the motor around its periphery.

2. S&EA Installation Stand - A fixture designed to support the Rocket Motor, or Burner II Structure and Equipment Assembly separately or together during and after rocket motor installation.

CENTAUR/BURNER II PRELAUNCH FUNCTIONAL FLOW - ETR

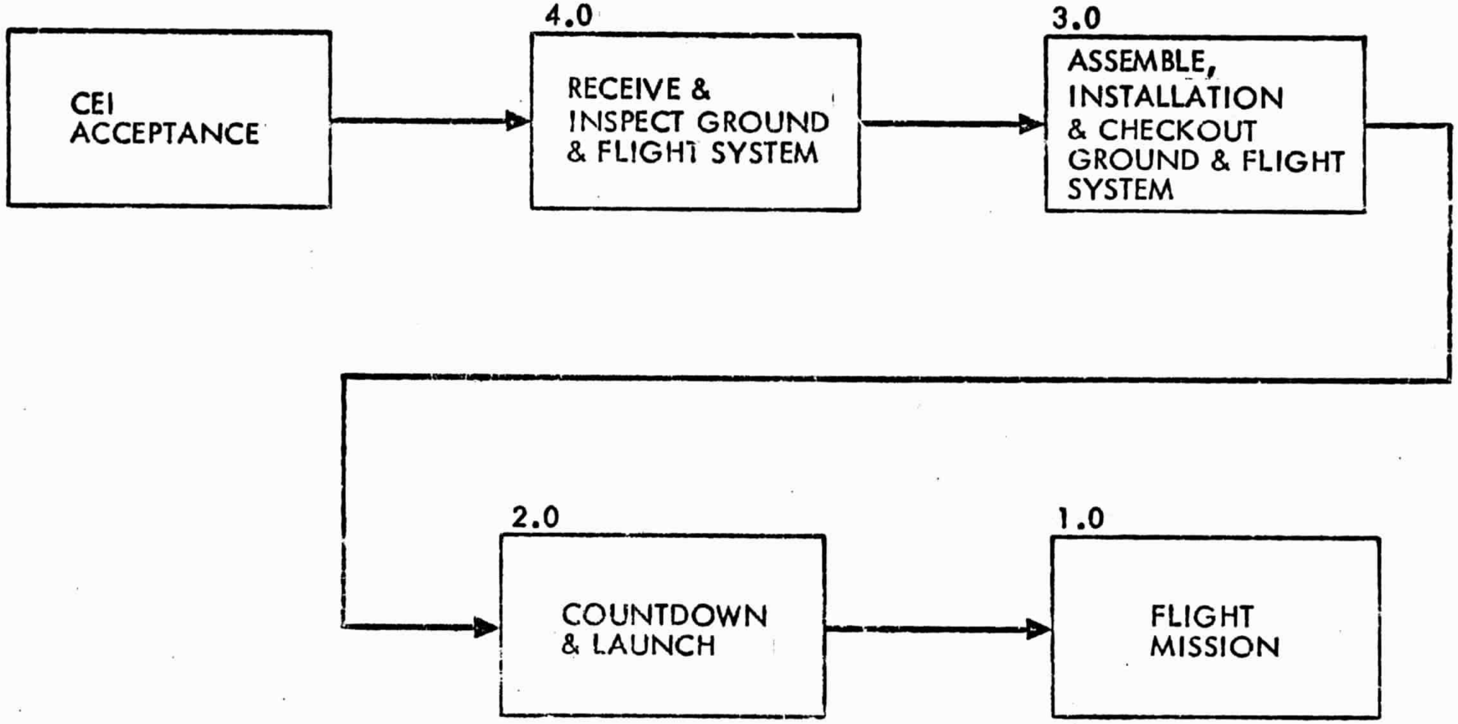
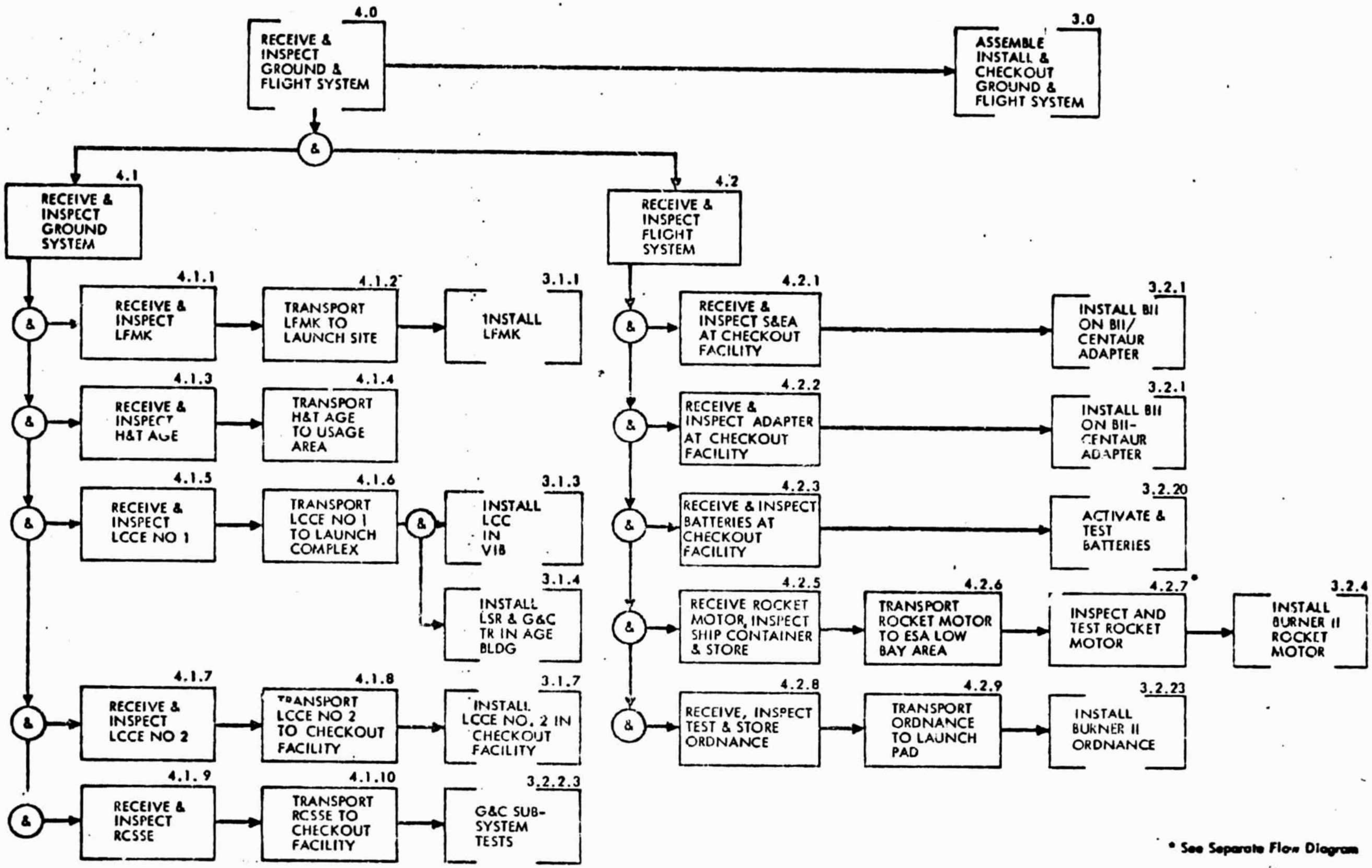
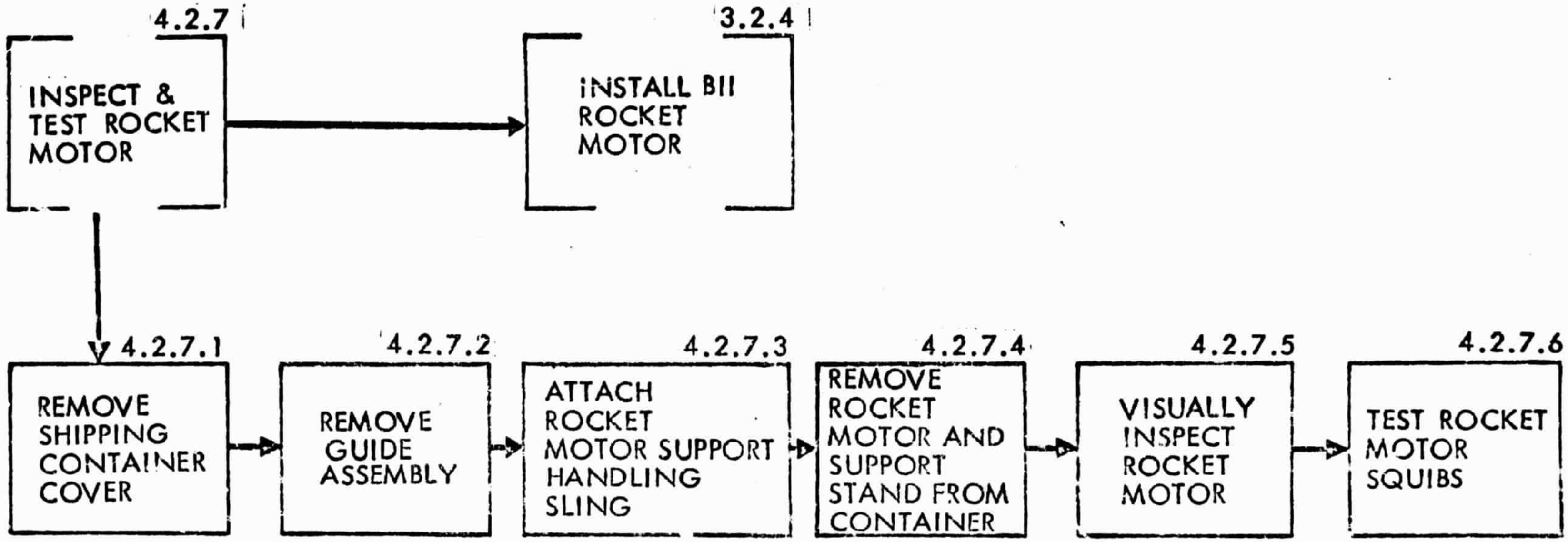


FIGURE 2.7-2

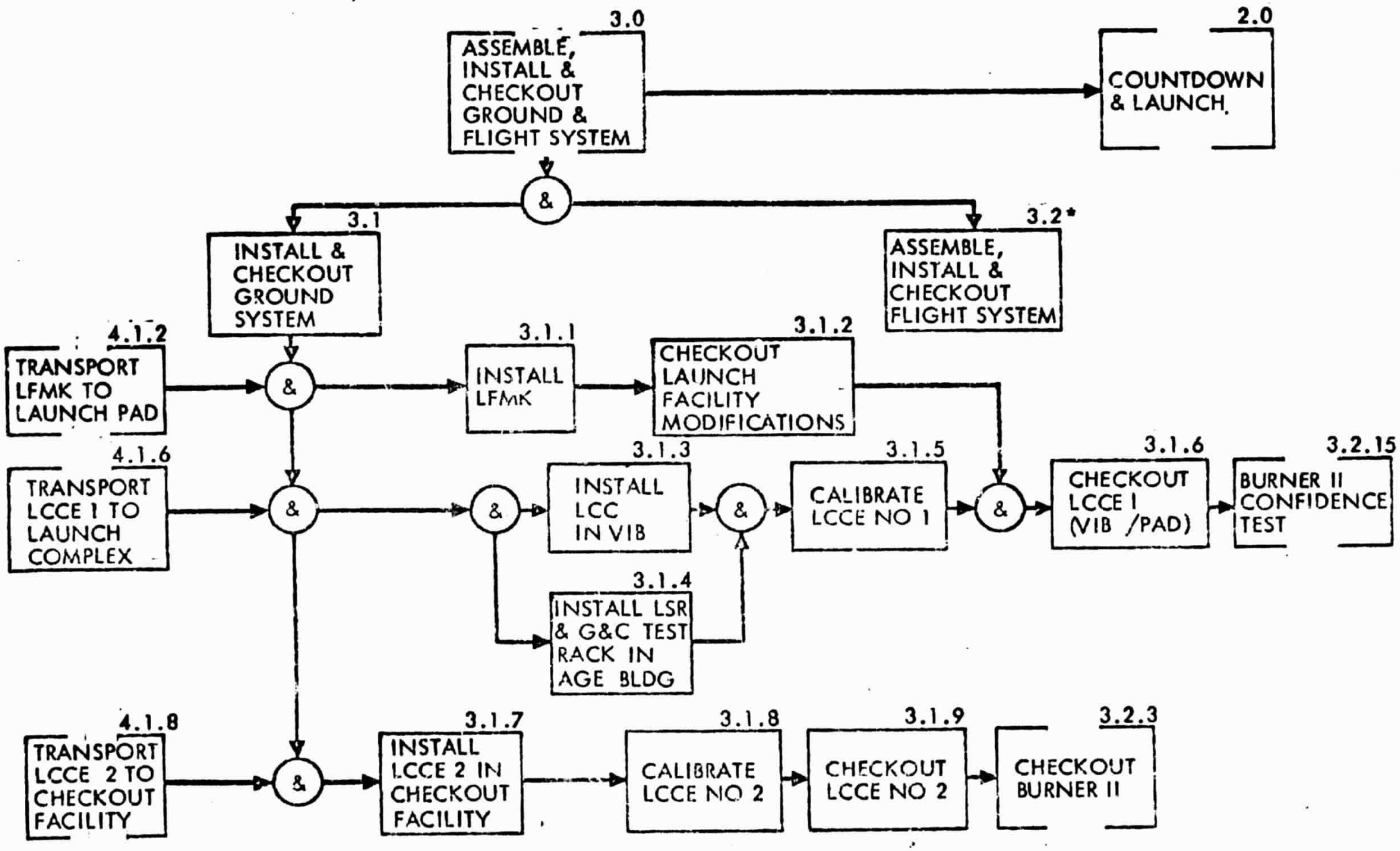


2.7-3: FUNCTIONAL FLOW 4.0, RECEIVE & INSPECT GROUND & FLIGHT SYSTEM



FUNCTIONAL FLOW 4.2.7 INSPECT & TEST ROCKET MOTOR

FIGURE 2.7-4



*See Separate Flow Diagram

Figure 2.7-5 FUNCTIONAL FLOW 3.0, ASSEMBLE, INSTALL & CHECKOUT GROUND & FLIGHT SYSTEM

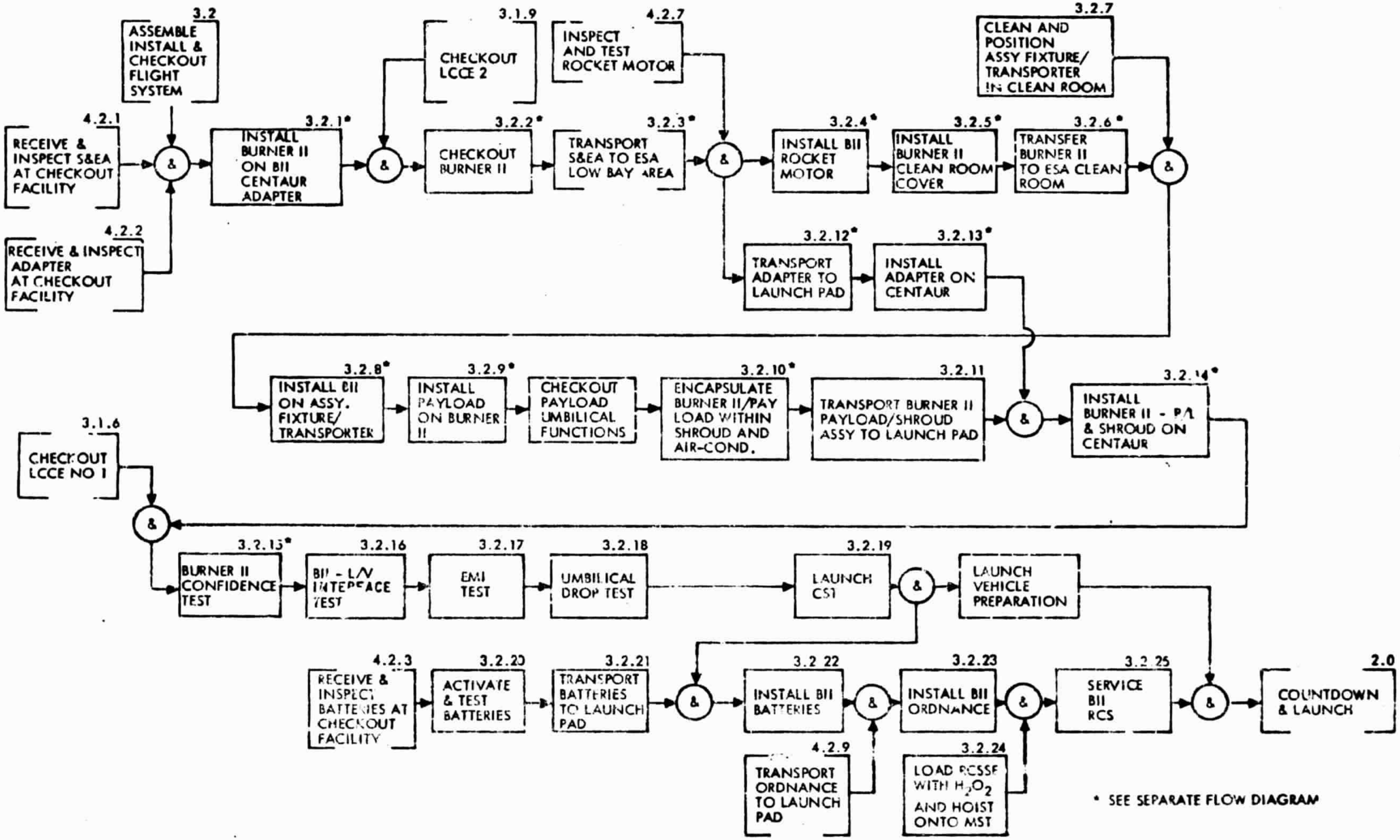


FIGURE 2.7-6
FUNCTIONAL FLOW 3.2, ASSEMBLE, INSTALL & CHECKOUT FLIGHT SYSTEM

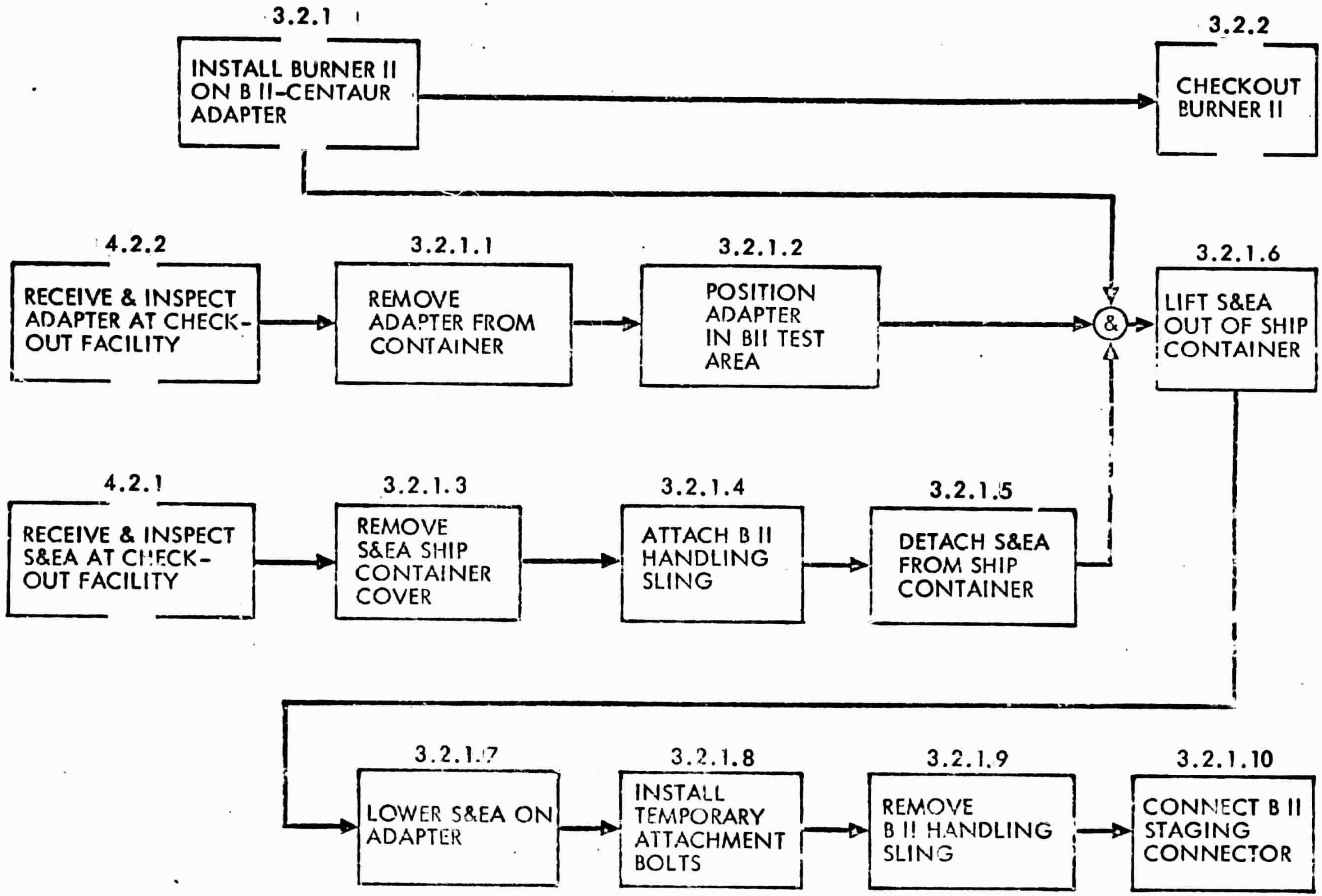


Figure 2.7-7 FUNCTIONAL FLOW 3.2.1, INSTALL BURNER II ON BII/CENTAUR ADAPTER

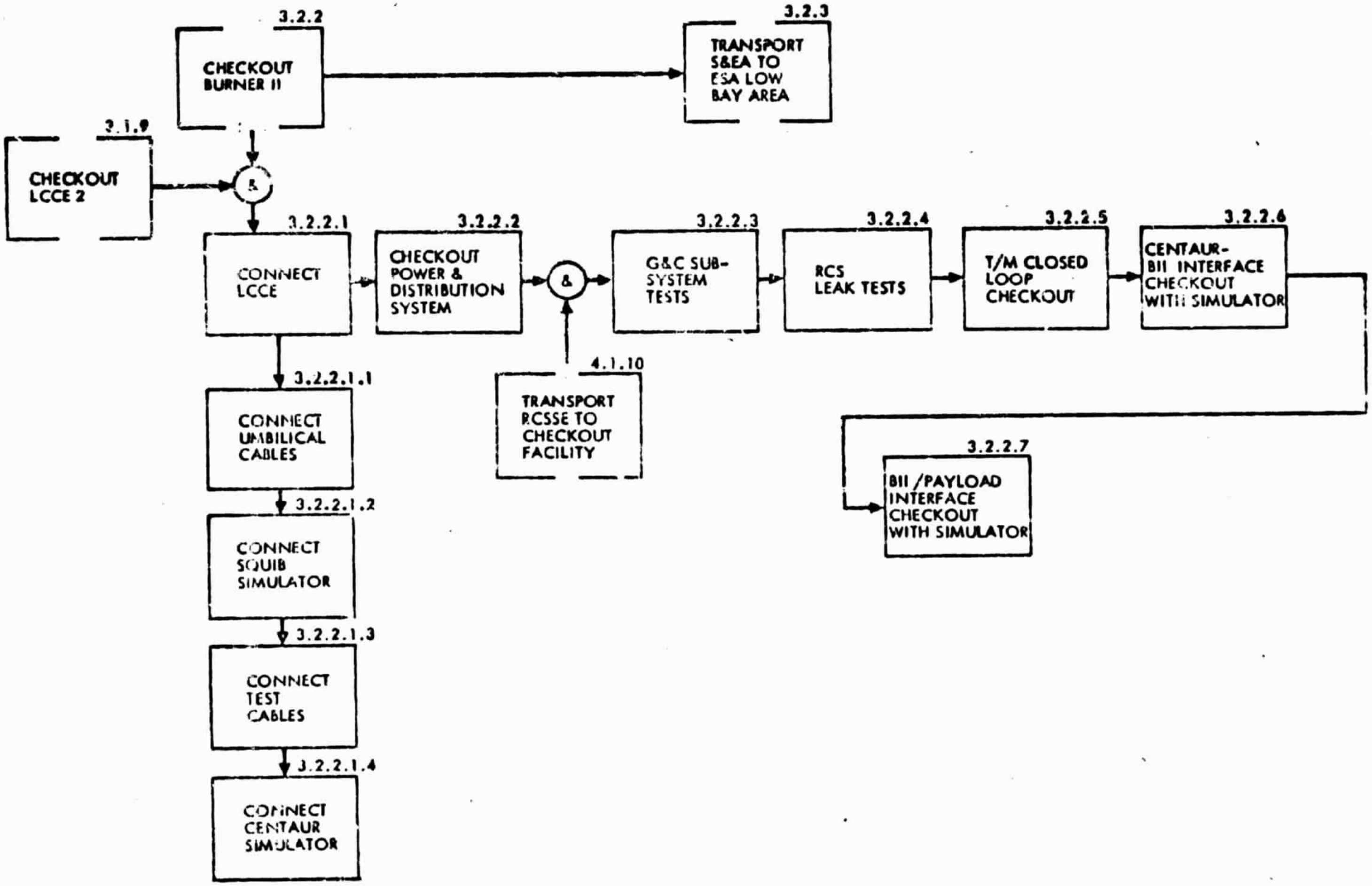


FIGURE 2. 7-8: FUNCTIONAL FLOW 3.2.3, CHECKOUT BURNER II

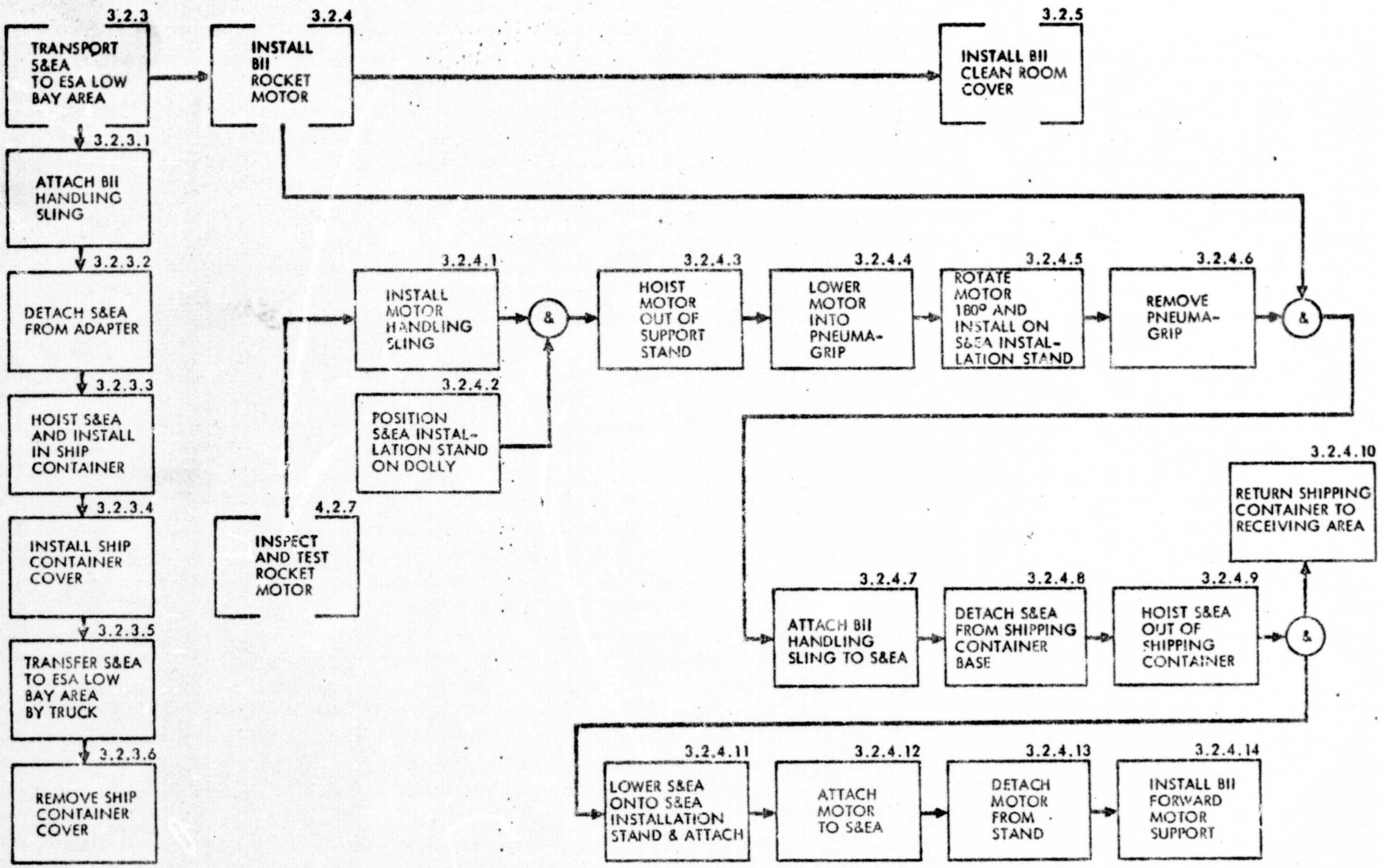


FIGURE2. 7-9: FUNCTIONAL FLOW 3.2.3 AND 3.2.4, TRANSPORT S&EA AND INSTALL ROCKET MOTOR

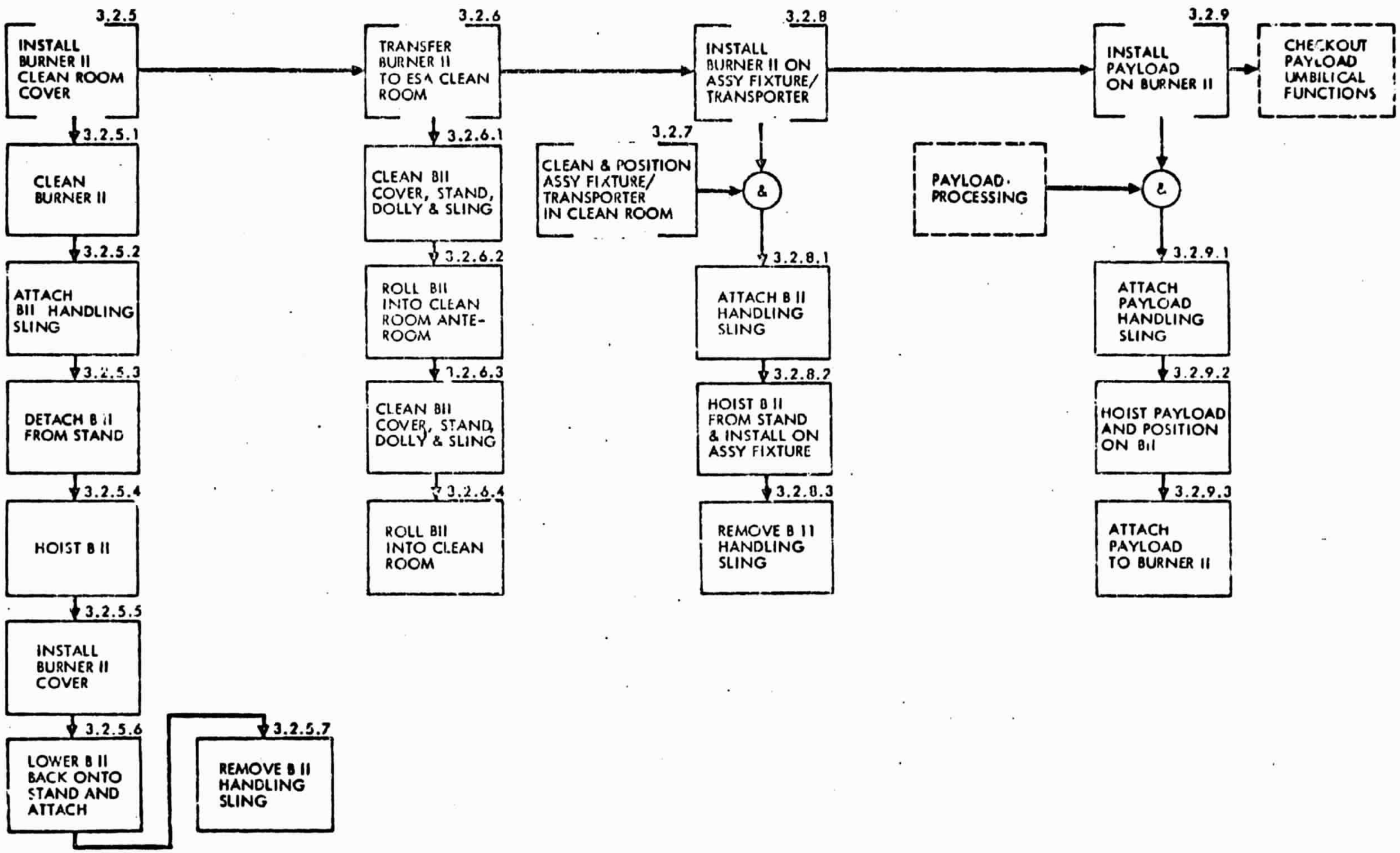


FIGURE 2.7-10: FUNCTIONAL FLOWS 3.2.5, 3.2.6, 3.2.8 AND 3.2.9, INSTALL COVER, TRANSFER, INSTALL ON TRANSPORTER AND INSTALL PAYLOAD

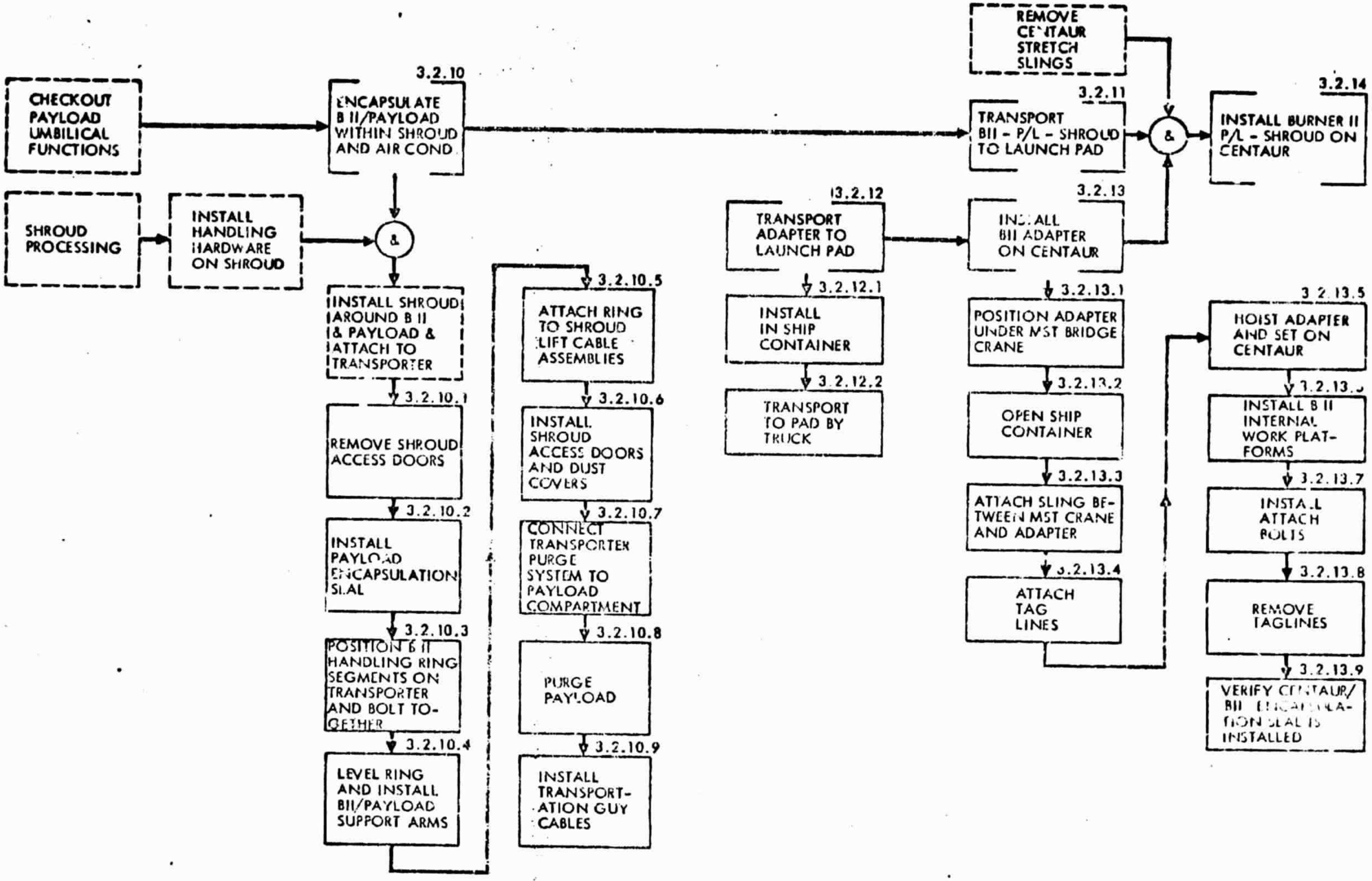


FIGURE 2.7-11: FUNCTIONAL FLOWS 3.2.10 THRU 3.2.13, ENCAPSULATE, TRANSPORT ADAPTER & BURNER II TO PAD AND INSTALL ADAPTER ON CENTAUR

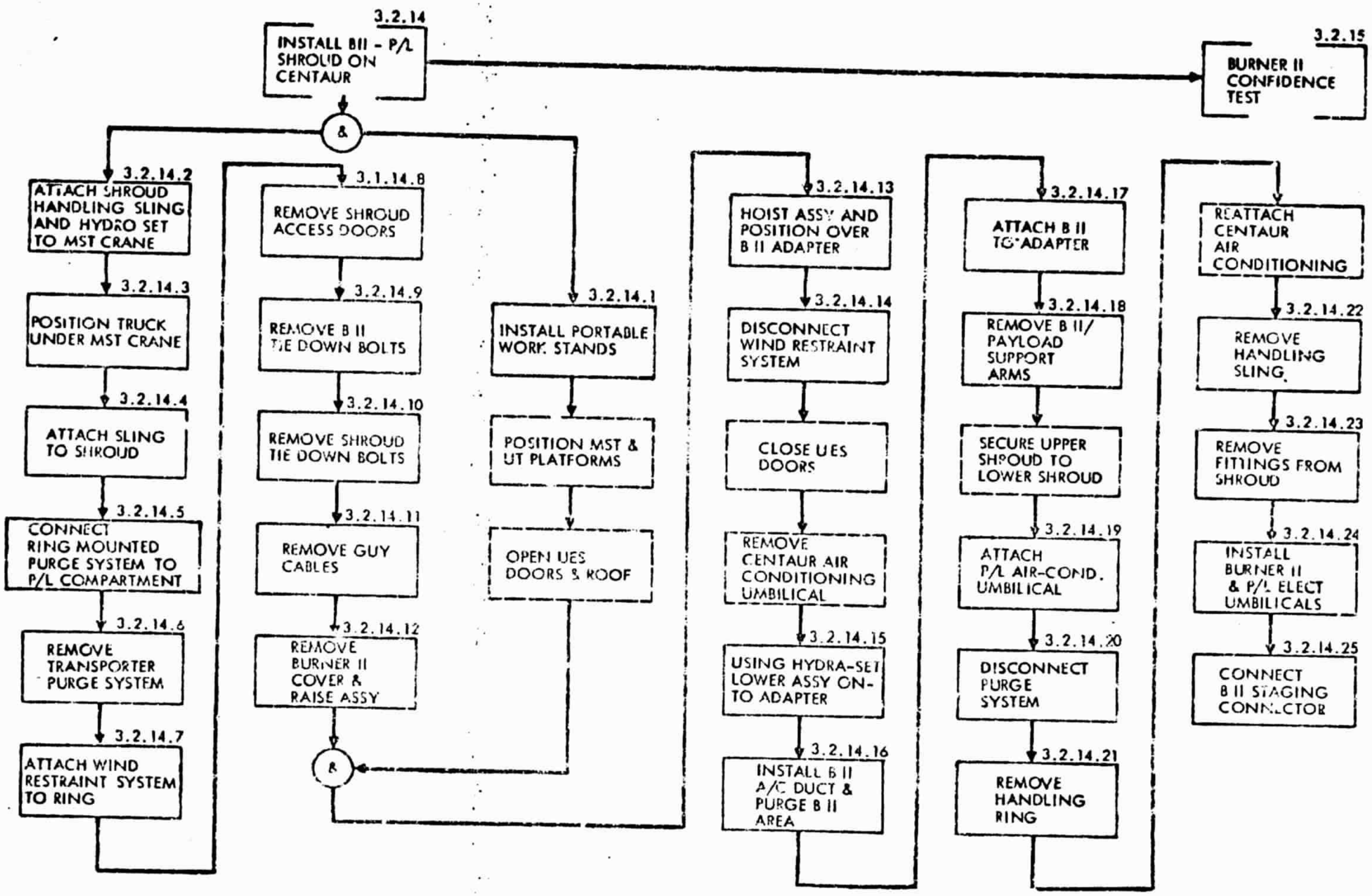


FIGURE 2.7-12: FUNCTIONAL FLOW 3.2.14, INSTALL BURNER II PAYLOAD-SHROUD ON CENTAUR

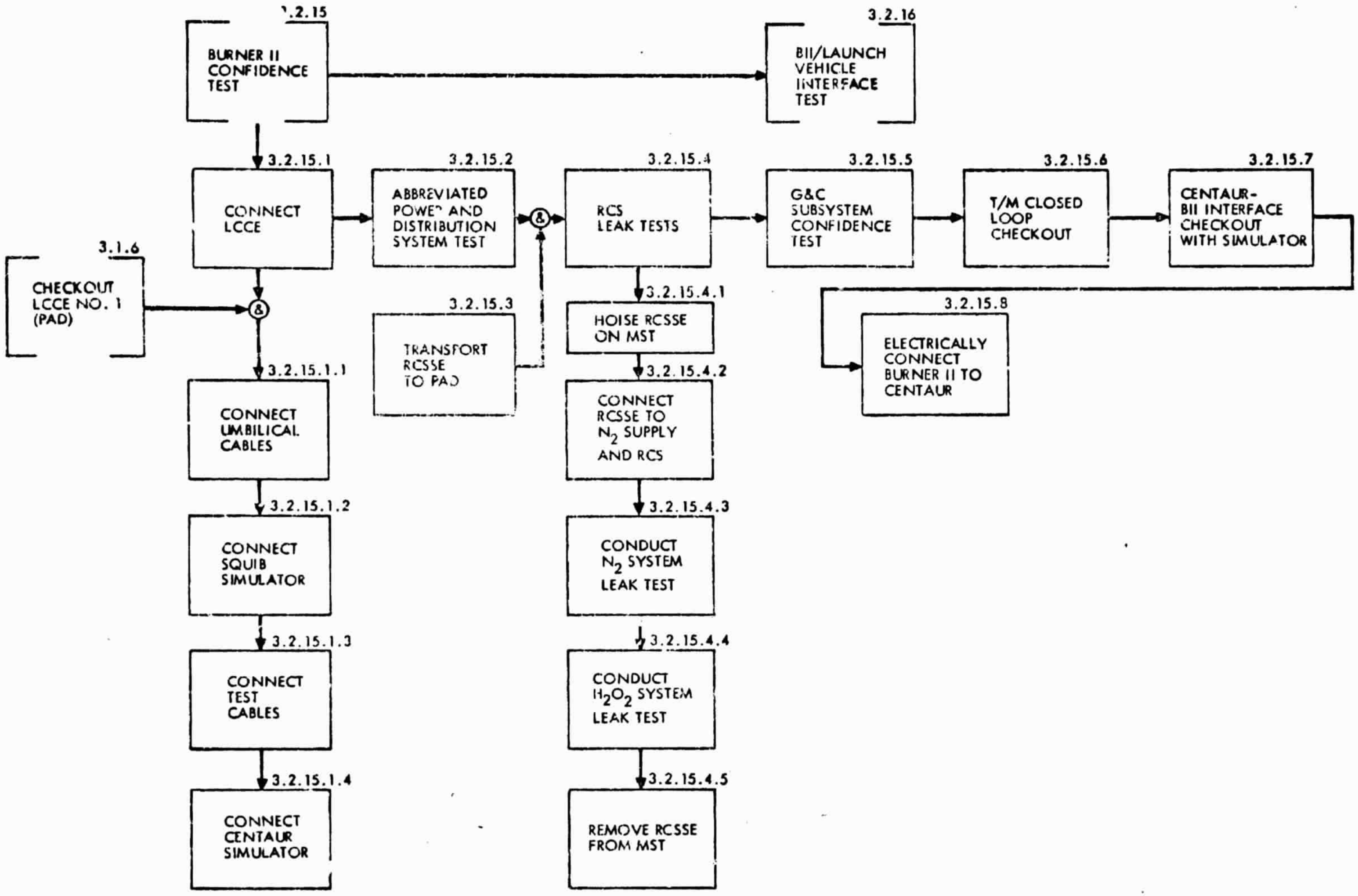


FIGURE 2.7-13
FUNCTIONAL FLOW 3.2.15, BURNER II CONFIDENCE TEST

MECHANICAL GROUND SUPPORT EQUIPMENT REQUIREMENTS

		EXISTING DESIGN	MODIFIED EXISTING DESIGN	NEW DESIGN	GFE
A.	ROCKET MOTOR SHIPPING CONTAINER	X			
B.	BURNER II SHIPPING CONTAINER		X		
C.	ADAPTER SHIPPING CONTAINER		X		
D.	HANDLING SLING - ROCKET MOTOR (25-53704)	X			
E.	PNEUMAGRIP (PRESRAY CORP. NO. PR1602-1)	X			
F.	S&EA INSTALLATION STAND (25-53789-1)	X			
G.	BURNER II HANDLING SLING	X			
H.	BURNER II TRANSFER DOLLY			X	
I.	BURNER II CLEAN ROOM COVER			X	
J.	ASSEMBLY FIXTURE/TRANSPORTER			X	
K.	HANDLING RING - BURNER II			X	
L.	HANDLING RING SLING (BRIDLE)			X	
M.	HANDLING SLINGS (MISCELLANEOUS)	X			
N.	LIFT CABLE ASSEMBLIES (4)			X	
O.	PAYLOAD ENCAPSULATION SEAL TOOL			X	
P.	SHROUD/BURNER II/PAYLOAD HANDLING SLING			X	
Q.	HYDRA SET (10 TON WITH REMOTE CONTROL)				X
R.	INTERNAL WORK PLATFORMS (24 SEGMENTS INSIDE THE SHROUD)			X	
S.	PORTABLE WORK PLATFORMS (10 SECTIONS IN THE MOBILE SERVICE TOWER AROUND EXTERIOR OF VEHICLE)			X	
T.	REACTION CONTROL SUBSYSTEM GSE				
	1. SERVICING EQUIPMENT (RCSSE) CART	X			
	2. MISC. SERVICING EQUIPMENT	X			
	3. DRIP PAN, RCSSE CART	X			

TABLE 2.7-1

MECHANICAL GROUND SUPPORT EQUIPMENT REQUIREMENTS

		EXISTING DESIGN	MODIFIED EXISTING DESIGN	NEW DESIGN	GFE
T.	REACTION CONTROL SUBSYSTEM GSE (CONT.)				
	4. H_2O_2 OVERBOARD DRAIN KIT		X		
	5. H_2O_2 SERVICING SCUPPER		X		
	6. PROTECTIVE CLOTHING, H_2O_2				X
	7. HANDLING SLING, RCSSE CART	X			
U.	TRUCKS, PICKUP, FLATBED AND TRACTOR				
V.	FORKLIFT				
W.	MOBILE CRANE				X
X.	PERSONNEL TRANSPORTATION VEHICLES				X
Y.	VACUUM CLEANER				X
Z.	GROUND CABLES AND TAG LINES				X
AA.	HARD HATS AND LEG STATS				X
AB.	STANDARD WORK PLATFORMS AND STEP LADDERS				X
AC.	PROTECTIVE CLOTHING, BATTERY SERVICING				X
AD.	PAYLOAD INTERFACE SIMULATOR				X
AE.	BURNER II SPIN BALANCE ADAPTER	X			
AF.	WIND RESTRAINT SYSTEM (LAUNCH PAD)				X

TABLE 2.7-1 (Continued)

3. Reaction Control Subsystem Servicing Equipment (RCSSE) Cart
   Servicing equipment for supplying N_2 pressure to the Burner II RCS during Burner II RCS leak tests, Burner II checkout and for N_2 system pressurization and H_2O_2 fueling during launch operations.

Concepts for new equipment designs are presented in Section 2.7.3.2.

2.7.2.2 Launch Control and Checkout Equipment.

Burner II Launch Control and Checkout Equipment (LCCE) provides for complete functional checkout of the Burner II prior to launch and for monitoring and control of the Burner II during the launch countdown.

LCCE required for Burner II ETR operations is listed in Table 2.7-2. Existing major equipment designs which require little or no modification are as follows:

1. Launch Control Console (LCC) which provides monitoring and control of the Burner II subsystems during Burner II checkout and launch operations. The LCC is shown in Figure 2.7-14.

2. Launch Support Rack (LSR) which provides Burner II ground power and control and monitor interfaces between the Burner II and the LCC. The LSR is shown in Figure 2.7-14.

3. Guidance and Control Test Set (G&C T/S) which provides checkout capability of the Burner II Guidance and Control Subsystem including Gyro drift tests, Timer timing tests and Reaction Control Subsystem Phasing tests. The G&C T/S is shown in Figure 2.7-15.

4. Telemetry (T/M) Test Set (S-Band)-A portable test set which provides the capability to calibrate individual high level voltage controlled oscillators, makes RF power and antenna signal strength measurements and assist in trouble-shooting of the data channels. The T/M test set is shown in Figure 2.7-16.

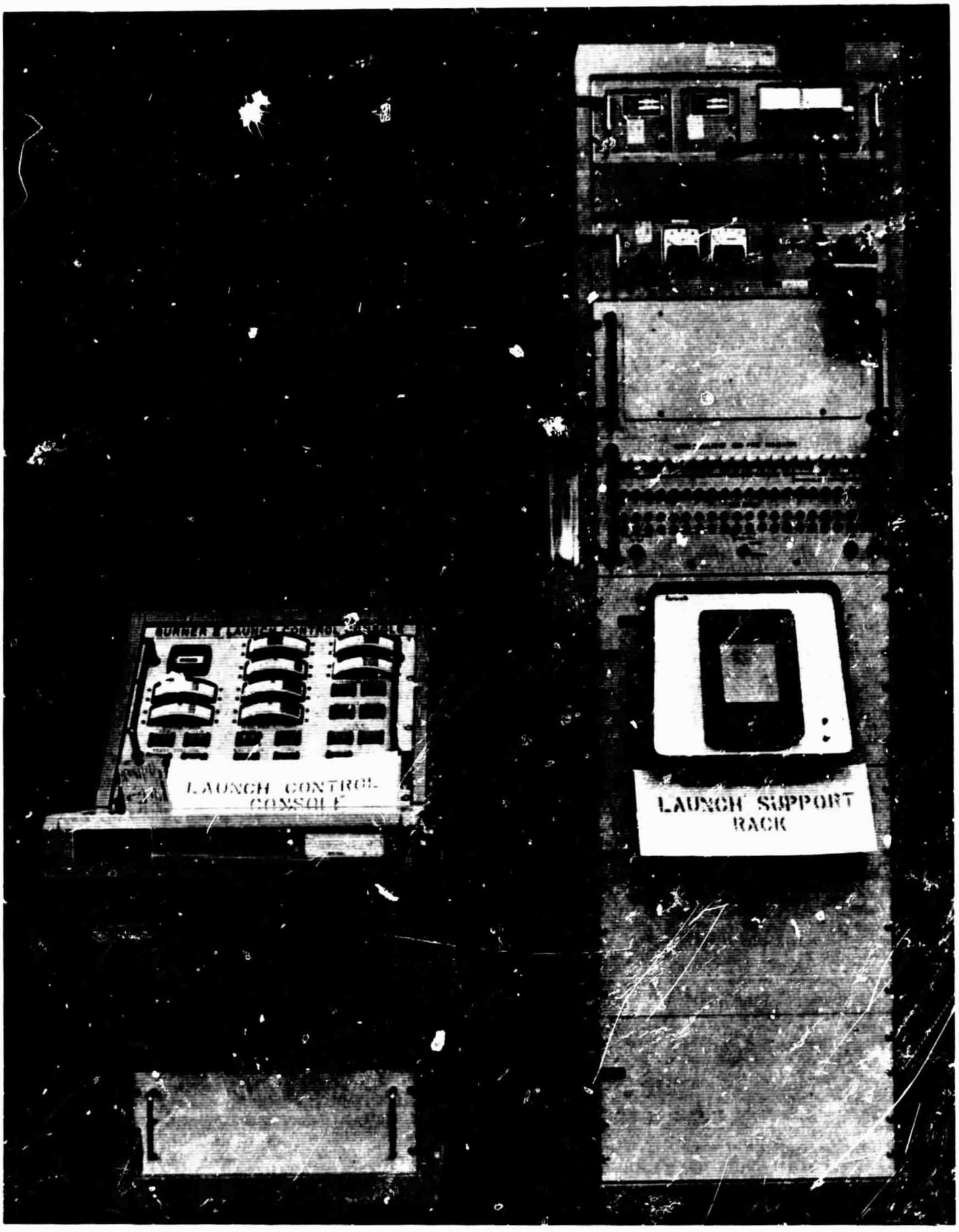
Existing designs which will require modification are interconnecting cabling (length, conductor size and number and connector types) for launch pad installation and a Squib Simulator. The Squib Simulator is a portable tester which indicates the occurrance of firing currents on any squib line and monitors the destruct firing line for stray current during countdown. The existing Squib Simulator design will be modified as required to delete or add circuit breakers, indicators and test jacks.

Two new LCCE designs will be required, a Burner II/Centaur Simulator and a Payload Simulator, which are discussed in Section 2.7.3.4.

LAUNCH CONTROL AND CHECKOUT EQUIPMENT (LCCE) REQUIREMENTS

		EXISTING DESIGN	MODIFIED EXISTING DESIGN	NEW DESIGN	GFE
A.	LAUNCH CONTROL CONSOLE (LCC)	X			
B.	LAUNCH SUPPORT RACK (LSR)	X			
C.	GUIDANCE AND CONTROL TEST SET (G&C T/S)	X			
D.	TELEMETRY (T/M) TEST SET (S-BAND)	X			
E.	MISC LCCE CHECKOUT EQUIPMENT -BREAKOUT BOXES, TEST LEADS, RESISTORS, ETC.	X			
F.	ORDNANCE SIMULATORS (FUSES)	X			
G.	IGNITER TEST SET ADAPTERS	X			
H.	CABLE SET		X		
I.	BURNER II/CENTAUR SIMULATOR			X	
J.	DC POWER SUPPLY	X			
K.	SQUIB SIMULATOR		X		
L.	BATTERY ACTIVATION & TEST EQUIPMENT	X			
M.	IGNITER TEST SET				X
N.	BONDING RESISTANCE TESTER (ALINCO)				X
O.	TEST RACK TO FACILITY GROUND CABLES				X
P.	PAYLOAD SIMULATOR			X	
Q.	SAFE AND ARM DEVICE TEST SET (A/E-24T-40)				X
R.	COMMUNICATIONS EQUIPMENT - LAUNCH SITE				X
S.	TELEMETRY CLOSED LOOP HARDLINE - LAUNCH SITE				X

TABLE 2.7-2



LAUNCH CONTROL CONSOLE LAUNCH SUPPORT RACK

FIGURE 2.7-14

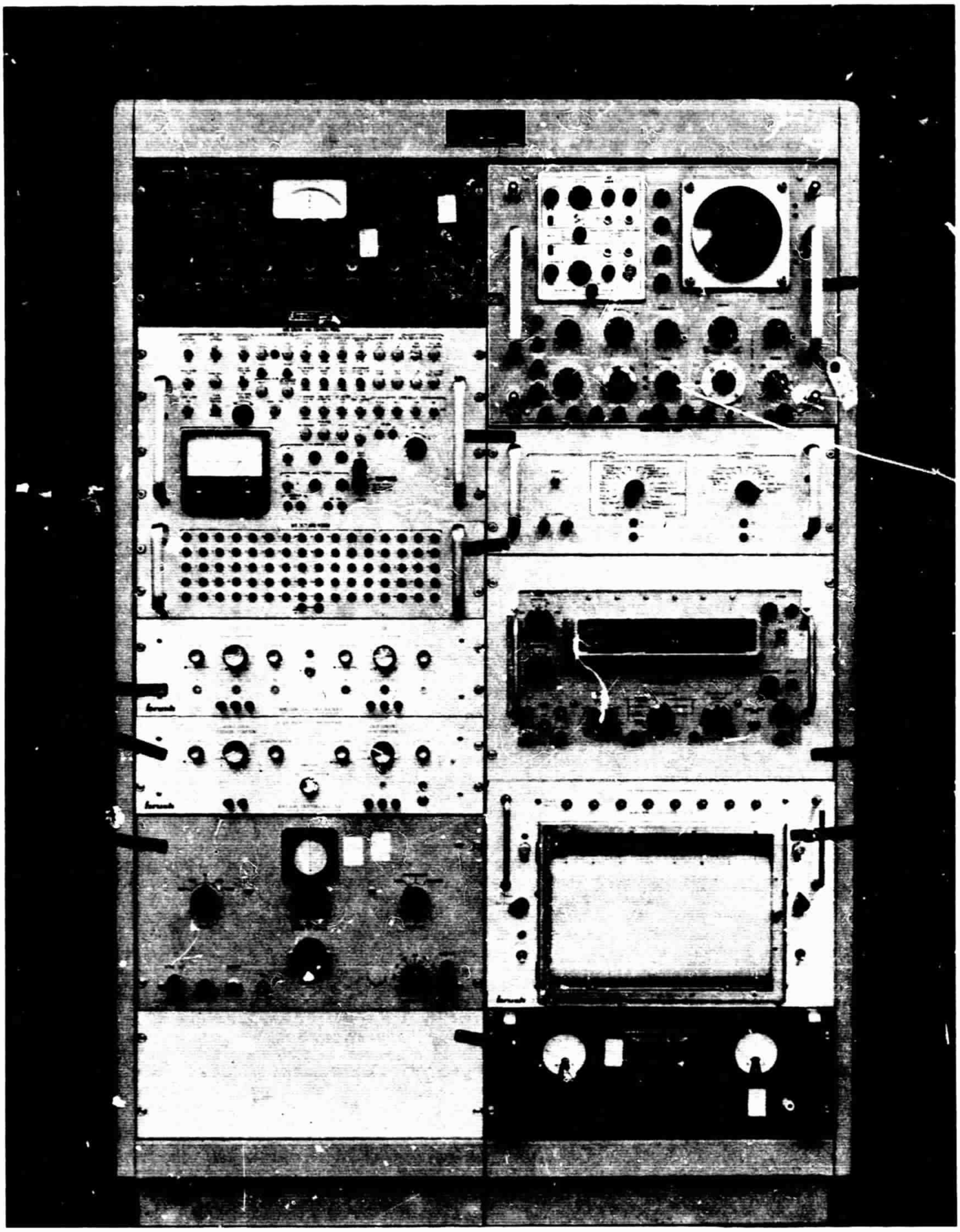


Figure 2.7-15: GUIDANCE & CONTROL TEST SET

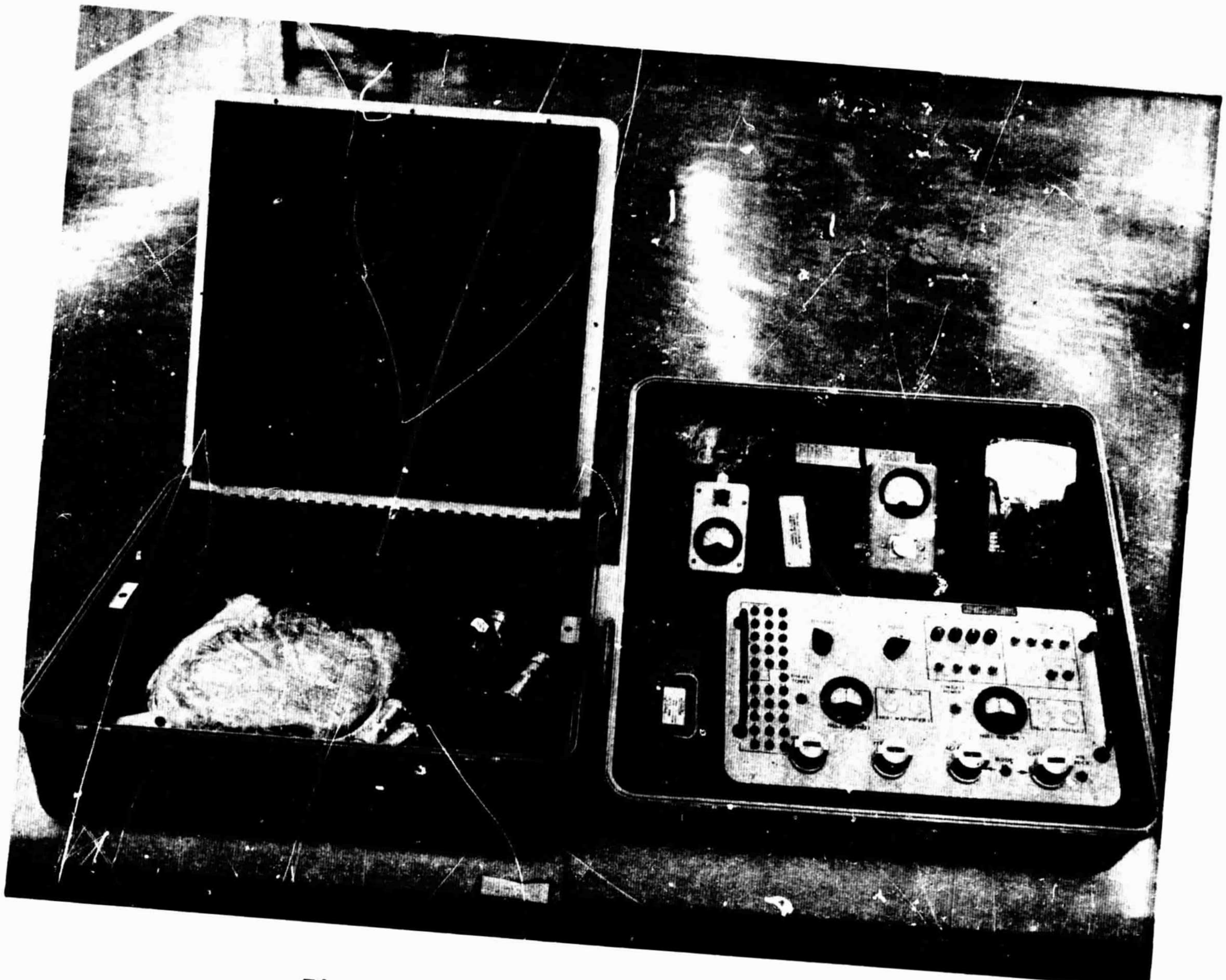


Figure 2.7-16: TELEMETRY TEST SET

Interconnection requirements for the launch area LCCE installation are shown in Figure 2.7-17. The umbilical cable junction box and all permanently installed cables between LCCE and the UT junction box or DTS will be supplied in the Launch Facility Modification Kit (Section 2.7.2.6). The signals which must be transmitted between the LCCE and LSR through the Data Transmission Set are shown in Figure 2.7-18. This study is based on the capability of transmitting analog signals which are used for Burner II go-no-go launch criteria through the DTS non-decision making signal channels. Additional threshold sensing equipment and LCC indicator modification would be required to provide this go-no-go data through the DTS decision making signal channels.

2.7.2.3 Services.

Requirements for Government Furnished Services at the ETR for Burner II operations are listed in Table 2.7-3.

2.7.2.4 Facilities.

Requirements for Government Furnished Facilities at the ETR for Burner II processing and launch operations are described in Table 2.7-4. The major requirement for new (non-existant) facilities is for a high bay clean room at the ESA for assembling the Burner II, payload and shroud nose section on an assembly fixture/transporter as described in Section 2.7.3.2.

2.7.2.5 Launch Facility Modification.

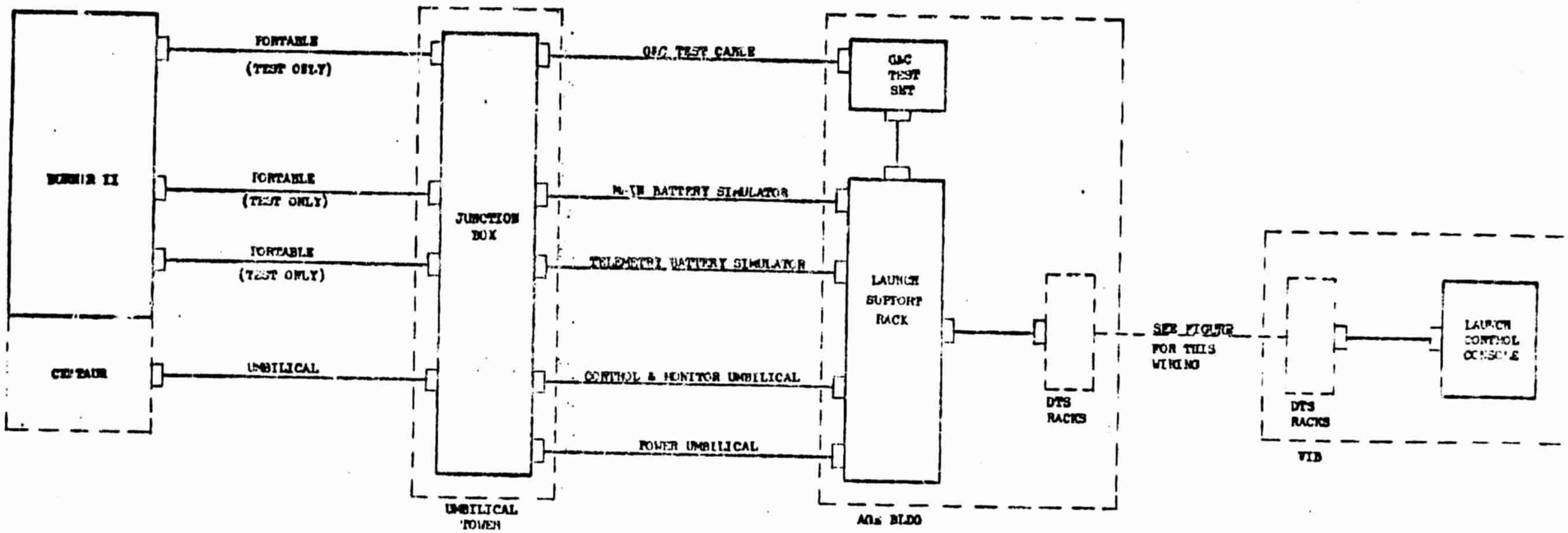
Requirements for modification to the present launch pad configuration for Burner II operations are listed in Table 2.7-5. Modification of the Mobile Service Tower (MST) and Umbilical Tower (UT) platforms is required to accommodate the 168 inch diameter nose shroud and will probably be completed prior to Burner II/Improved Centaur/Titan IIID integration. The required modifications are described in Section 2.7.3.3.

2.7.2.6 Launch Facility Modification Kit.

The Launch Facility Modification Kit (LFMK) consists of all Boeing supplied equipment which must be installed at the ITL launch facility to support Burner II launch operations. This equipment is listed in Table 2.7-6.

2.7.2.7 Expendables

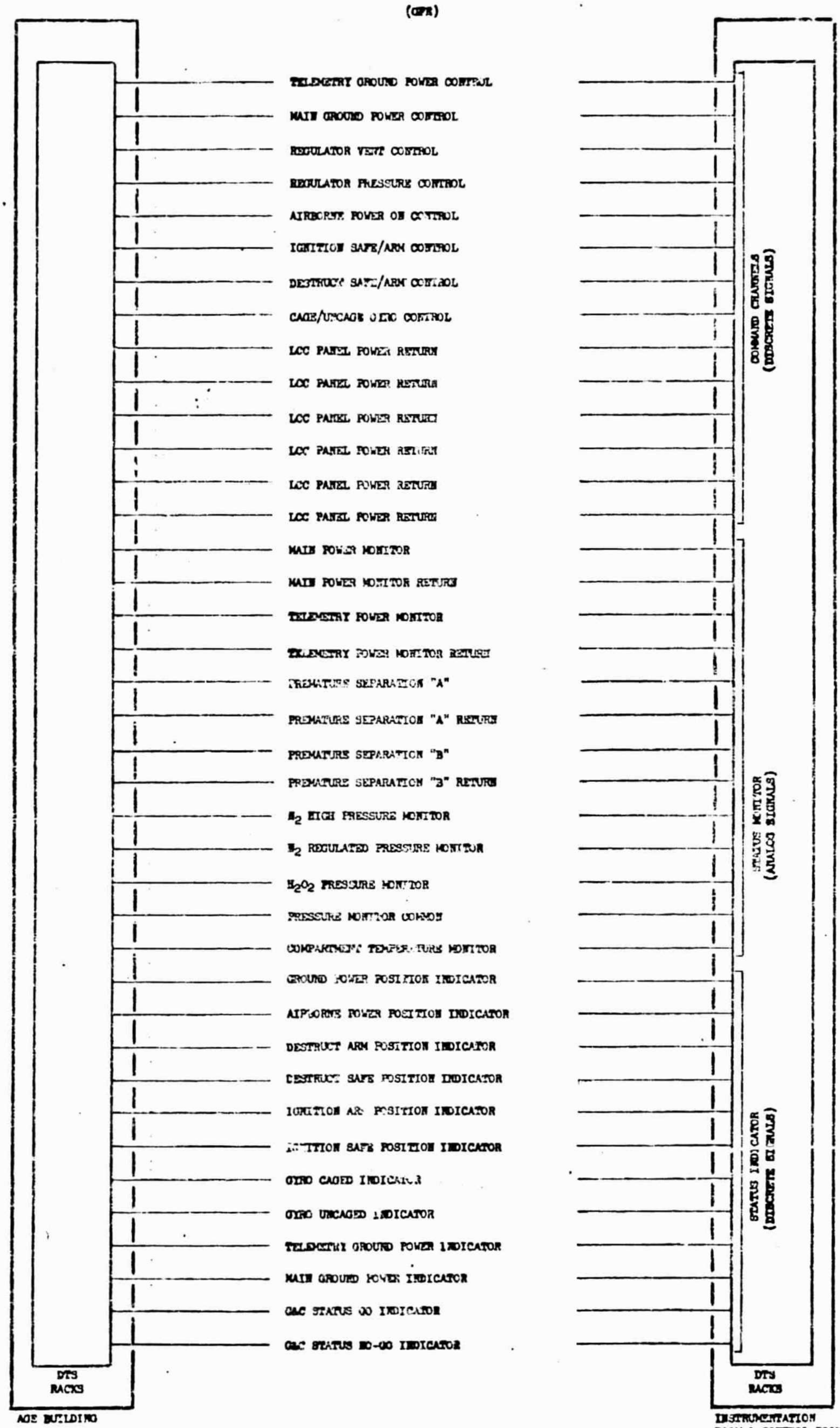
Thirty pounds of GN_2 will be required for each processing cycle and approximately fifty pounds of H_2O_2 will be required for each Burner II fueling cycle.



GSE/BURNER II INTERFACE

FIGURE 2.7-17

(OPR)



BURNER II/DTS INTERFACE SIGNAL

FIGURE 2.7-18

GOVERNMENT FURNISHED SERVICES

A. CALIBRATION OF ELECTRONIC, ELECTRICAL, MECHANICAL AND HYDRAULIC SUPPORT EQUIPMENT.

B. REPAIR OF STANDARD ELECTRONIC TEST EQUIPMENT.

C. LAUNCH PAD MODIFICATION INCLUDING INSTALLATION OF LAUNCH FACILITY MODIFICATION KIT (INCLUDES INSTALLATION OF LAUNCH CONTROL AND CHECKOUT EQUIPMENT INTERCONNECT CABLES)

D. TELEMETRY STATION SUPPORT DURING FIELD PROCESSING.

E. ORDNANCE RECEIVING, STORAGE AND TRANSPORTATION AT CKAFS.

F. DESTRUCT SAFE AND ARM CHECKOUT.

G. FIRE PROTECTION AND SECURITY

H. SPECIAL HANDLING AND TRANSPORTATION SUCH AS BRIDGE CRANE OPERATION, MOBILE CRANE OPERATION AND SERVICE TOWER OPERATIONS.

I. COMMUNICATIONS AND RANGE TIMING.

J. GOVERNMENT FURNISHED TRANSPORTATION (GBL)

TABLE 2.7-3

GOVERNMENT FURNISHED FACILITIES

A. RECEIVING AND STORAGE AREAS

1. AVE and AGE - 400 SQUARE FEET.
2. SOLID PROPELLANTS AREA - 100 SQUARE FEET
   (ROCKET MOTOR AND ORDNANCE)

B. OFFICE AREA AND EQUIPMENT

1. OFFICE SPACE (VIB OR PAD) - 400 SQUARE FEET
2. SIX STANDARD DESKS AND ONE SECRETARIAL DESK
3. SEVEN TELEPHONES ON THREE LINE HUNT SYSTEM
4. THREE STANDARD FIVE DRAWER FILE CABINETS
5. ONE STANDARD ELECTRIC TYPEWRITER.

C. BURNER II CHECKOUT AREA (HAZARDOUS TEST AREA)

1. LOW BAY SHOP AREA - 600 SQUARE FEET (20' X 30') WITH 1/2 TON OVERHEAD HOIST: 110 V, 60 Hz POWER: 3500 PSIG AND GN_2 SUPPLY (3500 PSI MINIMUM)

D. EXPLOSIVE SAFE AREA

1. LOW BAY SHOP AREA WITH 2-TON (MINIMUM) HOIST AND 110 V, 60 Hz POWER (BURNER II ROCKET MOTOR INSTALLATION) - 400 SQUARE FEET (20' X 20')

2. HIGH BAY CLEAN ROOM ENTRY ROOM - 1125 SQUARE FEET (25' X 45') WITH STANDARD CLEAN ROOM CLEANING DEVICES AND 45' HIGH DOORS ON 25' SIDES LEADING FROM OUTSIDE AND INTO CLEAN ROOM.

3. HIGH BAY CLEAN ROOM WITH 5-TON 45 FOOT (MINIMUM) HOOK HEIGHT AND 45 FOOT (MINIMUM) DOOR -3600 SQUARE FEET (60' X 60') (PAYLOAD AND BURNER II MATING AND SHROUD INSTALLATION) DOES NOT PERMIT HORIZONTAL PROCESSING OF MORE THAN ONE SHROUD SECTION AT A TIME.

TABLE 2.7-4

E. LIQUID PROPELLANT (H_2O_2) STORAGE AND LOADING AREA

1. ELEVATED (6 FOOT MINIMUM) PLATFORM - 20 SQUARE FEET
2. STORAGE AREA FOR REACTION CONTROL SERVICING CART - 100 SQUARE FEET

F. VERTICAL INTEGRATION BUILDING

1. SPACE AND FACILITIES FOR INSTALLATION OF BURNER II LAUNCH CONTROL CONSOLE, 21 1/16" W x 41" D x 43" H., 120 V, 60 Hz 1 ∅, 15 A CIRCUIT BREAKER, 2/0 CABLE TO FACILITY GROUND

G. TITAN III LAUNCH SITE WITH THE FOLLOWING SPECIAL PROVISIONS

1. AGE BUILDING - SPACE AND FACILITIES FOR THE FOLLOWING:

A. INSTALLATION OF:
LAUNCH SUPPORT RACK, 21 1/16" W, x 26" D x 77 1/2" H., 120 V, 60 Hz, 1 ∅, 30 A CIRCUIT BREAKER, 2/0 CABLE TO FACILITY GROUND.

B. INSTALLATION OF:
G&C TEST SET, 48" W x 26" D x 60" H,
120 V, 60 Hz, 1 ∅, 30A CIRCUIT BREAKER, 2/0 CABLE TO FACILITY GROUND.

C. STORAGE OF:
PORTABLE EQUIPMENT, TEST CABLE CASES (APPROXIMATELY 20" x 15" x 11')
SQUIB SIMULATOR (APPROXIMATELY 32" x 16" x 9")
TELEMETRY TEST SET (APPROXIMATELY 41" x 41" x 15")
BURNER II/CENATUR SIMULATOR (APPROXIMATELY 32" x 15" x 9")
AND, PAYLOAD SIMULATOR (APPROXIMATELY 20" x 20" x 6")

TABLE 2.7-4 (Continued)

G. (CONTINUED)

2. UMBILICAL TOWER

   A. PROVISION FOR BURNER II CABLE AND JUNCTION BOX INSTALLATION

   B. AIR CONDITIONING FOR BURNER II - TEMPERATURE 65 ± 5 DEG. F. DEW POINT 50 DEG. F. RATE 80 POUND/MINUTE

   C. HARDWARE BACK TO TELEMETRY STATION FOR CLOSED LOOP CHECKOUT OF BURNER II TELEMETRY SYSTEM, UG-30 D/U FEEDTHROUGH, SIGNAL AT INTERFACE, +25 DBM @ 2200-2300 MHz.

3. MOBILE SERVICE TOWER

   A. N_2 SUPPLY LINE 3500 (MIN/PSI) AT LEVEL 11

   B. SHOWER AND EYE WASH AT LEVEL 11 (H_2O_2 SAFETY)

   C. 110 V, 60 POWER AT LEVEL 11

   D. PROVISIONS FOR PERSONNEL AND EQUIPMENT GROUNDING,

   E. REACTION CONTROL SERVICING CART SPACE AT LEVEL 11 (5' x 4' , 1700 POUND)

TABLE 2.7-4 (Continued)

LAUNCH PAD MODIFICATION

A. MOBILE SERVICE TOWER (MST)

1. MODIFY PLATFORM 11 TO FOLD UP 90° (FROM 85°)
2. REMOVE FOLDING SECTIONS FROM PLATFORMS 12 AND 13
3. ADD TWO NEW FOLDING SECTIONS ON PLATFORM 13

B. UMBILICAL TOWER (UT)

1. REMOVE FOLDING SECTIONS FROM PLATFORM 13
2. INSTALL LAUNCH FACILITY MODIFICATION KIT

TABLE 2.7-5

LAUNCH FACILITY MODIFICATION KIT

A. ELECTRICAL UMBILICAL CABLE (UT J-BOX TO BURNER II)

B. ELECTRICAL UMBILICAL CABLE RETRACT LANYARD SYSTEM

C. ELECTRICAL JUNCTION BOX (UT LEVEL 11)

D. UMBILICAL CABLES (2) J-BOX TO LSR

E. TEST CABLES (2) J-BOX TO LSR

F. TEST CABLE J-BOX TO GUIDANCE AND CONTROL TEST SET

G. AIR CONDITIONING UMBILICAL RETRACT LANYARD SYSTEM

H. SIGNAL CABLE BETWEEN LSR AND DTS

I. SIGNAL CABLE BETWEEN LCC AND DTS

J. H_2O_2 OVERBOARD DRAIN

TABLE 2.7-6

2.7.2.8 Software

2.7.2.8.1 Program Documentation . Program Documentation requirements are defined in Section 10.

2.7.2.8.2 GSE Integration and Launch Documentation.

Test Plans. An integrated Centaur/Burner II test plan will be prepared which defines how the total system is integrated and where the individual tests are performed. This test plan will be based upon the test requirements contained in the System and CEI Specifications. Detailed test plans for all contractor inplant testing and field testing will then be prepared.

Test Procedures. Test procedures will be prepared for each of the tests specified in the test plan. These procedures will be similar to existing procedures with modification required to accommodate new equipment, changes to existing equipment, Centaur/Titan launch vehicle, and ITL launch complex. The procedures will consist of the following:

A. Functional Acceptance Test Procedures for each item of Launch Control and Checkout Equipment (LCCE).

B. Functional Acceptance Test Procedures for the LCCE when connected.

C. Functional Acceptance Test Procedures for the Burner II vehicle.

D. Burner II Field Assembly and Checkout Procedures.

E. Burner II inputs into the Titan/Centaur/Burner II combined checkout procedures (Interface, EMI, Umbilical Drop and CST)

F. Burner II inputs into the Integrated Titan/Centaur/Burner II countdown manual. These inputs will provide for the following:

1. Checkout and connection of destruct system.
2. Guidance and Telemetry Confidence checks.
3. Safing Pin removal.
4. Pressurization of H_2O_2 System.
5. Transfer to internal power (T-3 minutes)
6. Arming destruct system and rocket motor.

2.7.3 Conceptual Designs

Exising facilities and equipment designs have been specified for Burner II ETR operations where feasible. Where new designs or facility modifications were required, further study of field processing requirements was performed to develop conceptual designs. This section presents the results of these studies and the conceptual designs which were developed.

Several areas requiring further definition and study are discussed at the end of this section. The ground rules assumed for the study are as follows:

2.7.3.1 Assumptions and Ground Rules.

1. The payload and Burner II will be encapsulated within the 168-inch diameter Conceptual Shroud (upper section) shown on NASA Lewis Research Center drawings CR 600310 through CR 600336, and Convair-Astronautics drawing SKC-11. The integrated assembly will be erected on top of the Titan III/Improved Centaur on the pad at ETR Launch Complex 41.

2. Concepts developed in this study for assembling, encapsulating, handling, and erecting the encapsulated payload and Burner II shall be compatible with the launch complex structures and equipment as described in the Titan III/Improved Centaur Integration Study.

3. Concepts developed in this study shall be adaptable, with minimum modification to handle and erect the 132-inch diameter straight Centaur nose shroud.

4. The encapsulated payload and Burner II will be transported to the launch pad in an upright position.

5. The Centaur stage will be pressurized and stretch hardware removed prior to payload/Burner II/Shroud erection.

6. The wind restraint system described in the Titan III/Improved Centaur Integration Study will be used when erecting the payload/Burner II/Shroud if wind velocities exceed 15 miles per hour. If winds exceed 25 knots, erection will not proceed.

7. The payload and Burner II will be encapsulated within the nose shroud in a clean-room having a 5-ton minimum capacity bridge crane with a minimum hook height of 45 feet.

8. The payload will require positive pressurization of the nose shroud at all times after leaving the clean-room.

9. Nose shroud segments will arrive separately at ETR and will be handled on individual dollies.

10. Burner II will be manufactured in a standard facility at Kent, Washington without the use of special clean-room facilities and procedures.

2.7.3.2 Mechanical Ground Support Equipment

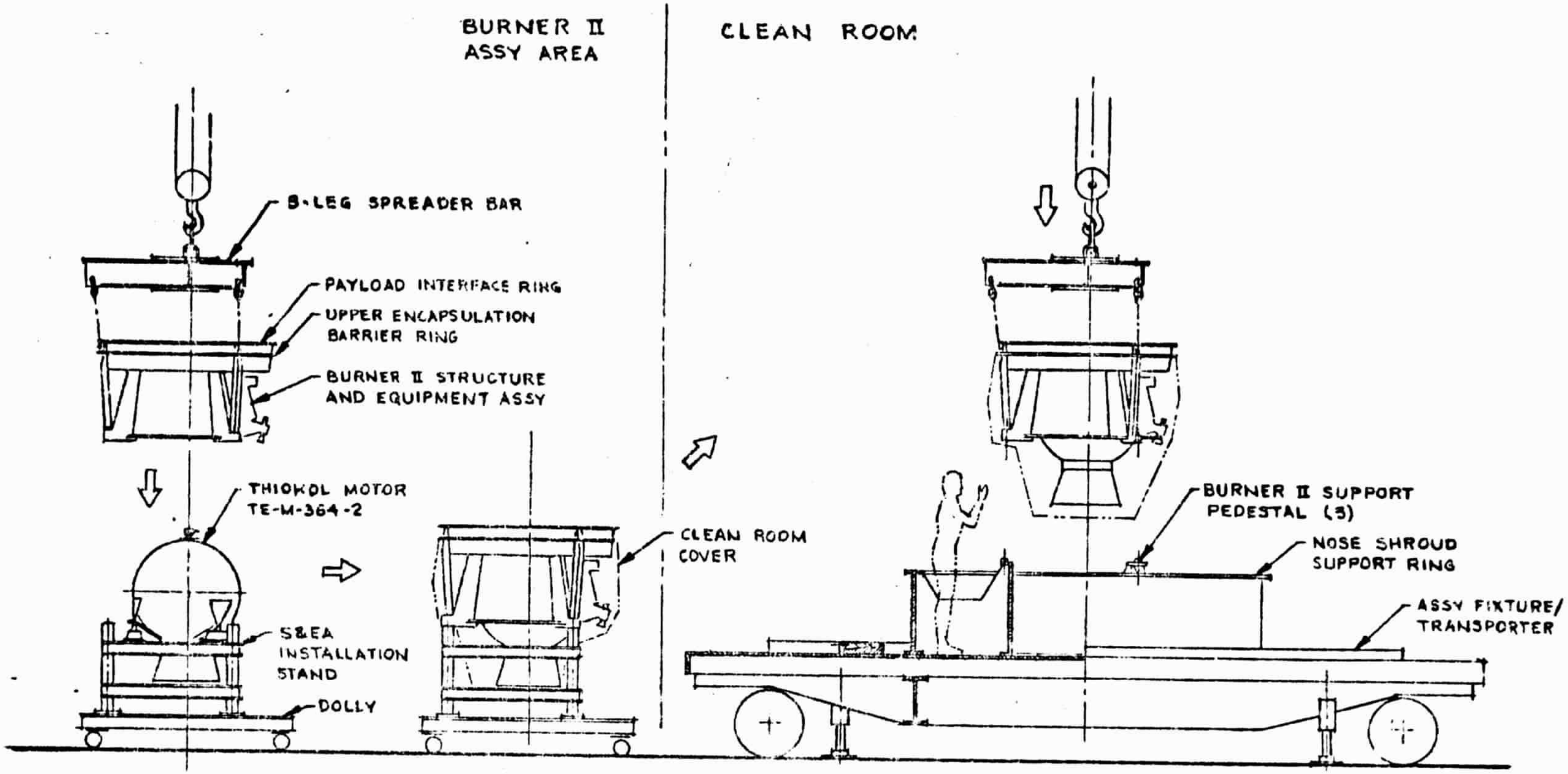
A preliminary study was made of Burner II, payload and nose shroud mechanical integration requirements to determine the adequacy of the Titan III launch facility at the Eastern Test Range (ETR) and to identify requirements for mechanical Ground Support Equipment (GSE). Procedures and conceptual GSE designs were developed for assembling the Burner II stage, encapsulating it with a payload within the conceptual 168-inch diameter Centaur nose shroud forward section and erecting the assembly at the launch pad. The resulting mechanical GSE requirements are listed in Table 2.7-1 and are described as follows:

2.7.3.2.1 Burner II Assembly and Installation. The Burner II stage and solid propellant motor will be shipped separately to ETR. After receiving inspection and Burner II systems test, the motor will be installed on the stage. The motor will first be placed in the installation stand, as shown in Figure 2.7-19. A handling sling and pneumagrip tool will be used to lift the motor out of its shipping container and position it, nozzle down on the stand. The stand is an existing piece of equipment, mounted on a new transfer dolly.

The Burner II stage will be lifted out of its shipping container, using a three leg spreader bar sling, and installed on the stand over the motor. The motor attach bolts will then be installed, and the assembled stage will be lifted off the stand for installation of the Burner II clean-room cover. This cover, made of a non-static, conductive material, will envelop the Burner II stage below the encapsulation support ring, being fastened to the ring with a removable strap. The cover, together with the closed payload interface ring, will seal the Burner II for subsequent operations in the payload integration clean-room.

The sealed Burner II will be placed on the installation stand and moved into the clean-room entry on its dolly, together with its handling sling, where all exterior surfaces including the handling equipment, will be wiped clean before entry into the clean-room.

A four-wheel assembly fixture/transporter trailer (See Figure 2.7-19) will be positioned in the clean room, after being cleaned, to receive the Burner II stage, payload and nose shroud. This transporter will contain Burner II and nose shroud support and tie-down provisions, leveling wedge assemblies, nose shroud guying cable provisions, and a tow bar. Prior to being brought into the clean-room, the transporter will be jacked up and the road running gear will be removed. This gear will then be replaced by special wheeled gear used only for clean-room operations. The Burner II stage will be placed on the transporter using the bridge crane hoist and Burner II sling, and fastened to three support pedestals with transportation tie-down bolts. Leveling jacks on the transporter will maintain stability.



BURNER II ASSEMBLY AND INSTALLATION ON TRANSPORTER
BURNER II WITH STD. MOTOR (TE-M-364-2)

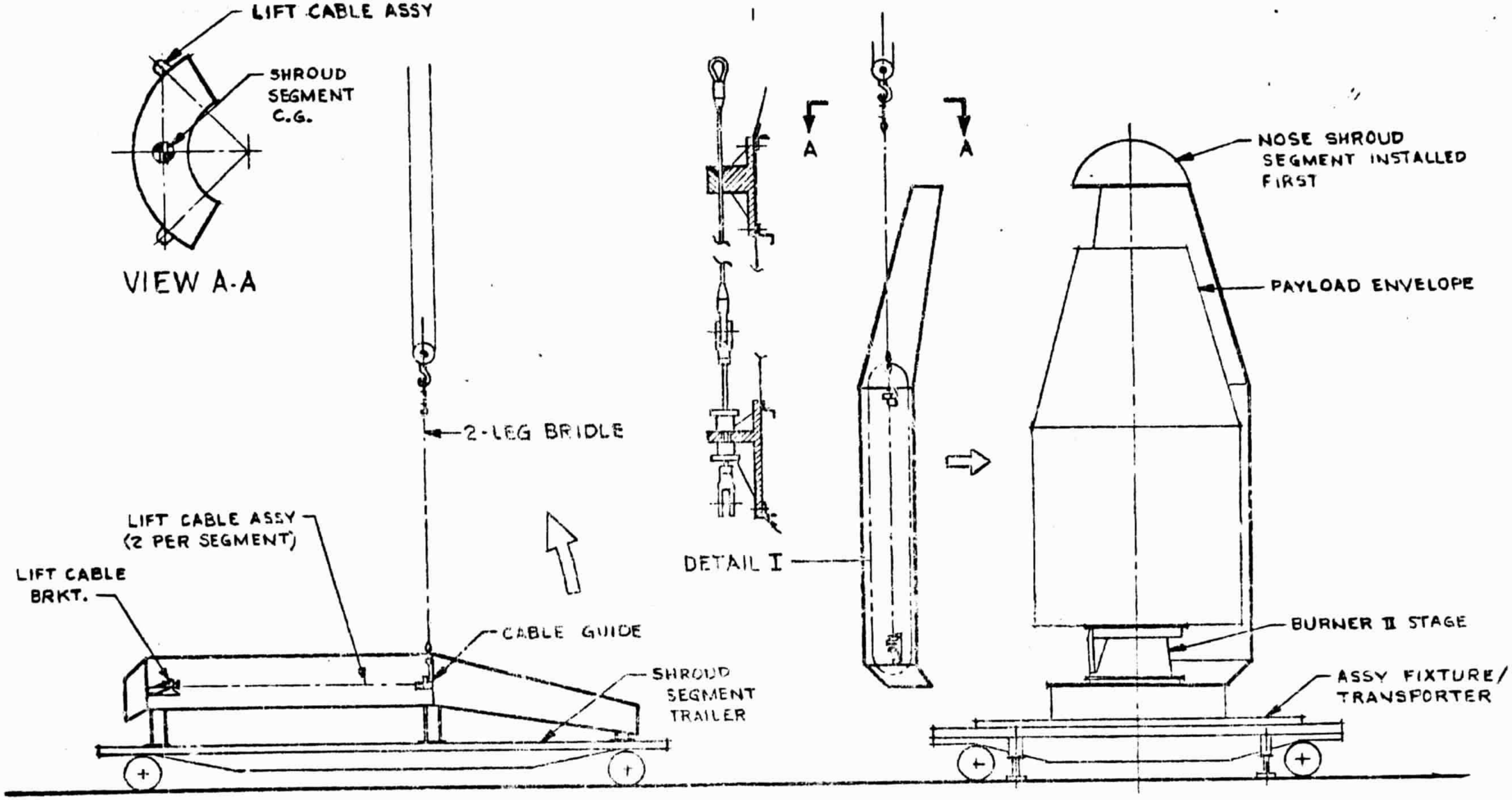
FIGURE 2.7-19

2.7.3.2.2 Payload Installation. Handling and transportation equipment for the payload has not been defined. It is assumed such equipment will be provided by the payload contractor and will be compatible with clean-room procedures and hoisting equipment. The payload will be mated to the Burner II payload support ring and connecting bolts will be installed. Electrical staging connectors will be connected and, it is assumed, payload checkout will be conducted at this time prior to encapsulation within the nose shroud.

2.7.3.2.3 Payload/Burner II Encapsulation. The GSE and procedures for installing the nose shroud and encapsulating the payload and Burner II are illustrated on Figure 2.7-20 and 2.7-21. Each nose shroud segment will be brought into the clean-room horizontally, convex side up on its handling trailer. Two lift cable assemblies will be fastened to the exterior of the segment as shown in Figure 2.7-20. Each assembly consists of a lift cable, lift cable bracket, tie rod, two hand knobs, and a cable guide (see Figure 2.7-20, Detail I). A two leg bridle sling will be attached to the ends of the lift cables and the nose shroud segment will be rotated to the vertical position. A portable hoist may be used to support the lower end of the segment, or rotation provisions may be included in the handling trailer. The lift cable assembly are located radially on the segment so the center of lift coincides approximately with the segment center of gravity when it is vertical (see Figure 2.7-20, View AA).

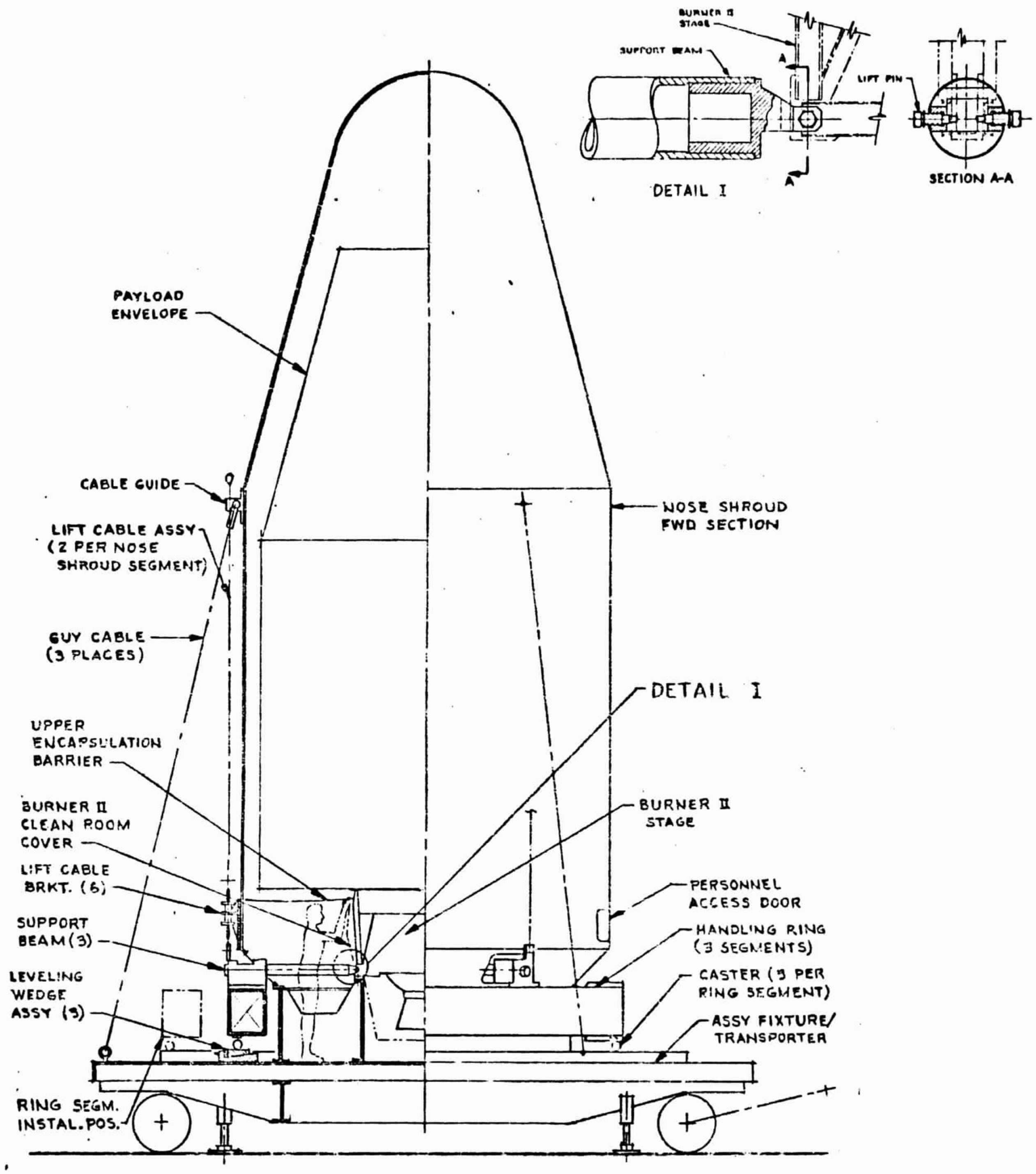
With the segment suspended in the vertical position, the upper encapsulation barrier section will be attached to the appropriate segment internal ring. The segment will then be moved laterally into position onto the transporter nose shroud support ring, enveloping the payload and Burner II. Transportation bolts will be installed to fasten the segment to the ring. One lift cable assembly will then be removed from the segment, leaving the remaining one installed which is located in line with a Burner II beam. The removed assembly will be used during the erection and installation of the remaining two nose shroud segments in a similar manner. At the completion of this procedure, three lift cable assemblies will remain on the nose shroud to be used during the erection of the encapsulated payload and Burner II at the launch pad.

After erection of the nose shroud segments, the shroud separation devices will be installed. The upper encapsulation barrier sections will then be joined and attached to the Burner II barrier ring with pin pullers using the special seal tool shown on Figure 2.7-22. Personnel access within the shroud for this operation will be provided by openings in the nose shroud support ring and one in the shroud cylindrical section. The height of this ring will be such that the nose shroud field splice plane at Station 2510.7 will be located an inch above its final position relative to the Burner II field splice plane.

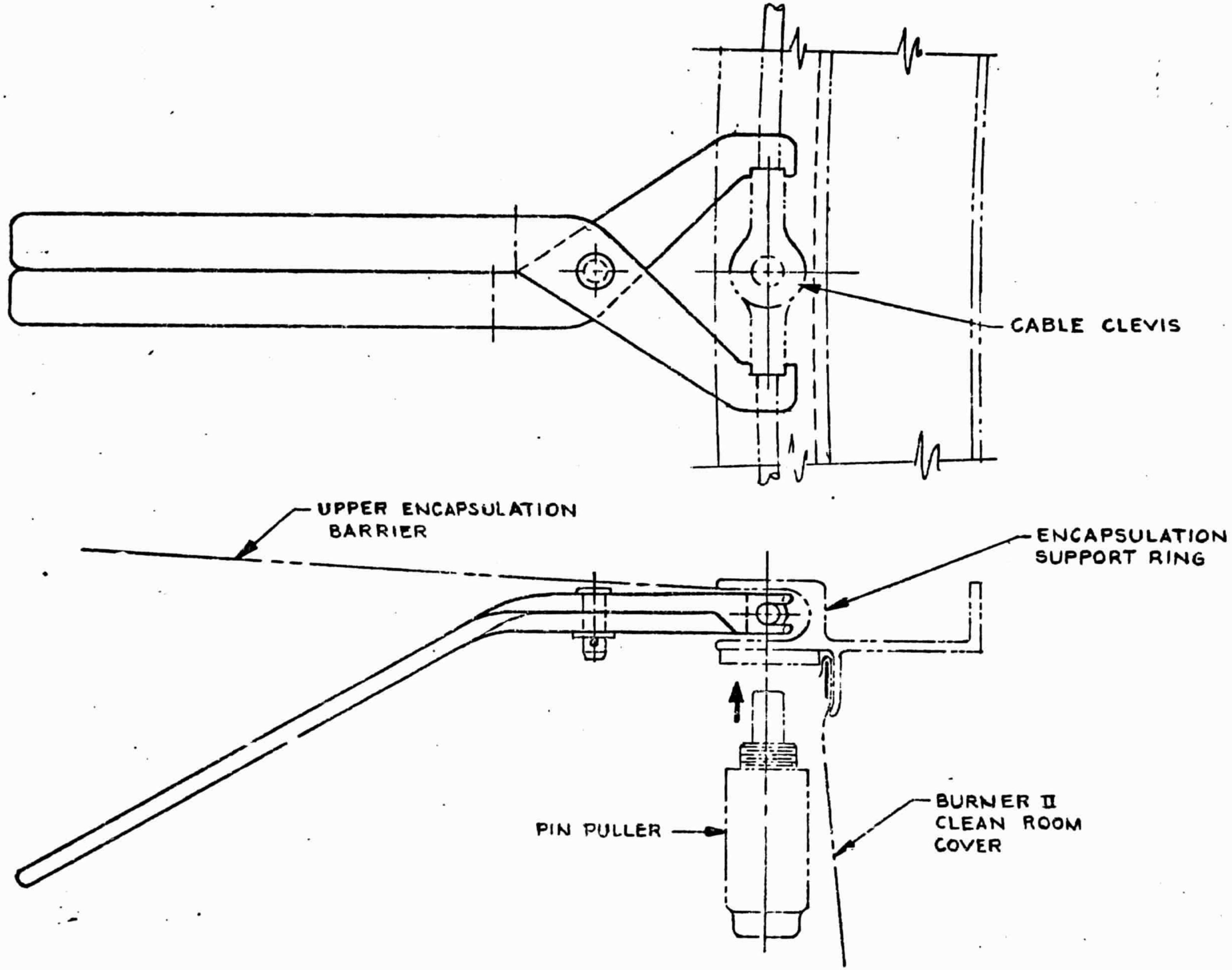


NOSE SHROUD ASSEMBLY AND INSTALLATION ON TRANSPORTER

FIGURE 2.7-20



PAYLOAD/BURNER II ENCAPSULATION CONCEPT
BURNER II WITH STD. MOTOR (TE-M-364-2)
FIGURE 2.7-21



PAYLOAD ENCAPSULATION SEAL TOOL

FIGURE 2.7-22

2.7.3.2.4 Handling Ring Installation. The handling ring supports the mated payload and Burner II during erection at the pad. It is connected rigidly to the three lift cable brackets by the tie rods, as shown on Figure 2.7-21, thereby preventing relative motion between the shroud and payload during the erection process.

The handling ring consists of three identical, rectangular box-section segments, bolted together to form a complete ring. Each segment carries one Burner II support beam contained in a bolt-on pedestal. Each pedestal contains a lift lug which mates with a clevis on a lift cable tie rod. Each ring segment also contains three swiveling casters on its underside which are used for handling of the segments.

The handling ring is installed by placing the individual segments on the periphery of the transporter, as shown in Figure 2.7-21, using the clean-room crane and a two-leg bridle sling. The segments will then be rolled inwards, bolted together and rotated into proper position. At this time, three of the casters (120 degrees apart) will be located on top of leveling wedges on the transporter. These wedges will be used to raise and adjust the level of the ring so that the three support beams can be inserted through the pedestals and engaged with the Burner II beams, as shown in Detail I of Figure 2.7-21. The two lift pins in each support beam will engage lift holes in the ends of the Burner II beams and the support beams will be locked to the pedestals.

After the support beams are installed, the hand knobs securing the tie rods and lift cables will be loosened. The tie rods will be lowered until the bottom clevises engaged the lift lugs on the ring pedestals. After inserting tie bolts, slack will be taken out by tightening the upper and lower hand knobs (see Figure 2.7-21).

The final operations prior to towing the transporter to the pad will include installation of three guying cables, duct covers closing the support beam openings in the shroud, replacement of the personnel access doors on the shroud, installing a portable pressurization unit on the handling ring, and connecting the transporter environmental conditiong unit to the payload air conditioning umbilical connection on the shroud. The road running gear will be replaced on the transporter outside the clean-room.

2.7.3.2.5 Payload/Burner II Erection at Pad. Several preparatory operations must be performed before erecting the encapsulated payload and Burner II on the Centaur. It is assumed that the Titan III/Centaur vehicle is on the pad, enclosed with the MST and UES. UES and UT platforms 11, 12, 13 and 14 are extended, the three 47-inch long Centaur forward fairing sections and the lower encapsulation barrier are installed, and the Centaur electrical and air conditiong umbilicals are connected. In addition, the Centaur stretch sling may be in place with the stage unpressurized.

The Centaur must first be pressurized and the stretch sling removed. The Burner II portable work stand will then be installed on platform 11 as shown in Figure 2.7-23. The work stand will consist of several light and portable sections which are bolted together. When assembled it will provide a complete platform around the Centaur lower fairing. The work stand framing will be designed with clearance for the Centaur umbilicals, and will bridge the new cutout required in platform 11 to clear the Centaur liquid hydrogen (LH_2) vent fin.

The Burner II/Centaur adapter will be brought to the pad on its handling dolly by truck. A three-leg spreader bar sling will be used with the MST-10 ton auxiliary crane to install the adapter on the Centaur conical equipment module.

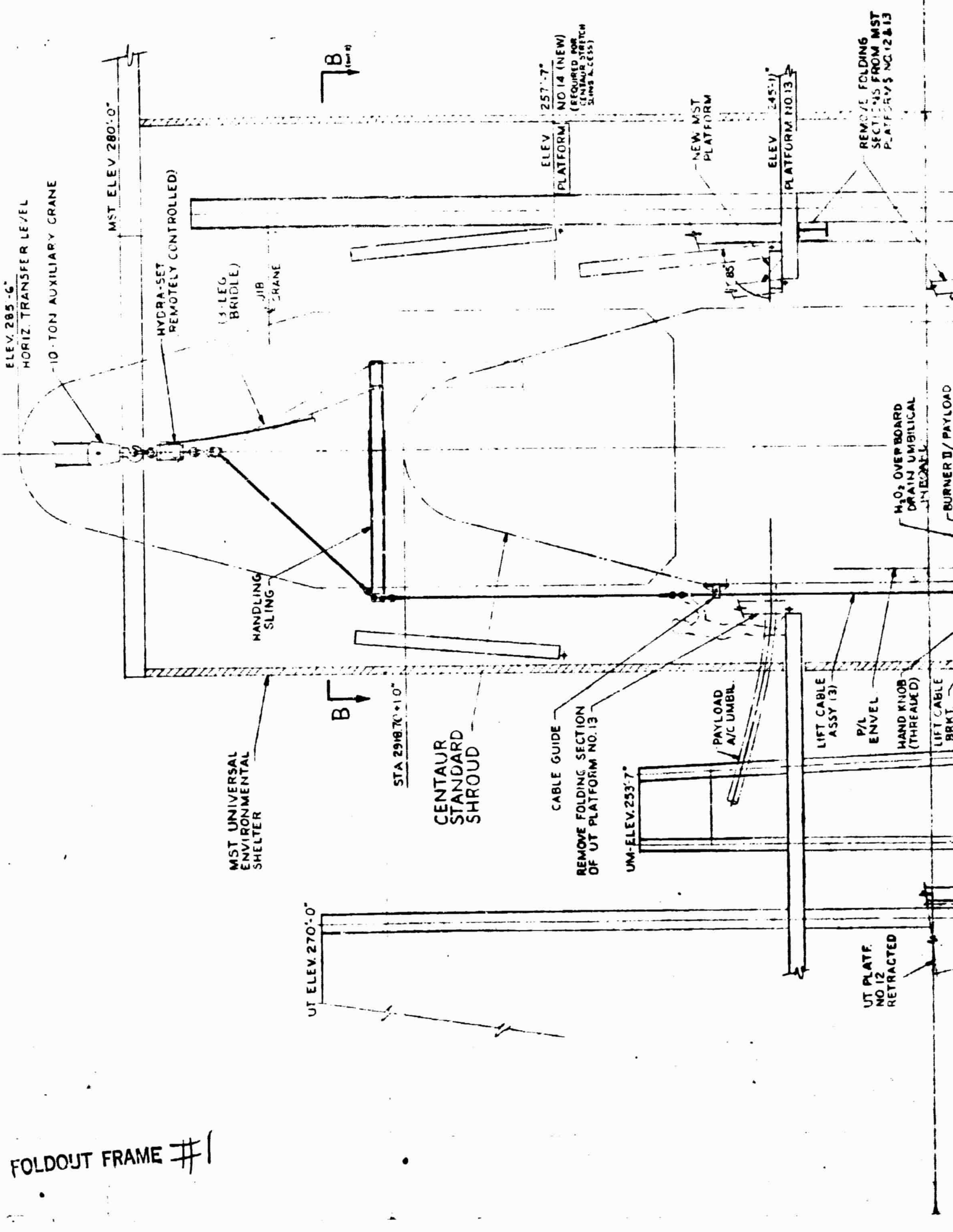
After the adapter is positioned on Centaur, several sections of the internal work platform will be installed between the adapter and the fairing external ring. These sections will provide working positions for installing the adapter interface bolts. The platform sections will be shifted as required. When all bolts are installed, all the platform sections will be installed.

The final operations before erecting the payload and Burner II will be to move the UES jib crane to its extreme North position, retract UES and UT platforms 12, 13 and 14 and open the UES door and roof.

The encapsulated payload and Burner II will be erected using a three-leg spreader bar sling on the MST 10-ton auxiliary crane. Accurate and positive control will be provided during final load positioning by a remotely controlled Hydra-Set unit between the crane hook and erection sling as shown in Figure 2.7-23. The Hydra-Set unit will also provide shock control against potential crane surges.

The Hydra-set and sling will be lifted by the crane sufficiently to allow clearances for the payload/Burner II transporter to be positioned under it. The height of lift will be limited by the length of the hose between the Hydra-set and its remote control console which will be temporarily positioned on its stand clear of the transporter position.

After the transporter is positioned under the crane, its leveling jacks will be adjusted and the crane will lower the sling to approximate height. The Hydra-set remote control console will be used to adjust the final sling height, and a mobile crane may be used to provide personnel access to connect the three sling cables to the lift cables previously installed on the nose shroud and handling ring. The guying cables will also be disconnected from the lift cable guides at this time.



FOLDOUT FRAME #1

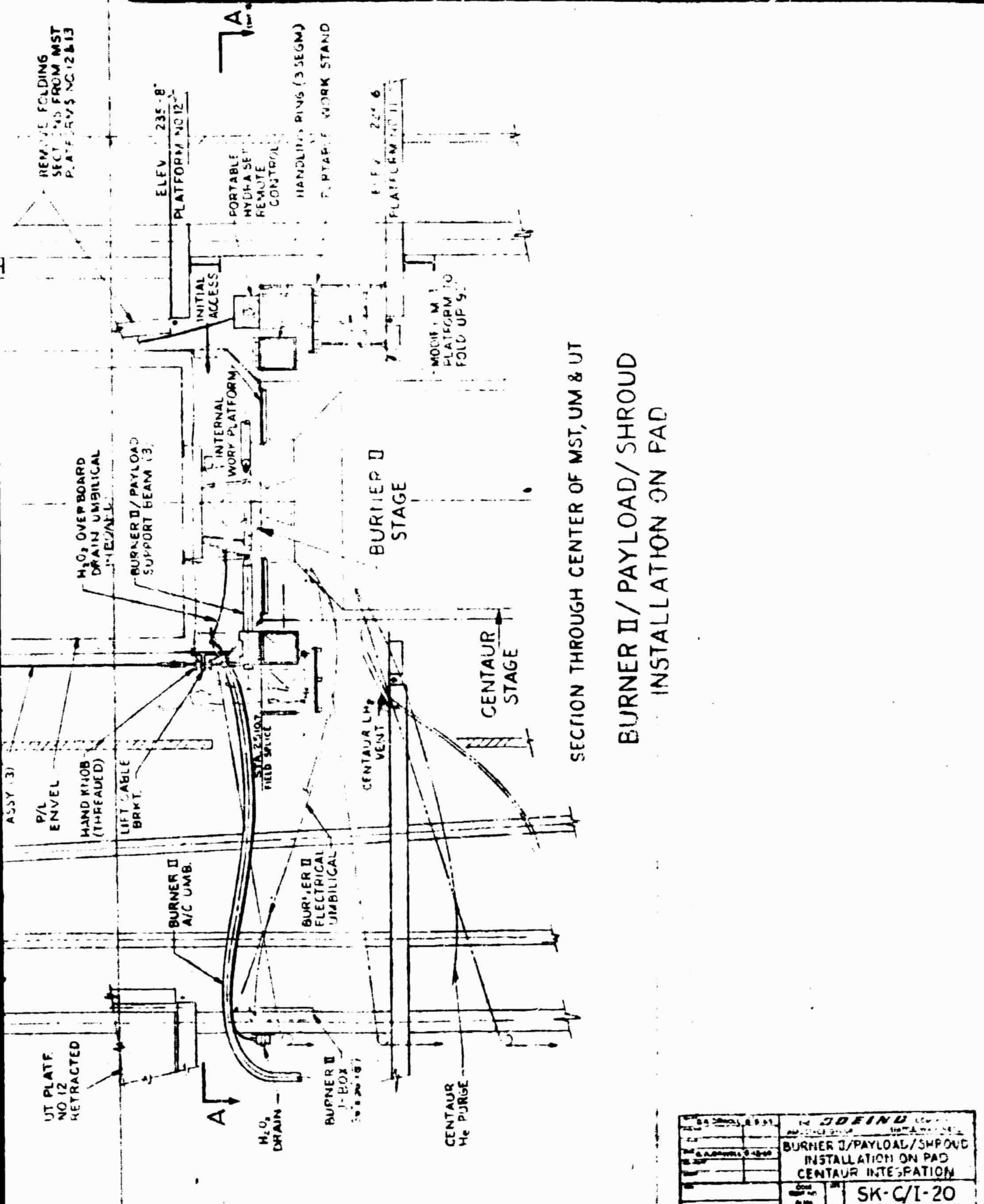
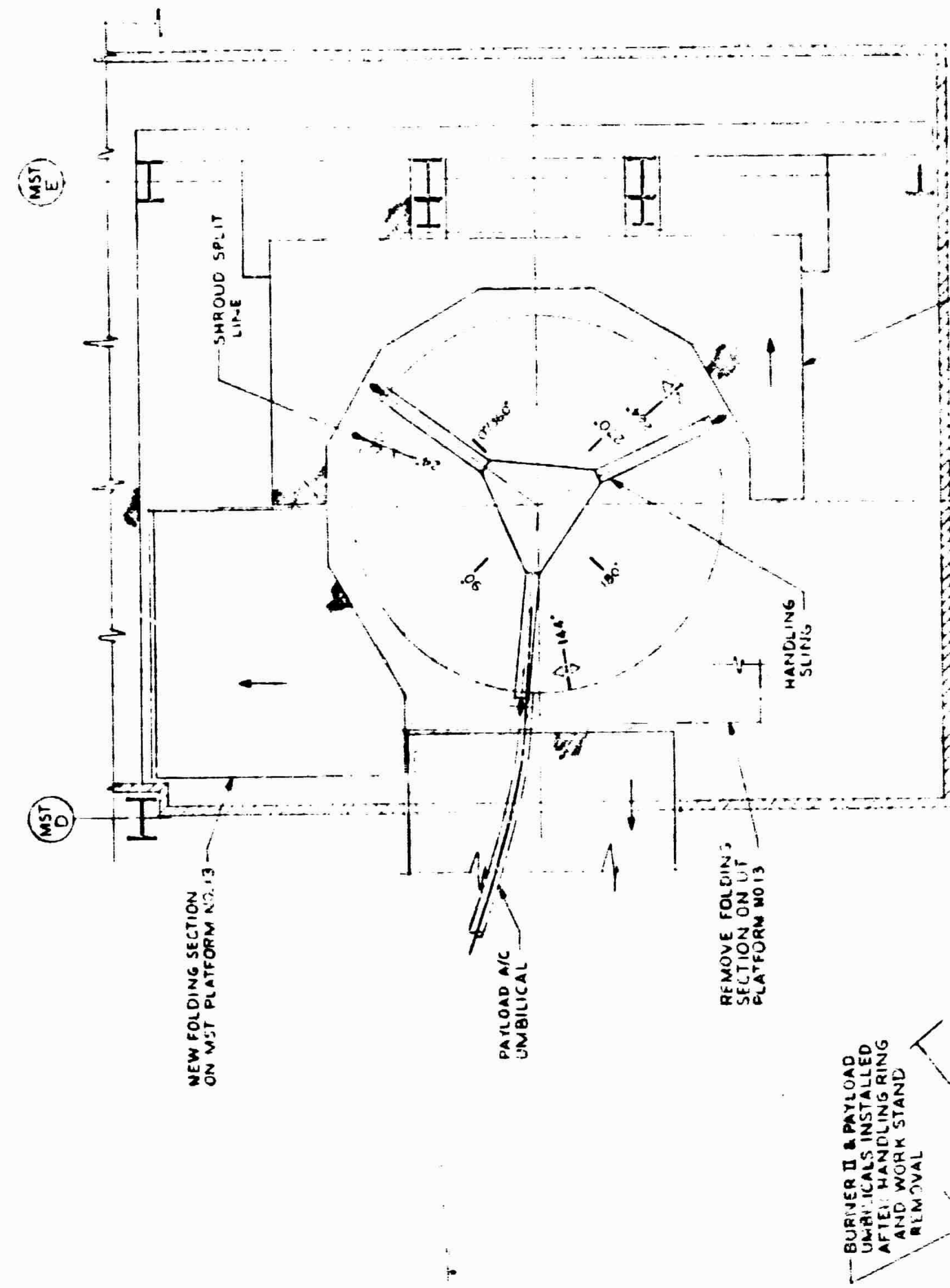
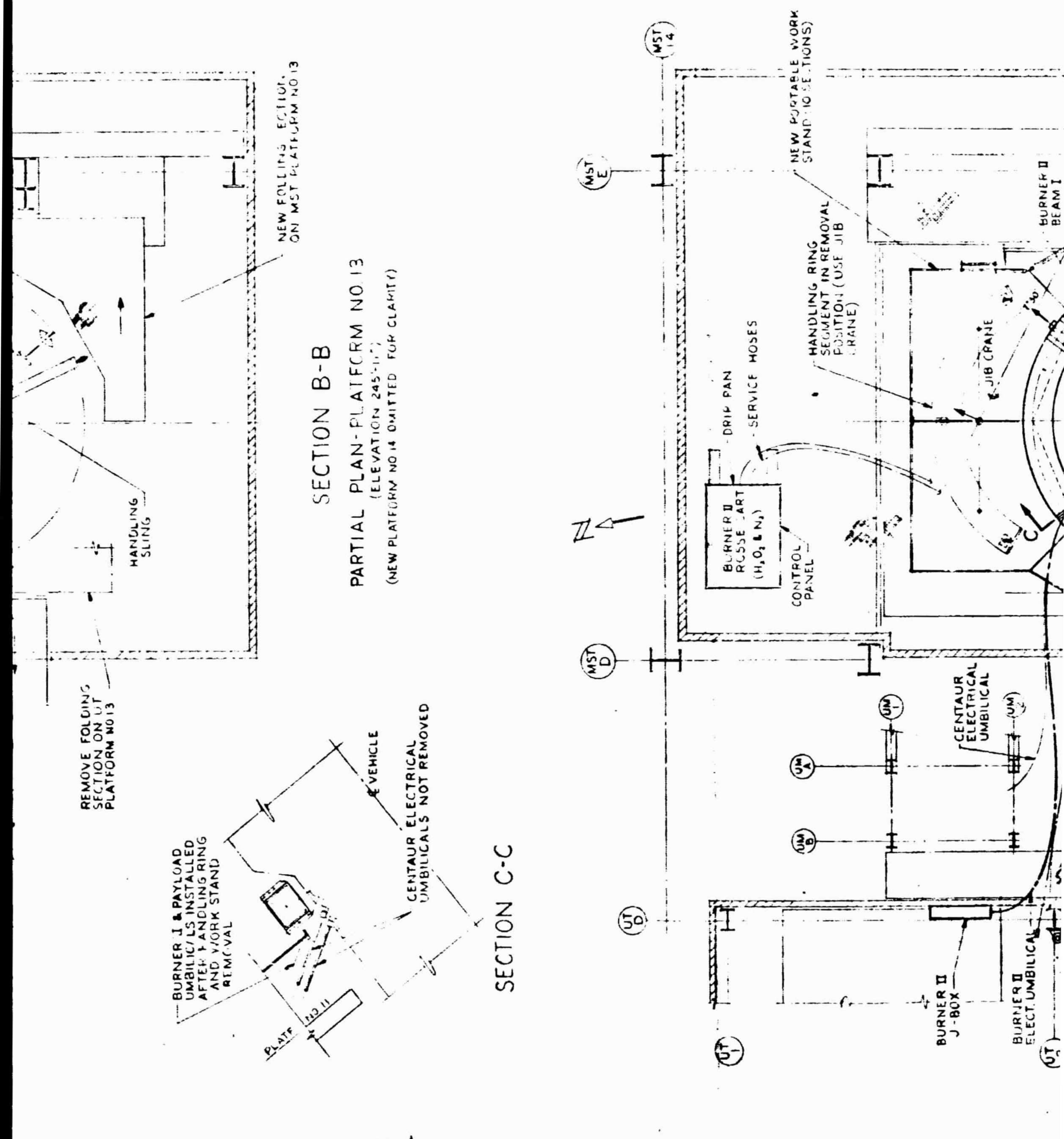
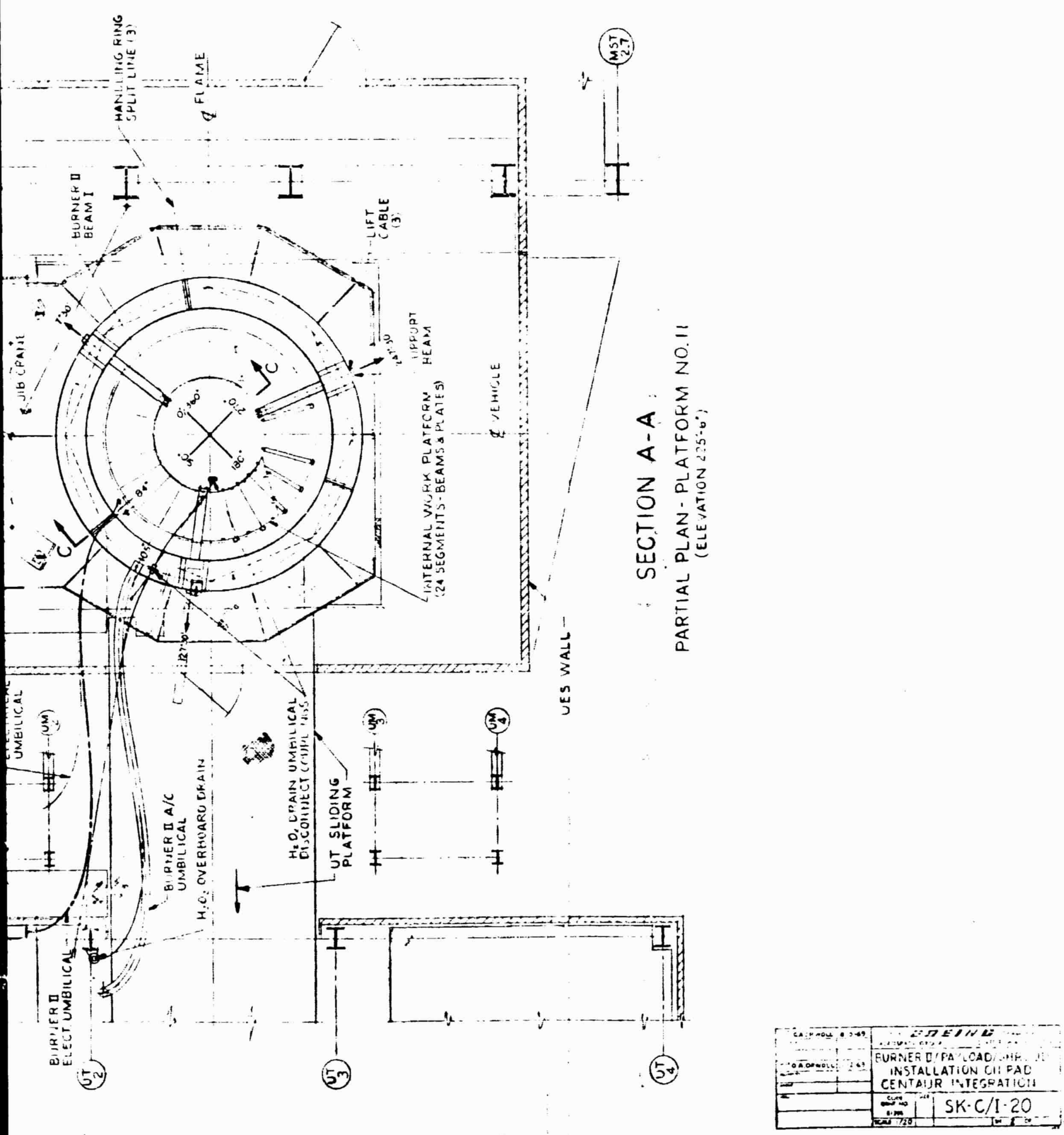

REMOVE FOLDING SECTIONS FROM MST PLATFORMS NO 12 & 13
ELEV 235'-8" PLATFORM NO 12
PORTABLE HYDRASET REMOTE CONTROL
HANDLING RING (3 SEGM)
PORTABLE WORK STAND
PLATFORM NO 11
INITIAL ACCESS
MODIFY M1 PLATFORM TO FOLD UP 9
INTERNAL WORK PLATFORM
H_2O_2 OVERBOARD DRAIN UMBILICAL
BURNER II / PAYLOAD SUPPORT BEAM (3)
BURNER II STAGE
CENTAUR STAGE
P/L ENVEL
HAND KNOB (THREADED)
LIFT CABLE BRKT
STA 25.102 FIELD SPLICE
CENTAUR LH2 VENT
BURNER II A/C UMB.
BURNER II ELECTRICAL UMBILICAL
UT PLATE NO 12 RETRACTED
H_2O_2 DRAIN
BURNER II J-BOX
CENTAUR He PURGE
A
SECTION THROUGH CENTER OF MST, UM & UT
BURNER II / PAYLOAD / SHROUD INSTALLATION ON PAD
BURNER II/PAYLOAD/SHROUD INSTALLATION ON PAD CENTAUR INTEGRATION
SK-C/I-20

FIGURE 2.7-23


MST E
MST D
SHROUD SPLIT LINE
90°
180°
144°
HANDLING SLING
NEW FOLDING SECTION ON MST PLATFORM NO. 13
PAYLOAD A/C UMBILICAL
REMOVE FOLDING SECTION ON UT PLATFORM NO13
BURNER II & PAYLOAD UMBILICALS INSTALLED AFTER HANDLING RING AND WORK STAND REMOVAL



FOLDOUT FRAME #2



FOLDOUT FRAME #3

FIGURE 2.7-24

The Burner II clean-room cover and all tie-down bolts will be removed. The portable pressurization unit attached to the handling ring will be connected to the shroud and the transporter environmental conditioning duct will be removed. The load will then be raised off the transporter, using the Hydra-set remote control which will be attached with a special bracket to the side of the handling ring. The load will then be raised to approximately the 285 foot MST level as shown in Figure 2.7-23, and moved laterally into the UES over the vehicle centerline. The UES doors will then be closed.

The preceding described erection procedures will be modified if the wind at the pad exceeds 15 MPH. A wind restraint system will be used as described in Volume II, Part I, Section IV C, of the Titan III/Improved Centaur Integration Study. The payload/Burner II transporter must be positioned between the two wind restraint cables and cable guides will be attached to the handling ring before lifting the load off the transporter. The restraint cables will be taut while the payload/Burner II is being raised, and will be removed after the UES doors are closed.

The 14-foot spacing between the wind restraint cables shown in the Integration Study (Figure IV-60) must be increased to approximately 16 1/2 feet due to the larger size of the 14 foot dimaeter shroud and the handling ring. The width of the transporter will be approximately 16 feet.

After positioning thepayload/Burner II over the Centaur, the Centaur upper air conditioning umbilical must be disconnected and moved clear. Electrical umbilicals will be lowered to within approximately 6 inches of the Burner II/Adapter interface. The auxiliary crane will then be locked, and the Hydra-set remote control console will be positioned on its stand adjacent to the access door in the shroud cylindrical section. This door, and the dust covers on the support beam access openings, will be removed for visual access to the interface.

Using the Hydra-set, the payload/Burner II will be lowered onto the Burner II interface. The load will be adjusted downwards until the remove control gage indicates that only the combined weight of the payload and Burner II is supported by the adapter. The nose shroud field splice plane will now be approximately an inch above its mating interface position at Station 2510.7.

The Burner II air-conditioning umbilical will be connected at this time and the internal working area will be purged with conditioned air. A man will then enter the shroud through the access panel and install three Burner II separation nuts. The support beams will be unlocked and the Hydra-set will be adjusted, if necessary, to relieve the load on the beam lift pins. These will be removed, and the support beams will be retracted and stored.

The man will exit the shroud and the top hand knobs on the lift cable assemblies will be loosened and adjusted to full up position. This will ensure that the handling ring weight cannot be suspended from thenose shroud. The shroud will be lowered onto its mating interface and sufficient bolts will be installed to secure the shroud. The handling ring will then be lowered until it is supported on its casters by the work stand.

UES and UT platforms 13 now will be extended and the handling sling will be uncoupled from the lift cable assemblies. The Hydra-set remote control console will be disconnected and the handling sling will be lowered to the ground. The UES roof may then be closed.

The payload environmental conditioning duct will be installed and the portable pressurization unit will be removed from the ring. The free-standing handling ring can now be disassembled into three segments. These segments will be rolled around the vehicle and onto the work stand extension, one at a time. The two-leg bridle sling, used in the clean room, will be used with the UES jib crane to move the handling ring segments onto the side of UES platform 11. The segment may then be rolled out of the UES for temporary storage. Alternatively, the segments may be lowered to the ground, using the MST auxiliary crane.

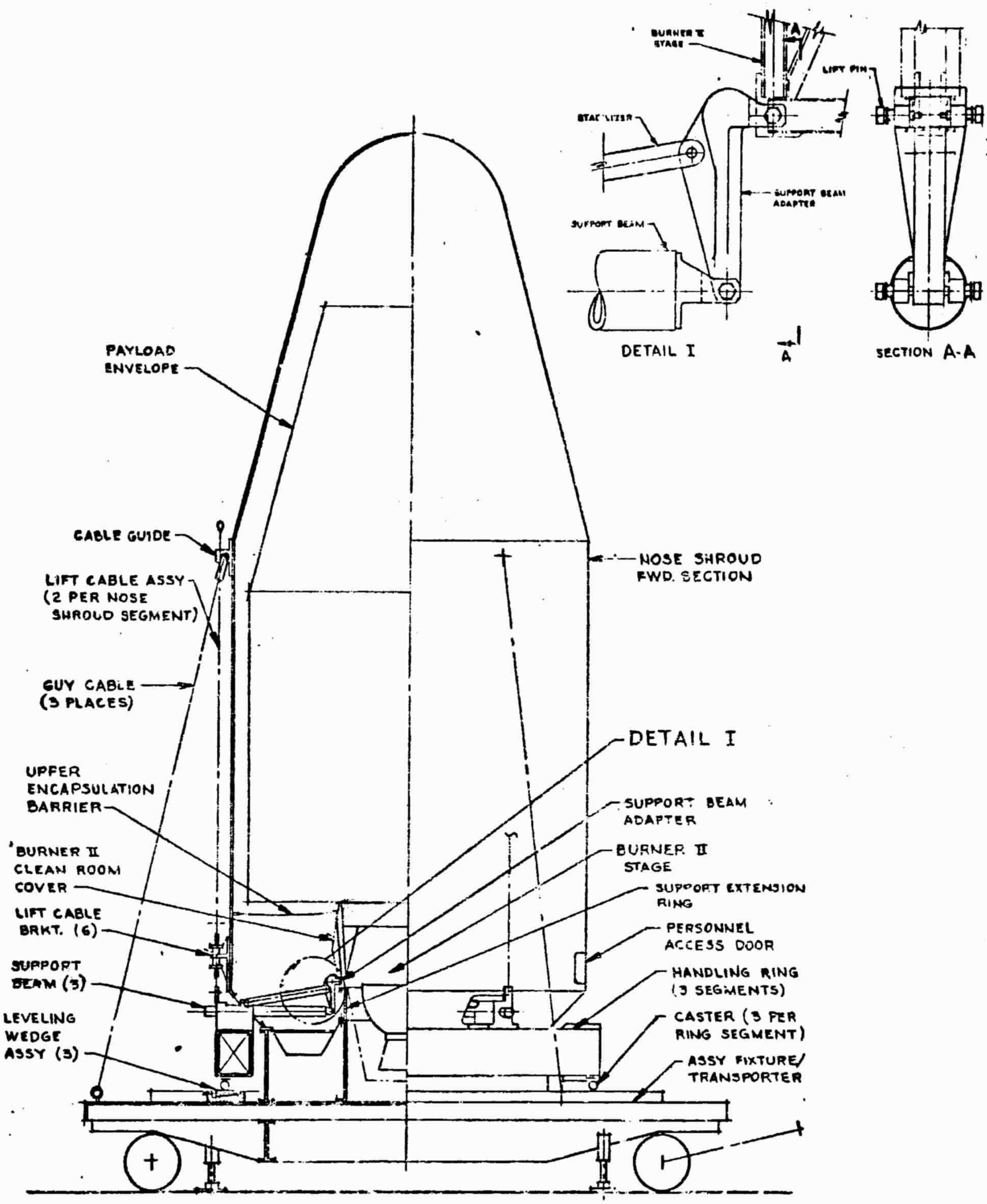
The center upper-air-conditioning umbilical will be reconnected at this time.

The lift cable assemblies will be disconnected and removed by hand, and the new UES platform 14 sections (see Figure 2.7-23) may be lowered. The remaining nose shroud bolts can then be installed.

The final operations prior to beginning Burner II checkout will be to install the payload and Burner II electrical umbilicals, install the inboard and outboard H_2O_2 drain umbilicals, rig all lanyards, and connect the payload and Burner II staging connectors. One or two sections of the work stand must be removed to provide clearance for the electrical umbilicals. The remaining sections and the internal work platform will remain in position until the completion of checkout and vehicle servicing prior to launch. This equipment may be temporarily stored on theMST until after launch.

2.7.3.2.6 Large Motor Burner II. Assembly and erection procedures and equipment for the large motor Burner II will be identical to those for the small Motor Burner II with the following exceptions:

Extension adapters must be attached to the S&EA installation stand shown in Figure 2.7-25 to accommodate the longer motor and changed mating interface. A longer clean-room cover will also be used.



PAYLOAD/BURNER II ENCAPSULATION CONCEPT
BURNER II WITH LARGE MOTOR (TE-M-364-4)

FIGURE 2.7-25

A Burner II support extension ring will be installed on top of the three support pedestals on the assembly fixture/transporter, as shown in Figure 2.7-25. This figure also shows the support beam adapters and stabilizers, which are required to mate the large motor Burner II with the support beams.

The support beam adapters and stabilizers must be assembled after the support beams are inserted through the pedestals on the ring. They must be removed after the Burner II is mated to the Burner II/Centaur adapter at the pad, before the support beams can be retracted.

2.7.3.2.6 Further Studies. Several areas requiring additional study and definition were identified in the analysis of Burner II and payload mechanical integration and erection.

Handling Ring Sizing. The payload and Burner II Handling Ring was made as small in diameter as possible to minimize the effects on the launch pad structures and to be more readily adaptable to handling the 132-inch diameter straight Centaur nose shroud. A larger ring, sized to clear the 168-inch shroud diameter would necessitate extensive changes to the fixed portions of UES platforms 12 and 13 for clearance during erection. Use of the smaller ring will limit the required modification to the folding sections only.

The smaller diameter ring has had the additional advantage of having shorter Burner II support beams, thereby minimizing deflections under load, and resulting in a lighter more compact ring structure. The smaller ring also results in a smaller width assembly fixture/transporter, thereby minimizing the required spacing between the Wind Restraint System cables.

A possible disadvantage of the small ring is the requirement to disconnect the Centaur upper air-conditioning umbilical during part of the payload and Burner II erection process due to physical interference. The effect of distupting the flow of conditioning air to the Centaur upper equipment section must be evaluated. A potential solution, if continuous air conditioning is rquired, will be to temporarily insert a special, narrow-width extension adapter between the vehicle and the air-conditioning umbilical connector which can be cleared by the internal diameter of the ring.

Additional factor affecting the size of the ring, and consequently the launch pad structure, is the configuration of the nose shroud at the transition from the 168-inch diameter to the 132-inch diameter. The effects on the ring and pad structures must be reevaluated if any changes are made in the future to the shroud configuration.

Erection Loads on the Nose Shroud. The full weight of the nose shroud is carried by the three lift cable brackets, positioned 120 degrees apart, during the erection at the pad. These brackets transmit the erection loads to the two lower, 186-inch diameter internal shroud rings, the shroud skin, and adjacent external stringers. The capability of the shroud structure to meet these concentrated loads with minimum weight penalty must be evaluated. A potential means of modifying the load distribution is to use six lift cable assemblies retained as installed during individual shroud segment installation on the assembly/transporter.

Umbilical Retraction System. It was assumed in this study that a lanyard system would be used to retract the payload and Burner II electrical umbilicals similar to the system proposed in the Titan III/Improved Centaur Integration Study for the Centaur upper electrical umbilicals. Because all the umbilicals are connected at the same disconnect panel located near the Centaur forward electronic compartment, the possibility of using a common retraction system should be investigated. Such a system must be compatible with requirements to connect the Centaur umbilicals in the Vertical Integration Building after stage erection, and the payload and Burner II umbilicals at the pad.

Centaur Forward Compartment Venting Provisions. NASA-Lewis Research Center drawing No. CR 600319 shows provisions for venting the Centaur forward electronic compartment. These provisions include a series of internal ducts venting out through openings in the 168-inch diameter of the nose shroud. The effect of this ducting on the handling and erecting of the encapsulated payload and Burner II must be investigated and the mechanical interfaces must be defined.

2.7.3.3 Launch Facility Modification.

The Titan III launch complex is adaptable with minor modifications, to support the preparation and launch of the Burner II and payload. These modifications have been analyzed and conceptual designs were prepared. The analysis was based on the Launch Complex 41 configuration as modified to accommodate the Improved Centaur. This configuration was described in Volume II, Part I of the Titan III/Improved Centaur Integration Study (Contract NAS8-8718). It was recognized that that study considered only the 132-inch diameter nose shroud.

The modifications proposed in this study, which include the Burner II umbilical installations and servicing access requirements, are consistent with an objective stated in the referenced study, of restoring the pad to the Titan IIIC configuration within a five-day conversion period.

Modifications to the Missile Service Tower (MST), and the Umbilical Tower (UT) are shown on Figures 2.7-23 and 2.7-24. These modifications will accommodate the 168-inch diameter Standard Centaur Nose Shroud, and the provisions for erecting mating and launching the encapsulated payload and Burner II. These modifications are in addition to those defined in the Titan III/Improved Centaur Integration Study.

2.7.3.3.1 Mobile Service Tower Modification. The 13-foot octagonal cutouts in the folding sections of UES platforms 12 and 13 interfere with the 168-inch diameter of the nose shroud. These sections, even if raised, do not provide sufficient clearance for installation of the shroud and eventual removal of the tower. The platform 13 folding section must be removed and replaced with two new hinged platforms as shown in Section B-B, Figure 2.7-24, to provide access for removing the payload and shroud handling sling and lift cables.

Similar folding sections will be required on platform 12 if access is required to the full length of the shroud vertical split lines.

The platform 11 folding section cut-out is adequate for clearance around the lower section of the Centaur fairing. However, it must be modified to fold up 90 degrees instead of 85 degrees to clear the upper nose shroud before removing the MST prior to launch.

2.7.3.3.2 Umbilical Tower Modification. The folding sections of UT platforms 12 and 13 interfere with the nose shroud like the corresponding platforms in the UES. Unless UT platform 12 is required for access to the nose shroud split line, it may be kept in the retracted position during the erection, checkout, and servicing of the launch vehicle.

UT platform 13 is required for removal of erection equipment, shown on Figure 2.7-23. To provide this access, the folding sections of the platform may be removed and a guard rail installed on the end of the sliding section. This section will provide adequate access to the shroud split line. If such access is required, platform 12 can be modified in a similar manner.

Electrical umbilicals are required on the UT for both the payload and Burner II. Only the Burner II requirements are shown in Figure 2.7-23. A 36 by 36 by 8-inch electrical junction box is required above UT platform 11. This box may be installed on the east side of the tower, north of the sliding platform. It is assumed that a drop-weight, lanyard retraction system will be used similar to the system described in the Titan III/Improved Centaur Integration Study. A similar system can be used for Burner II and payload air conditioning umbilicals which must also be installed on the tower.

A hydrogen peroxide (H_2O_2) overboard drain must be installed on the UT to protect against possible H_2O_2 leakage at the Burner II fill and drain fitting. It will be installed on the tower as shown in Figure 2.7-23. A flexible drain line from the container will be taped to the Burner II air-conditioning duct. The drain line will be connected to a self-sealing disconnect fitting on the nose shroud. This drain line will be retracted with the air conditioning duct.

2.7.3.4 Launch Control and Checkout Equipment.

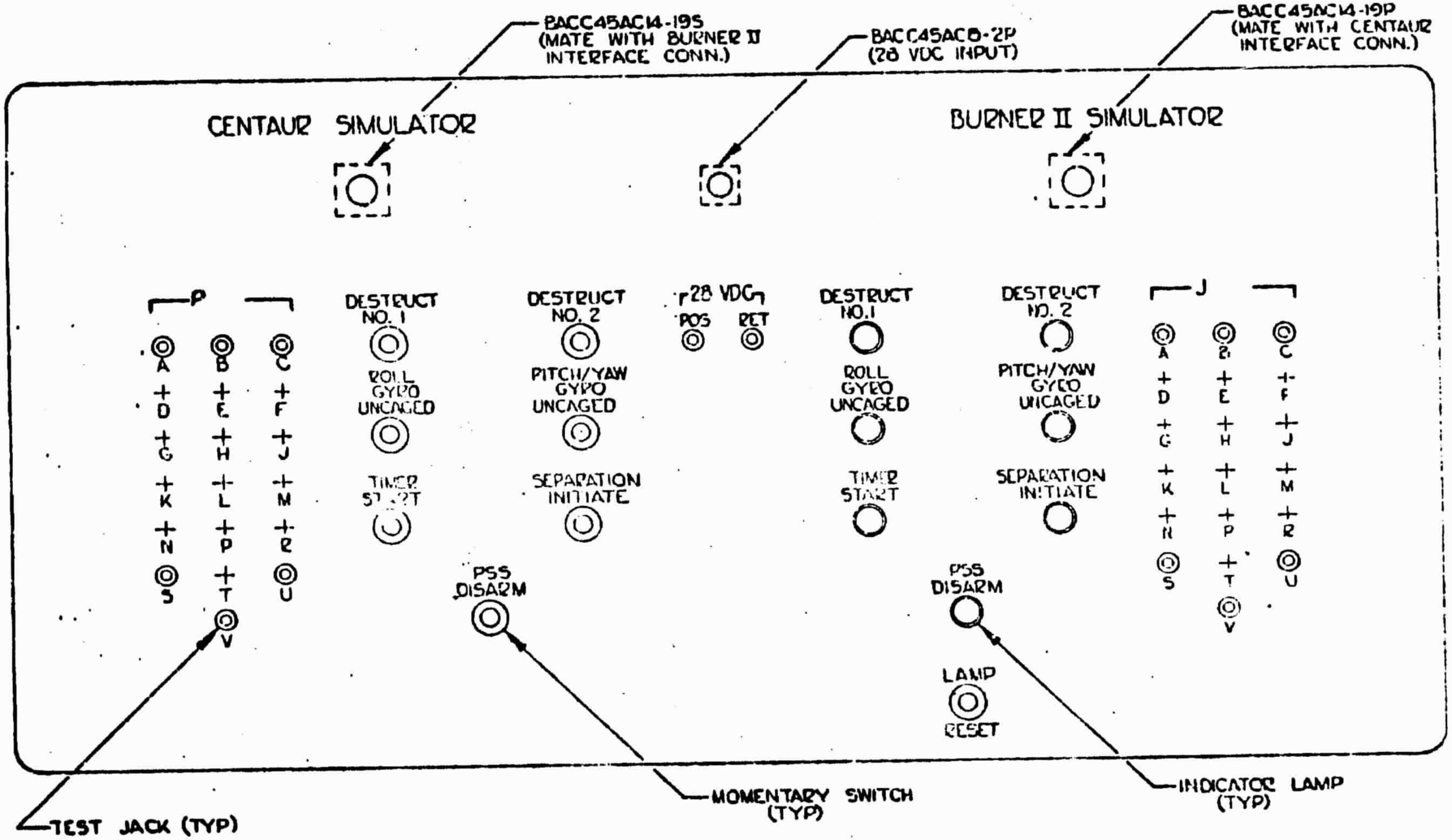
In addition to the existing LCCE described in Section 2.7.3.4, two new portable simulators will be required as follows:

2.7.3.4.1 Burner II/Centaur Simulator. Figure 2.7-26 shows the proposed conceptual design for a Burner II/Centaur Simulator which will provide the capability for simulating Burner II signals when connected to Centaur at the interface connector and for simulating Centaur signals when connected to Burner II at the interface connector. The simulator will be in a portable suitcase similar to the Burner II/Thor Simulator shown in Figure 2.7-27.

2.7.3.4.2 Payload Simulator. Figure 2.7-28 shows the proposed conceptual design for a Payload Simulator which contains test jacks for continuity testing of the payload umbilical and verifying payload separation signals transmitted from Burner II to the payload.

2.7.4 GSE Integration

Wherever possible the Burner II Ground Support Equipment will be fully integrated with the Burner II, Centaur and nose shroud before delivery to the ETR. Integration will be accomplished by performing all feasible interface verification in Seattle using actual, simulated or mocked up equipment. Additional discussion of GSE integration is presented in Section 2.10.



BURNER II/CENTAUR SIMULATOR

FIGURE 2.7-26

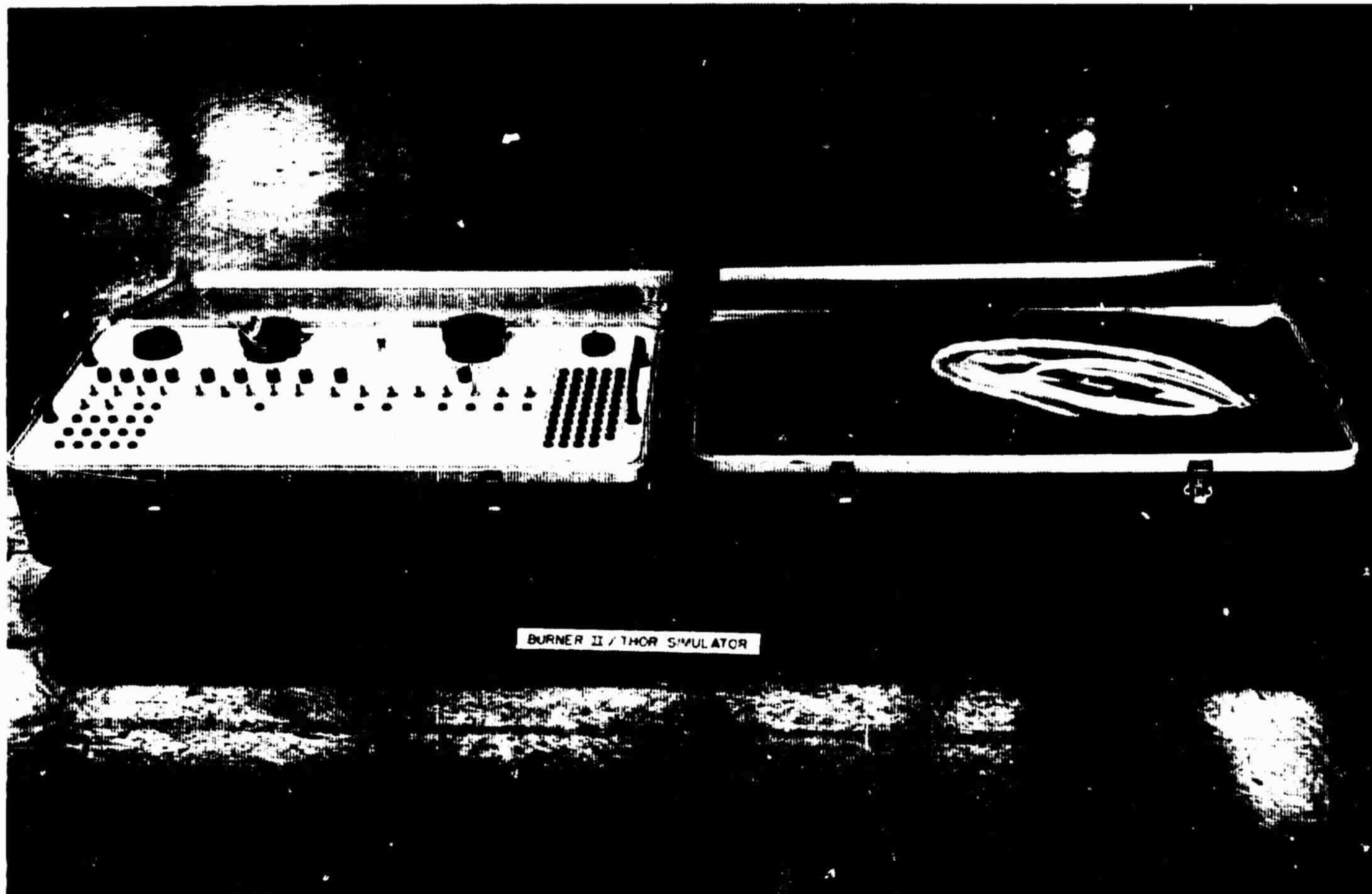


Figure 2.7-27: BURNER II - THOR SIMULATOR

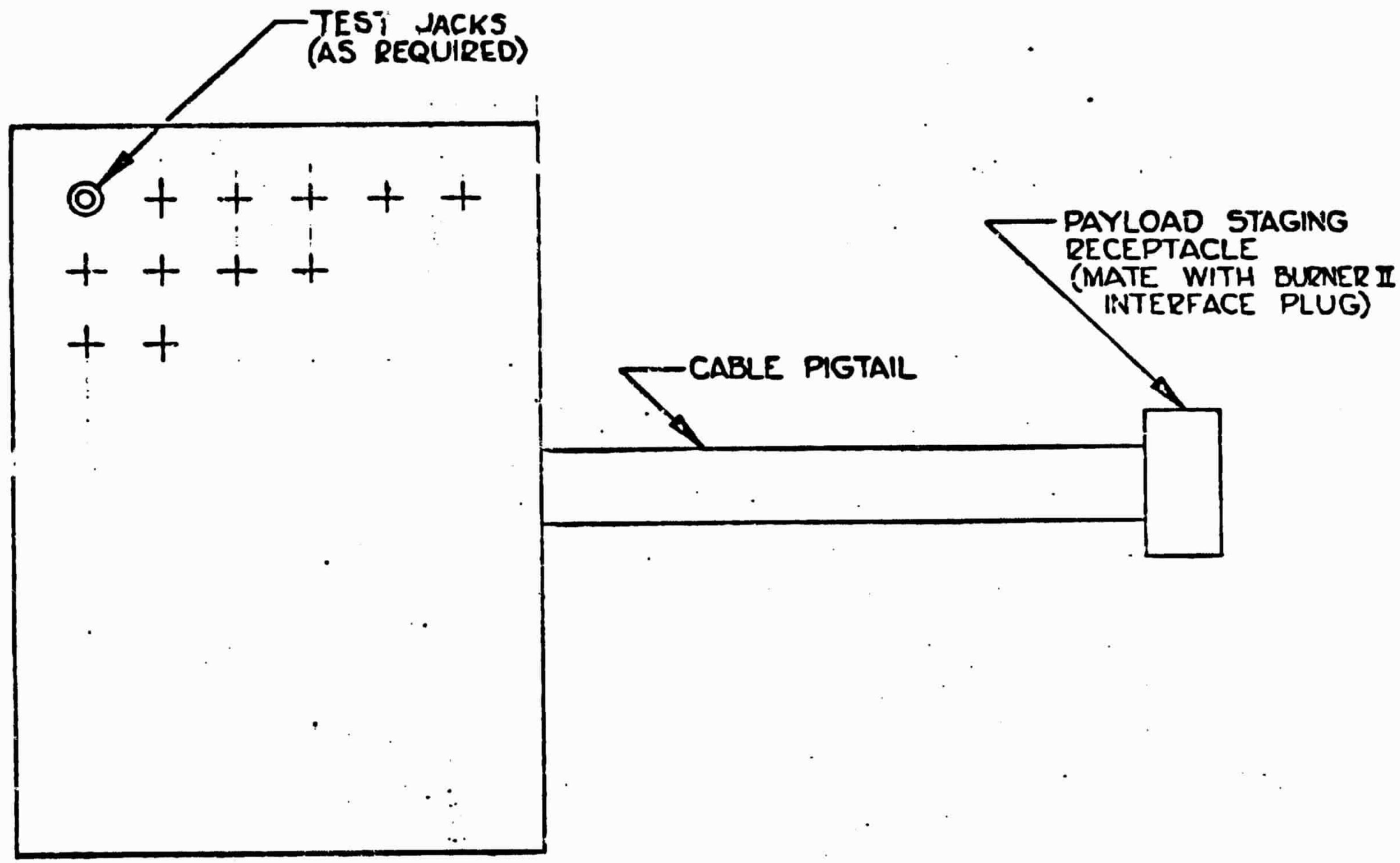


FIGURE 2.7-28 PAYLOAD SIMULATOR

2.7.4.1 Mechanical Ground Support Equipment.

During the Burner II AVE/AGE physical and functional integration testing at Seattle, all items of mechanical GSE will be exercised by performing all processing operations except those which are unique to the launch pad. Field procedures will be used for these operations. Integration of the ground handling equipment with ETR facilities will be accomplished during pad installation of the first vehicle.

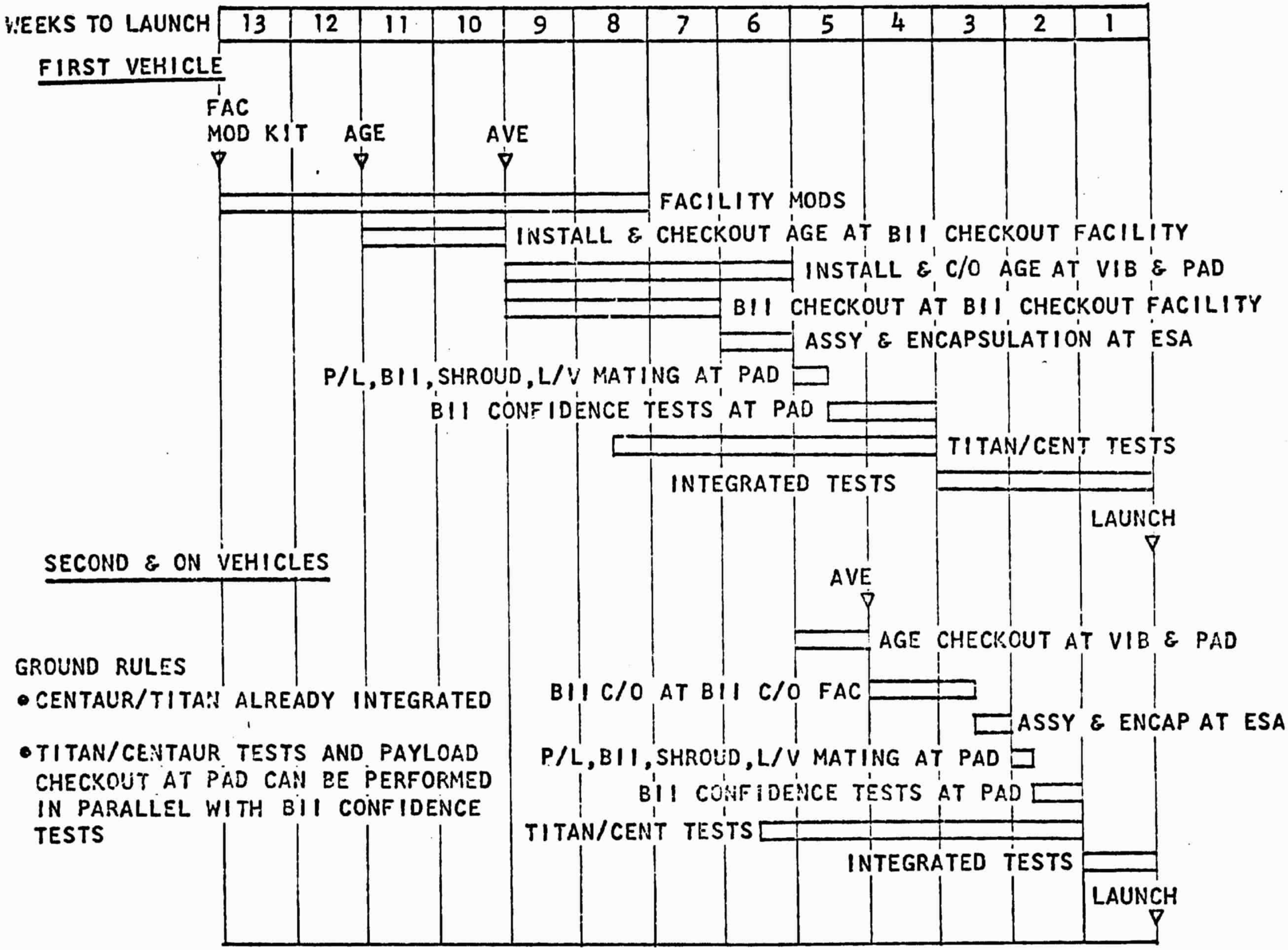
2.7.4.2 Launch Control and Checkout Equipment.

The LCCE and checkout procedures to be used for Burner II processing at ETR are identical to those used for Burner II checkout and integration in Seattle. Thus the equipment designs will be fully integrated with the Burner II before being used at the ETR. The only LCCE interface which must be verified at the ETR is between the DTS and the LCC and LSR. This interface, which is described in Section 7.3.2, will be verified during LCCE Installation and Checkout at the ETR using simulated Burner II monitor signals and electrical loads.

2.7.5 Field Processing Schedule

The schedule shown in Figure 2.7-29 presents the field processing time required to perform the tasks identified in the field processing flow diagrams, section 2.7.1. The schedule is based on the assumption that the Titan and Centaur have previously been integrated and that Titan/Centaur and payload checkout at the launch pad can be performed in parallel with Burner II confidence testing. For second and on launches, the addition of the Burner II adds approximately one-half week to the normal Titan III/Centaur on-pad flow time.

BURNER II/CENTAUR SCHEDULE - AF ETR



2.8 TASK 8 BURNER II GROUND FACILITIES

(Task 8, "Ground Facilities" material is presented as an integral part of Task 7 "Ground Support Equipment" in Section 2.7)

2.9 TASK 9 - RELIABILITY AND SAFETY

This section describes the results of analyses conducted to investigate the reliability and safety characteristics of the Burner II System integrated into the Titan III/Centaur vehicle. The probability of mission success has been estimated and the hazards of the stage are identified for inclusion in subsequent program planning.

2.9.1 Reliability

The analysis performed indicates that the Burner II vehicle, integrated with the Titan III/Centaur vehicle can perform a synchronous equatorial mission with a high probability of success, comparable to that of the Standard Burner II Mission.

The requirements of the prediction analysis provide a basis for reliability numerical requirements, and a source for a comparative evaluation of the configuration and mission concepts considered in the integration study, with other possible configuration and missions.

2.9.1.1 Analysis

A preliminary analysis has been performed, and the Burner II reliability for the Titan/Centaur synchronous equatorial mission has been estimated to be .955, as indicated in Figure 2.9-1; this value is based on flight and test data and is not considered the maximum reliability potential but is an estimate for the first Titan/Centaur/Burner II flight. The analysis is based on the basic Thor/Burner II mission analysis adjusted for differences in boost environment and mission time differences for time sensitive equipment. The modifications to the Burner II basic design, (primarily interface and minor design changes to the Guidance and Control equipment) have been included.

The Burner II Space Vehicle is considered a flight proven system, based not only on its flight performance of eight successful missions out of eight launches*, but also based on the successful performance of its components on other programs. In particular, similar Walter Kidde Reaction Control equipment has flown successfully in 98 Scout flights (2 complete Reaction Control Subsystems per vehicle), and similar Guidance and Control equipment, manufactured by Honeywell, has flown successfully in 172 flights (combined Thor-Delta, Scout, and Burner II flights).

2.9.1.2 Effects on Van Allen Belt Radiation

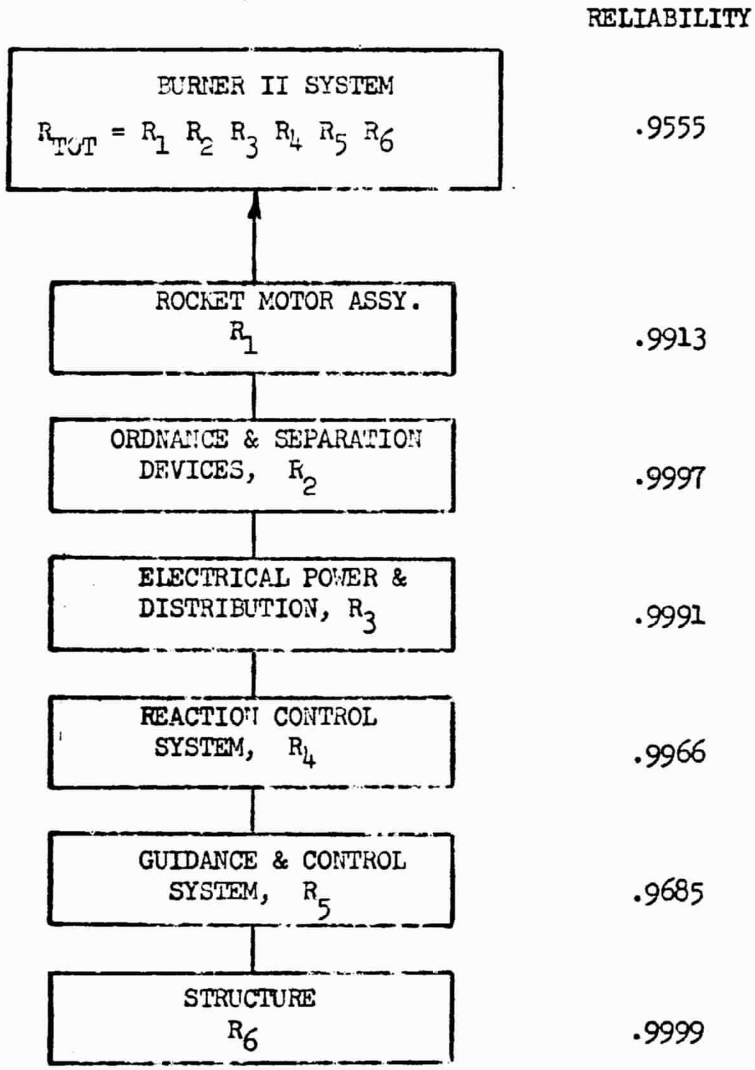
An evaluation of the natural radiation environment encountered by the Burner II vehicle while passing from a 100 nautical mile circular orbit to synchronous altitude has been made, and it was determined that the typical total radiation doses, received under 20 mils of aluminum during the transfer maneuver, range from 1 to 1000 rads (Si). These radiation levels are not expected to result in any deleterous effects on the Burner II electronics system.

*A ninth flight, the SESP 68-1 mission, an Atlas/Burner II vehicle does not constitute a Burner II test since a nose fairing failure prior to Burner II operation precluded the mission continuance.

BURNER IIA SYSTEM RELIABILITY

BLOCK DIAGRAM

SYNCHRONOUS EQUATORIAL MISSION



GROUND RULES:

- MISSION CONSIDERED TO START AT LIFTOFF AND TO END AT PAYLOAD SEPARATION.
- TELEMETRY IS NOT CONSIDERED ESSENTIAL FOR MISSION SUCCESS.
- EFFECTS OF VAN ALLEN BELT EXPOSURE ON MISSION RELIABILITY HAVE BEEN EVALUATED AND FOUND TO BE NEGLIGIBLE.

FIGURE 2.9-1

A previous study *(of a Centaur/BII for a NASA application) to determine the survivability of the Burner II electronics in a radiation environment created by a SNAP Generator (RTG), indicated that for a worst case evaluation (minimum shielding of parts, with these operating in their most vulnerable mode) and for a critical mission of 24 hours, Burner II could survive the radiation exposure with no changes in circuitry or parts.

The Burner II exposure to the Van Allen Belt environment during a Titan/Centaur/Burner II synchronous equatorial mission is considered less severe that that created by the RTG, further confirming that the effects of natural radiation on Burner II are not significant. The study indicates that the most vulnerable Burner II equipment has a damage threshold of 5.0×10^8 neutrons/cm^2, while the worst proton exposure due to natural radiation is approximately 107 protons/cm^2. As the protons are less effective than the neutrons, the natural radiation is more than one order of magnitude away from the Burner II equipment damage threshold.

It should also be noted that Lunar Orbiter Vehicles, having electronics design characteristics similar to those of Burner II (solid state components with no special shielding), encountered no problems while traversing through the Van Allen Belt.

2.9.2 Safety

A preliminary safety analysis has been performed to investigate the gross hazards of the Burner II system as integrated into the Titan III Centaur vehicle, for the purpose of identifying safety requirements and provisions and evaluating the safety elements of risk related to the integration task. The analysis has included a review of the safety characteristics and hazards of the Burner II system, and an evaluation of the effects of the integration on Burner II safety, with considerations for vehicle assembly, and for interfaces with the shroud, AGE, and the launch facility.

2.9.2.1 Analysis Results and Recommendations.

The analysis indicates that the hazards to be encountered during the integration task are typical of current missile and space systems involving ordnance devices, solid and liquid propellants, and pressurized systems, and that the integration can be performed by currently accepted techniques and within the normally acceptable risk limits for unmanned space systems.

It is noted however, that the following integration phase will require a detailed safety analysis requiring well defined payload characteristics, detailed operating procedures, and event sequences for Titan, Centaur, Burner II and Payload field operations, as system safety is not only dependent on the evaluation of gross hazards but also on attention to details of the system.

*Boeing internal memo. Copy was provided at the first Progress Review and was included in the package of internal Boeing analyses provided to the Centaur Study Manager at the second Progress Review.

Possible total system safety hazards due to Centaur integration with Titan III (I.e. effect of combinations of possible failures from all stages) have not been included in this analysis.

2.9.2.2 Typical Burner II Hazards.

The hazards inherent to the Burner II system are identified in the "Burner II System Safety Analysis" Document, D2-82667-1. These hazards are minimized and controlled by Burner II design safety characteristics and by proven operating procedures with considerations for equipment and personnel safety. For the Burner II/Centaur integration task, most of these hazards remain unchanged, and as such, will be minimized and controlled in a manner identical or similar to that of Burner II, as integrated to the Thor booster. There are, however, safety problem areas peculiar to the Burner II integration with Titan Centaur, which will demand special considerations during detail design activities and during preparation of detailed field operating procedures.

2.9.2.3 Assembly, Checkout and Encapsulation of Burner II.

Burner II hazards during this phase of the integration are primarily typical for Burner II operations for any vehicle, and are controlled as indicated above, Additional hazards due to changes in AGE, handling equipment, etc., are common to Aerospace System Transportation and Handling Operations, and are not significant, although they will require detailed safety considerations, such as grounding and bonding requirements, special hoisting controls requirements, rocket motor and pyrotechnic safety considerations, etc. Safety requirements due to interfaces with the payload are discussed in Section 2.9.2.7

Due to the conditions within the nose shroud, all operations for Burner II assembly, test and fueling within the shroud will require particularly good lighting, to prevent accidents to personnel, and possible equipment damage; the electric lighting required will be of an explosion-proof type to eliminate possible incidents in the event of a hazardous atmosphere caused by possible gas leakage from the payload, cleaning solvents, etc. This explosion-proof lighting will also be required during integration tasks with Centaur/Titan III, as an explosive atmosphere could also be created by LH_2 leak, spillage or venting from Centaur.

2.9.2.4 Propellant Incompatibility

The Titan III fuel, A-50 (UDMH/N_2H_4), and oxidizer (N_2O_4), and the Centaur LH_2 fuel can present safety hazards during the integration with Burner II.

The Titan III oxidizer (N_2O_4) in contact with moisture becomes nitric acid (HNO_3) which is highly corrosive. During Titan III down-loading of the N_2O_4, a large cloud is vented to the atmosphere and with adverse weather conditions, N_2O_4 or HNO_3 could settle on Burner II components and start corrosive action. Even if a N_2O_4 vent stack burner is used, N_2O_4 environment can still be expected in the vicinity of the vehicle due to leakage or spillage. Burner II equipment has not been designed specifically to withstand an HNO_3 corrosive atmosphere, and has not been evaluated against corrosivity specifications similar to those used for Titan III. To prevent the possibility of Burner II equipment damage, it is recommended that positive pressure be maintained within the Burner II compartment within the nose shroud during any time when a corrosive atmosphere may be present. This can be performed by the operation of the air conditioning from the time of "Wet Mock" during launch operations until liftoff.

The Titan III fuel, A-50 ($UDMH/N_2H_2$) is hypergolic with the Burner II Reaction Control H_2O_2. This creates a potential hazard for the integration task. A similar hazard, however, already exists with the Titan III/Centaur integration, as Centaur also required H_2O_2, in a much larger quantity than Burner II. Precautions required for the Centaur H_2O_2 fueling will be reviewed for incorporation into the Burner II detailed field operating procedures.

In particular, the Burner II H_2O_2 relief tube and container will be designed so there is no possibility of spillage prior to or during liftoff. It should be noted that during field operations of Burner II there has never been an H_2O_2 pressure rise requiring the actuation of the relief valve.

Any possible thermal or chemical incompatibility of Burner II with the Centaur LO_2 and LH_2 propellants will be counteracted by the relative isolation of Burner II from Centaur as the air conditioning and the debris shield with the lower encapsulation barrier will provide a thermal shield and positive pressure which will prevent oxygen and/or hydrogen from entering the Burner II area. The effects of gravity on any Centaur leakage will provide additional thermal protection for Burner II equipment.

2.9.2.5 Burner II/Centaur Electromagnetic Compatibility

The compatibility of Burner II with electromagnetic environment generated by Cenatur has been investigated in detail in Task 6; the analysis which includes an evaluation of the Burner II/Centaur interface signals, the Burner II and Centaur grounding systems and major Centaur RF sources, indicates that no safety problems should be anticipated. The design of all Burner II ordrance circuitry has been based on standard safety practices, in concurrence with military safety requirements (twisted wire pairs, grounded shielding, routing close to structure, etc.) and is considered non-sensitive to EMI; use of relays for power isolation, and use of diode suppressors for circuit protection provide additional safety features for the ordnance. It should be noted that all ordnance items (including rocket motor igniter initiators), selected for Burner II are rated as one amp, one watt no fire (for 5 minutes) and have also a very low sensitivity to high voltage currents.

2.9.2.6 Burner II RCS Fueling

Fueling the Burner II Reaction Control System within the nose shroud presents some hazards not previously encountered in Burner II. The following special safety considerations will be required for protection of personnel and equipment against the possibility of RCS propellant (H_2O_2 and N_2) leakage and/or spillage:

1. A protective scupper similar to the one used on Burner II during the SESP 68-1 mission fueling operation will be required to contain possible H_2O_2 leakage or spillage from the quick disconnect; the hose from this scupper will drain the H_2O_2 into a closed container with water, if possible outside the shroud.

2. The debris shield and the lower encapsulation barrier should be designed to provide protection of Centaur equipment against H_2O_2 and/or water, and should provide a means of draining or of collecting the liquid in a sump for ease of removal in an emergency.

3. A drip pan with water will be provided to protect the tower and equipment below from possible H_2O_2 spillage or leaks during fueling operations.

4. At the RCS servicing level on the tower, a personnel shower, eyewash and available water (with a garden type hose, compatible with H_2O_2, hand control valve and nozzle) will be provided for emergency use.

5. Due to the close quarters within the Burner II area with the shroud, and the relatively low maneuvering space during a possible emergency, the use of extended lanyards for uncoupling the RCS quick disconnects will be considered during the detail design phase.

6. After the RCS system has been pressurized, the air conditioning system must be in operation for at least several minutes prior to personnel entering the Burner II nose shroud area, to eliminate possible hazards in the event of N_2 leakage.

Detailed safety procedures and requirements already incorporated into the Burner II field operating procedures for RCS fueling operations will also be incorporated into the Burner II/Cenatur integration; these include considerations for grounding of the service cart, securing of pressurized lines, special valve operation sequences for safe fueling and defueling, use of protective clothing, etc.

2.9.2.7 Payload Interfaces

A safety evaluation of the interfaces of Burner II with the payload requires data not presently known about the payload characteristics. The evaluation should include Payload/Burner II safety considerations in the following areas; as applicable.

- Fuel, oxidizer and other propellant incompatibilities
- Thermal incompatibilities
- Air Conditioning incompatibilities
- Radiation and/or EMI incompatibilities
- Hazardous materials
- Pressurized systems
- Ordnance systems
- Grounding and bonding characteristics
- Mechanical stored energy
- Hazardous operations
- Payload field assembly, test and operating procedures.
- Mechanical and/or electrical interfaces.

2.10 TASK 10 COST AND SCHEDULES

(This material is presented in Volume II of this document.)

1. Request for Proposal NASA C-201383-Q, December 13, 1968

2. D2-116082-1 "Management Proposal - Burner II Integration Study", February 3, 1969

3. D2-116082-2, "Technical Proposal - Burner II Integration Study, " January 31, 1969

4. D2-116082-3, "Study Plan - Burner II/Centaur Integration Study", May 29, 1969.

5. D2-116082-4, "First Progress Report - Burner II/Centaur Integration Study", June 19, 1969

6. D2-116082-5, "Integration Plan and Costing Ground Rules - Burner II/Cenatur Integration Study," August 19. 1969

7. D2-116082-6, "Second progress Report - Burner II/Centaur Integration Study", September 4, 1969

8. M2-82601-5, "Mission Planners Guide to Burner II", April 1968