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Final report
D180-27677-2

Definition of Technology Development Missions for Early Space Stations

Large Space Structures
Phase II

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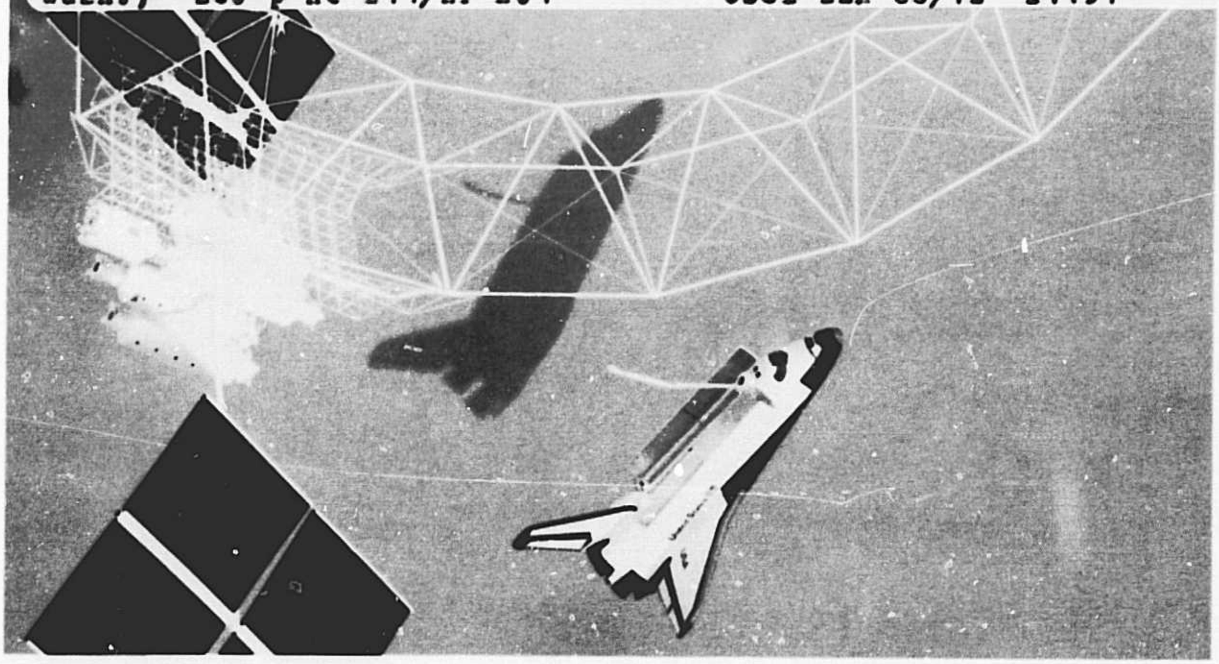

November 30, 1984

BOEING

DEFINITION OF TECHNOLOGY DEVELOPMENT MISSIONS FOR EARLY SPACE STATIONS

LARGE SPACE STRUCTURES

Contract NAS8-35043
PHASE II

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FINAL REPORT

November 30, 1984

Prepared for the

National Aeronautics and Space Administration
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FOREWORD

This report presents the results of Phase II of a study entitled, "Definition of Technology Development Missions for Early Space Stations - Large Space Structures". The study was conducted for the NASA George C. Marshall Space Flight Center, Huntsville, Alabama by The Boeing Aerospace Company, Seattle, Washington. The work was performed under contract NAS8-35043 during the period from July 1, 1983 through November 30, 1984, and was monitored by James K. Harrison of NASA. Mr. Richard M. Gates of Boeing was the Study Manager for the program. Detailed design of the technology development mission concepts was accomplished by Mr. Kenneth P. Hernley. The operations trade studies and operational analyses were performed by Mr. George Reid. He and Mr. D. C. Akers conducted the programmatics tasks. Mr. K. B. VerGowe provided the cost analyses for each of the technology development missions.

The authors of this report, Mr. R. M. Gates and Mr. G. Reid, wish to express their thanks to each of the contributors mentioned above for their technical contributions as well as their support to the program.

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1.0 INTRODUCTION

The ever increasing thirst for knowledge of the Universe and our planet Earth has led to the necessity for larger, more accurate space systems. The development and implementation of the Space Shuttle to provide transportation to low Earth orbit has provided an important step in the development of these large systems. The next step is to provide a place in low Earth orbit to construct these systems and to determine the technical needs for space construction. The costs involved in larger, more precise instruments are too great to accept the all-or-nothing philosophy of launching an automatically deployable satellite system which cannot be fully tested and checked out on Earth.

The use of the Space Station as a construction site will not only reduce the risks involved by providing on-the-spot test and checkout but also allow the design to be less complicated through the use of assemblable structures instead of the more complex automated systems. Advancements in space suit technology will make human involvement in the construction of large space systems more routine. The Space Station crew will be able to react to contingencies and make adjustments and repairs before the spacecraft becomes operational.

The objectives of this study were to define the testbed role of an early Space Station for the construction of large space structures. This was accomplished by defining, in more detail, the LSS technology development missions (TDMs) identified in Phase I of this program. Design and operations trade studies were used to identify the best structural concepts and procedures for each of the TDMs. Details of the TDM designs were then developed along with their operational requirements. Space Station resources required for each mission, both human and physical, were identified. The costs and development schedules for the TDMs provide an indication of the programs needed to develop these missions.

The results of this study point out the need to rely on the resources of the Space Station in the design of large space structures so that they can be constructed and checked out at the Space Station. It also identifies the need to design into the Space Station the necessary resources to accommodate LSS construction.

2.0 MISSION SELECTION

The first step in the design of large space structures (LSS) technology development missions (TDMs) is the determination of mission requirements. This was accomplished in Phase I of this study by identifying future missions which require large space structures, the timing of those missions and the objectives which must be demonstrated to advance the technologies necessary to bring them to reality. These objectives were used to define TDM requirements. Four TDMs were identified which demonstrate the objectives and requirements of future LSS missions.

The resulting LSS mission objectives and requirements were reviewed and amended in Phase II. The final selection of large space structures TDMs to be studied in detail in Phase II was made following an evaluation of candidates, including the TDMs identified in Phase I, against this criteria. The criteria used to select these missions and a description of each TDM are documented in the following sections.

2.1 Selection Criteria

The criteria used for TDM selection includes the technology development mission objectives identified in Phase I. Additional criteria include the benefits of long term missions to engineering and science, the demonstration of Space Station capabilities and the desirability of high technical return on the investment. The selection criteria is summarized in figure 2.1-1.

First, the missions must demonstrate the technology advancements which are needed to satisfy the objectives of future spacecraft requiring the use of large space structures. These objectives include large space systems construction which encompasses the techniques required for structural deployment, assembly and fabrication. This includes the development of advanced materials for use in future space systems. Many future space systems will require high precision and high stiffness to fulfill their mission requirements. Following the construction of the structural assembly, the subsystems and utilities which are not an integral part of the structure must be installed. One of the tasks which is common to a variety of large space systems, particularly antennas, is the installation of membrane reflector surfaces. Subsystem installation will be a time consuming process involving significant EVA or remote manipulation.

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Demonstrate technology development mission objectives Space deployment or assembly of large space structures Space assembly of rigid, high-precision structures Installation and checkout of subsystems on LSS Installation of membrane surfaces on large aperture antennas Precision control of LSS (pointing and figure control) Adaptive optics; assembly, test, calibration and control of large multi-mirror surface Demonstrate man's role and capabilities in space Materials development
Provide long term benefit As a scientific instrument As a technology development test bed As a permanent space station facility
Emphasize the benefit of a Space Station Stable construction base Long timeline capability TDM checkout and adjustment Orbit maintenance
Accomplish TDMs at a reasonable cost

Figure 2.1-1 TDM Selection Criteria

Another requirement which must be demonstrated is the precision control of large space systems. This not only involves the overall pointing and attitude control of the space system but also the figure control of critical surfaces such as antenna reflector surfaces and multi-faceted reflectors such as those envisioned for optical and IR telescopes.

The use of the Space Station as a construction site brings another valuable resource to the development of large space structures --- human involvement. The TDMs must be designed to demonstrate the role which humans will play in the process of space system construction and checkout.

Second, the TDM should provide a long term benefit to the development of large space systems or the Space Station, and not be a "dead-ended" experiment. This objective can be accomplished in several ways. The TDM can be designed to be a usable scientific instrument following its use as a technology demonstration mission, or it can be used as a testbed for the development of new and advanced technology, or it can become a permanent Space Station facility which satisfies a need.

Third, the selection of the TDMs must emphasize the need for a Space Station. The attributes of a Space Station which would enhance large space structures development include the ability to provide a stable construction base and the resources necessary for projects which require a longer time than can be provided with the space shuttle. The ability to provide the personnel, instrumentation and materials for system construction, checkout and maintenance will reduce the costs and risks involved with large, expensive systems.

Finally, the TDMs should be capable of demonstrating the required LSS technology at a reasonable cost.

2.2 Selected Missions

This section gives an overview of the technology development missions which will satisfy the mission objectives and other criteria discussed in the previous section.

2.2.1 Construction/Storage/Hangar Facility, LSS-1

Since most mission objectives require a storage location for structure, subsystems and other equipment and a location for assembly and checkout of spacecraft, the construction and storage facility shown in figure 2.2-1 was chosen as a TDM configuration. It consists of a deployable truss platform attached to a transfer tunnel located at a

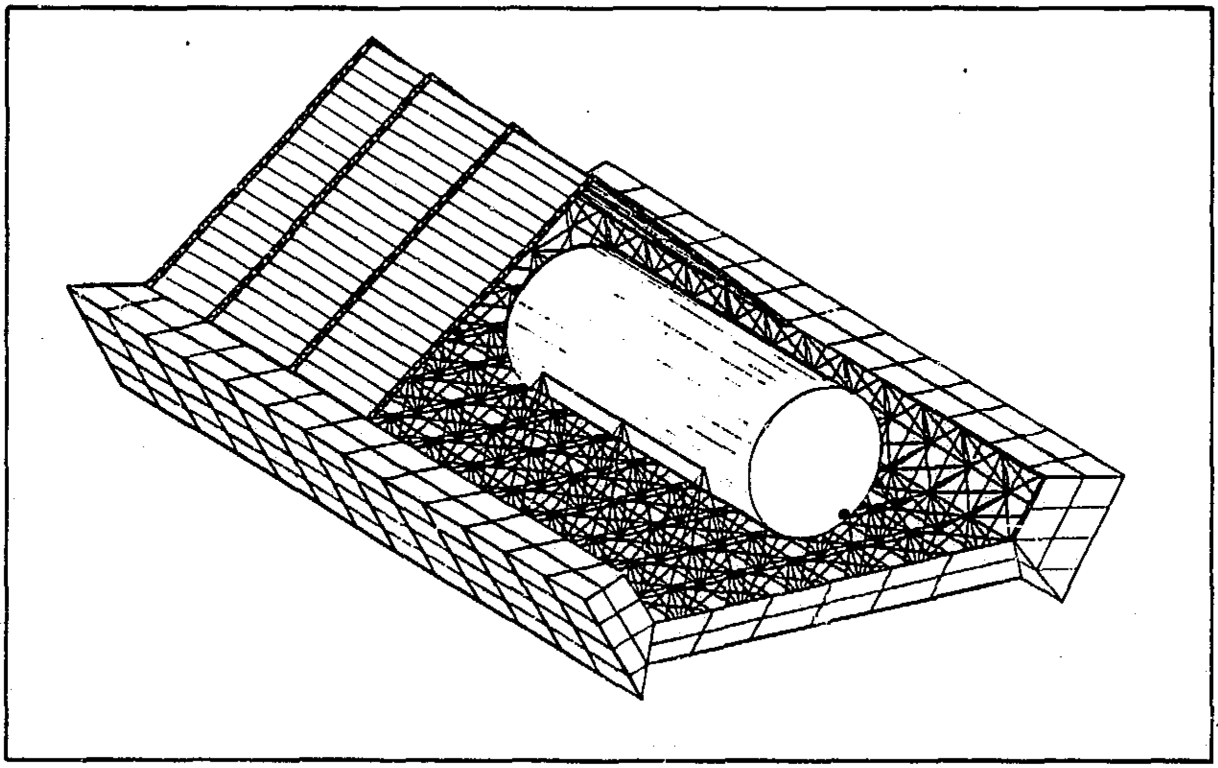


Figure 2.2-1 Construction/Storage/Hangar Facility, LSS-1

docking/berthing port on a Space Station module. A pair of rails supported by truss members would duplicate the orbiter bay longerons for the storage of large modules delivered to the Space Station. Compartments could be installed within the truss members to provide storage for small items such as tools, hold-down mechanisms, auxiliary lights, etc. Segments of the platform could have floor panels installed to provide storage areas for small modules and other equipment. This TDM was combined with a lightweight protective hangar (previously designated as TDM LSS-2) designed to protect EVA astronauts while performing tasks such as satellite servicing and refurbishment. It would protect the crew and equipment from solar heating, would provide containment in the event a small object floated free, and would provide untethered freedom for the crew when fully enclosed. Some of the panels would be permanently attached to the platform while the "roof" is retractable using extendable masts. The hangar would contain lights for illumination during EVA activity.

This TDM will satisfy several of the LSS technology development objectives: deployment and assembly, subsystem installation and checkout, and demonstration of the role of man in space. It is also designed to become a permanent Space Station facility, providing a needed location for future storage and construction.

Further details of the Construction/Storage/Hangar facility are discussed in Section 3.3, Mission Design.

2.2.2 Passive Microwave Radiometer, LSS-3

A large antenna system can be used to demonstrate a variety of mission objectives. The antenna system may serve as a test bed used to evaluate membrane surface installation techniques and various reflector shape control systems. It can also provide maximum benefit by being a functional antenna system upon completion of the technology demonstration. Construction of the antenna system will require both deployable structures and space assembled structures and subsystems.

The antenna system selected is a version of a microwave radiometer spacecraft (MRS) which can provide Earth resources measurements for soil moisture sensing and global crop forecasting. The microwave radiometer was selected as a TDM for several reasons: (1) a MRS of large, but reasonable size (100 meter diameter) can be functionally operated in LEO after the addition of electronic sensing equipment, (2) it doesn't require a gimballed pointing system since both the Space Station and the MRS are Earth oriented, and (3) following its use as a TDM, it can be equipped with control and propulsion subsystems and placed in a higher orbit (600-700 km) to continue its use as a scientific instrument.

The basic configuration of the microwave radiometer spacecraft is shown in figure 2.2-2. The reflector is a spherical segment, 100 meters (328 feet) in diameter, with a spherical radius of 158.6m (520 ft). A 104 meter diameter torroidal ring provides support to the reflector surface control cables as well as continuity between the dish surface and the support columns. The ring will also provide mounting support at nodal attachment points for subsystem modules and the construction fixture. The support ring is of pentahedral truss construction, utilizing 18 meter tapered columns as the structural elements. The deployable feed array truss beam is supported by deployable truss columns and stabilized by four cables attached to the truss ring.

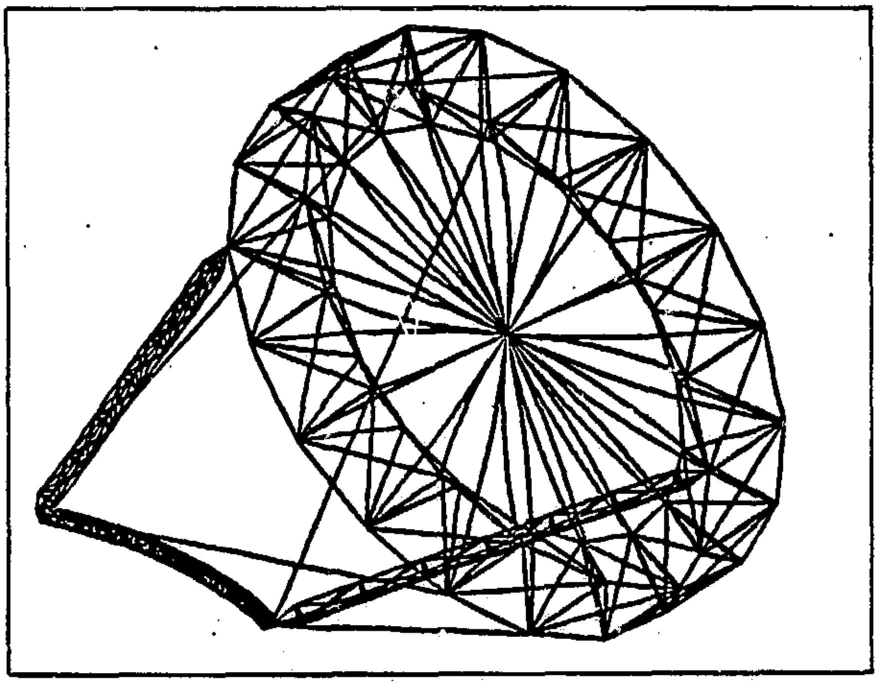


Figure 2.2-2 Passive Microwave Radiometer, LSS-3

The configuration and design details of the radiometer are discussed further in Section 4.3.

2.2.3 Precision Optical System, LSS-4

The precision optical system shown in figure 2.2-3 is a TDM which can be used to demonstrate a number of LSS mission objectives. The optical system requires a high-

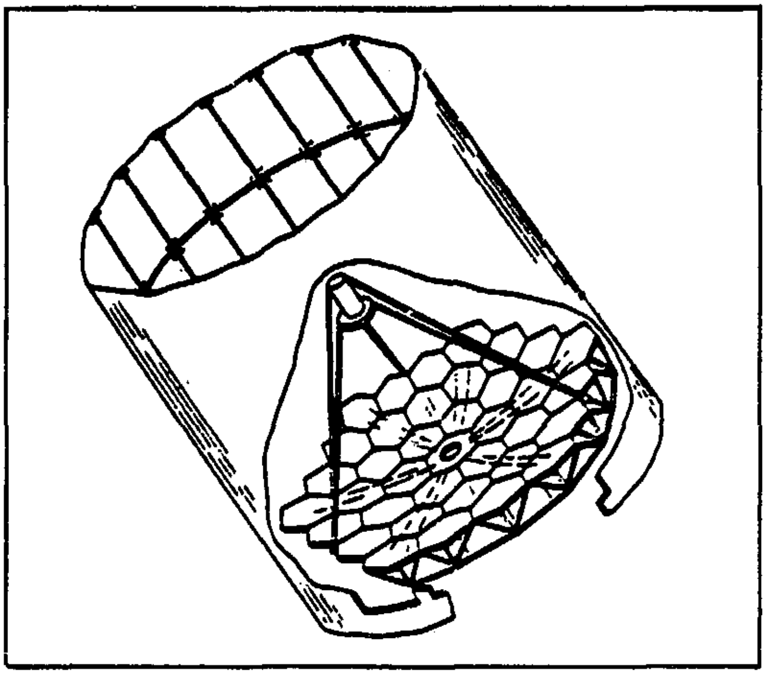


Figure 2.2-3 Precision Optical System, LSS-4

stiffness, accurately shaped truss structure to support a segmented mirror surface. The primary mirror system is envisioned as a modular assembly with each set of seven mirror segments attached on the ground to a deployable/assemblable backing truss. The backing truss is semi-deployable for efficient packaging in the Orbiter. Each module is then assembled at the Space Station and connected to the adjacent module to form the primary mirror array. The secondary mirror is supported by a tripod structure attached to the primary mirror backing truss. The whole instrument is then surrounded with a cylindrical light shield. This TDM demonstrates the deployment and assembly of a rigid, high precision structure and the role of man in this process. The structure can be used to advance the technologies involved with the precision control of segmented surfaces, the inclusion of damping augmentation, and the thermal control of optical systems.

Although the detailed development of this TDM was curtailed half way through the study, more details of this mission are included in Section 5.3.

3.0 CONSTRUCTION/STORAGE/HANGAR FACILITY, LSS-1

This section is a self-contained description of the tasks relating to the development of the Construction/Storage/Hangar Facility, LSS-1. Included in the study are design and operations trades, detailed structural design of the mission, an analysis of the operations required to perform the mission, precursor technology developments which can be accomplished on Earth or with Shuttle flights, and the programmatics of the mission. In addition to these topics, the accommodations which the Space Station must provide to the TDM are identified and, conversely, some of the problems and concerns which the TDM may impose on the Space Station are considered.

3.1 Design Trade Studies

The design issues relating to LSS-1 which were subjected to trade studies relate to the configuration, the materials used and the interfaces with the Space Station. Each will be discussed individually in this section.

3.1.1 Truss Type

Several options exist for the type of truss which can be used for a construction and storage platform: a tetrahedral truss, a pentahedral truss or a hexahedral truss. Plan views of each of these trusses are shown in figure 3.1-1. The tetrahedral truss consists of a repeating pattern of pyramids whose base is triangular in shape. The repeating pattern for the pentahedral truss is also a pyramid, but with a square base. The hexahedral truss is made up of a series of cubes.

Physical characteristics of each type of truss such as mass, stiffness and number of structural elements were calculated to assess their relative advantages and disadvantages. To base the assessment on an equal basis, the physical parameters were calculated per unit area or, in some cases, per unit length. Other characteristics such as the shape of the repeating pattern, the accessibility of the volume within the truss, and the overall complexity, which don't lend themselves to qualitative comparisons were considered in a qualitative assessment.

Figure 3.1-2 gives a summary of trade study results used to determine the type of truss to use for LSS-1. The flexual rigidity is an equivalent plate bending stiffness per unit length, and the frequency parameter is the square root of the bending stiffness

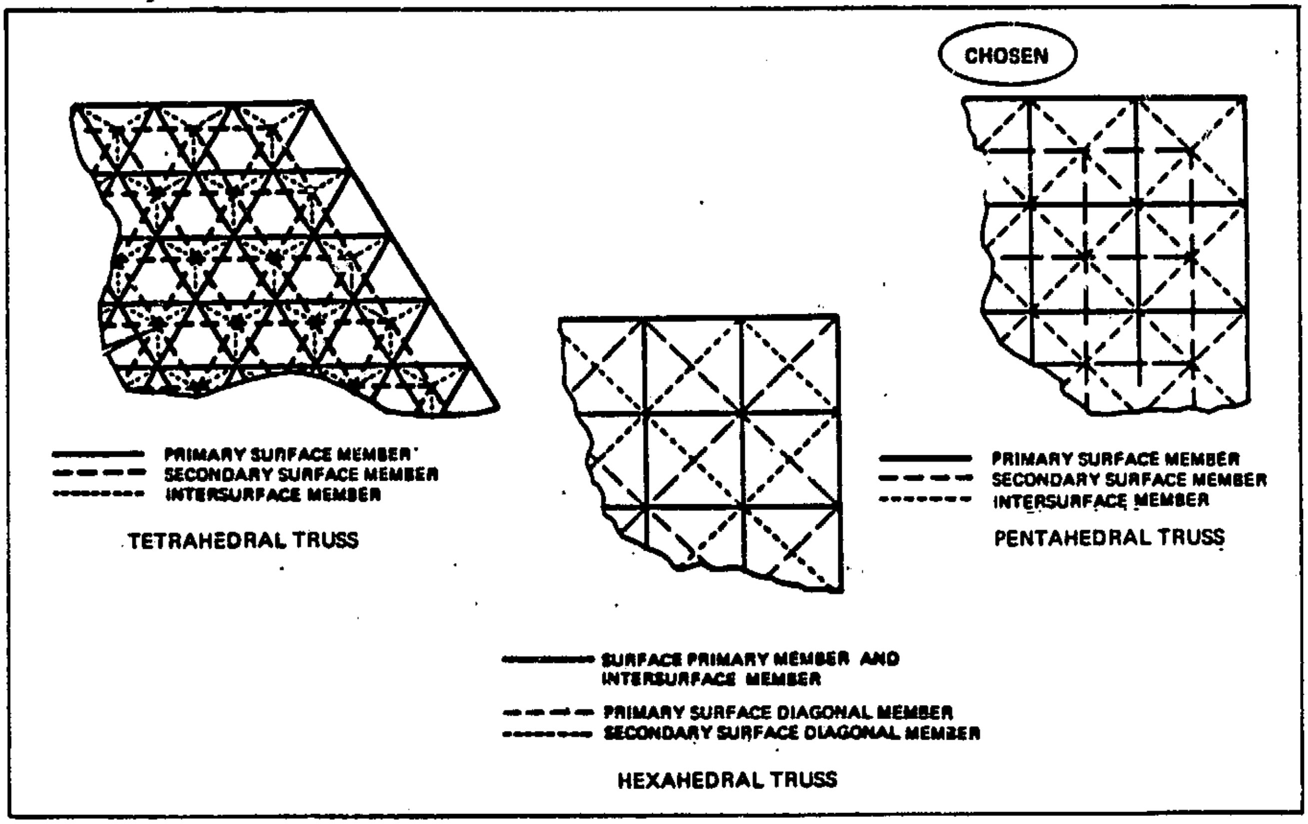


Figure 3.1-1 LSS-1 Truss Type Options

TRADE ITEMS	TETRAHEDRAL TRUSS	PENTAHEDRAL TRUSS (CHOSEN)	HEXAHEDRAL TRUSS
MASS PER UNIT AREA, M (KG/M^2)	1.21	1.22	1.31
FLEXURAL RIGIDITY, D (M-N)	1.15×10^7	1.04×10^7	1.17×10^7
FREQUENCY PARAMETER, $\sqrt{D/M}$	3083.	2920.	2988.
NUMBER OF ELEMENTS PER M^2	2.5	2.4	3.9
NUMBER OF CLUSTER JOINTS PER M^2	.66	.57	.63
NUMBER OF KNEE JOINTS PER M^2	1.66	1.44	1.62
OTHER CONSIDERATIONS:			
SHAPE OF REPEATING PATTERN	TRIANGLE	SQUARE	SQUARE
ACCESSIBILITY OF INTERIOR VOLUME	FAIR	GOOD	POOR
COMPLEXITY	LOW	MEDIUM	HIGH

Figure 3.1-2 LSS-1 Truss Type Comparisons

divided by the mass per unit area which is a relative measure of the structural vibration frequency. Based on these comparisons, the tetrahedral and pentahedral trusses are lighter than the hexahedral truss, the tetrahedral and hexahedral trusses are stiffer than the pentahedral truss, but the frequency parameters are within 6 percent of each other.

The pentahedral truss has fewer elements and joints per unit area than the other two trusses. The square repeating pattern in the truss surface for both the pentahedral and hexahedral trusses is considered an asset because it results in a linear truss edge. The requirement for diagonal shear ties in all faces of the hexahedral truss makes access to the interior of the truss very difficult, while the pentahedral truss provides the easiest access. Because the tetrahedral truss does not require extra shear ties for stability, it is judged to be the lowest in complexity.

The pentahedral truss type was chosen for LSS-1 because it has the lowest number of members and joints, it has low weight, its square repeating pattern is better than a triangular pattern, and it is judged to be less complex than the hexahedral truss pattern.

3.1.2 Truss Configuration

The two candidate truss configurations considered are shown in figure 3.1-3. The choice between a planar configuration and a "winged" configuration is primarily based on qualitative reasoning. Although the planar configuration is somewhat simpler and provides a large flat surface, the storage of modules or equipment on its surface may impair its ability to support construction of large space structures unless the construction fixture was high enough so that stored items were out of the way. The winged configuration reduces this problem by providing a raised attachment point for LSS construction projects. This configuration also has higher overall stiffness and provides a variety of attachment opportunities.

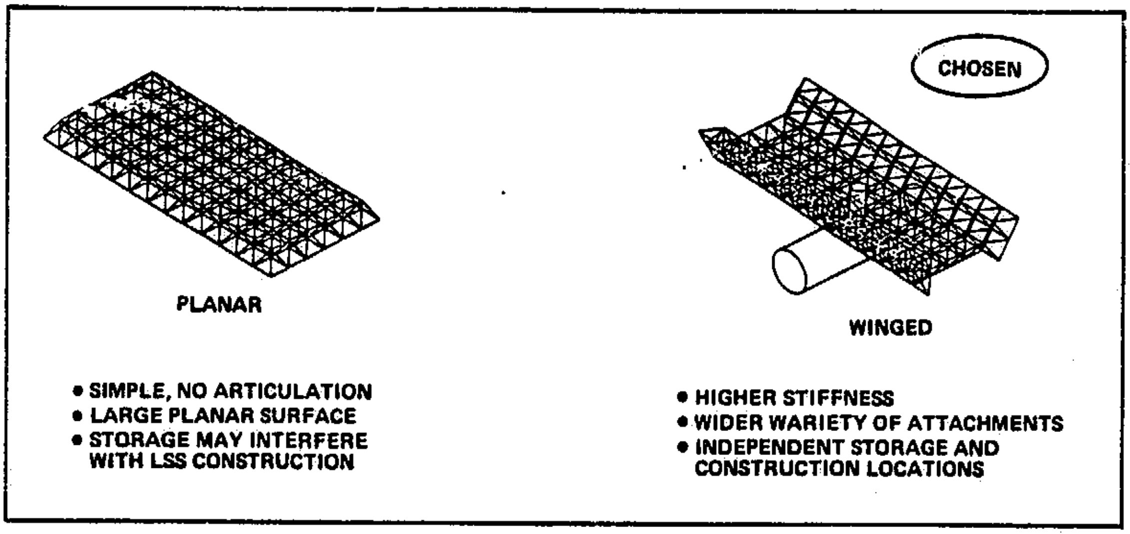


Figure 3.1-3 LSS-1 Truss Configuration Trade Study

3.1.3 Space Station Interface

The options identified for the attachment of LSS-1 to the Space Station, shown in figure 3.1-4, include three methods of berthing port attachment and one for attachment to a Space Station module. The latter is the preferred method of attachment since the platform loads induced by disturbances such as orbiter docking are distributed to many attachment points. This method also results in higher stiffness. Attaching to two or more berthing ports helps to distribute the loads. The single berthing port attachment

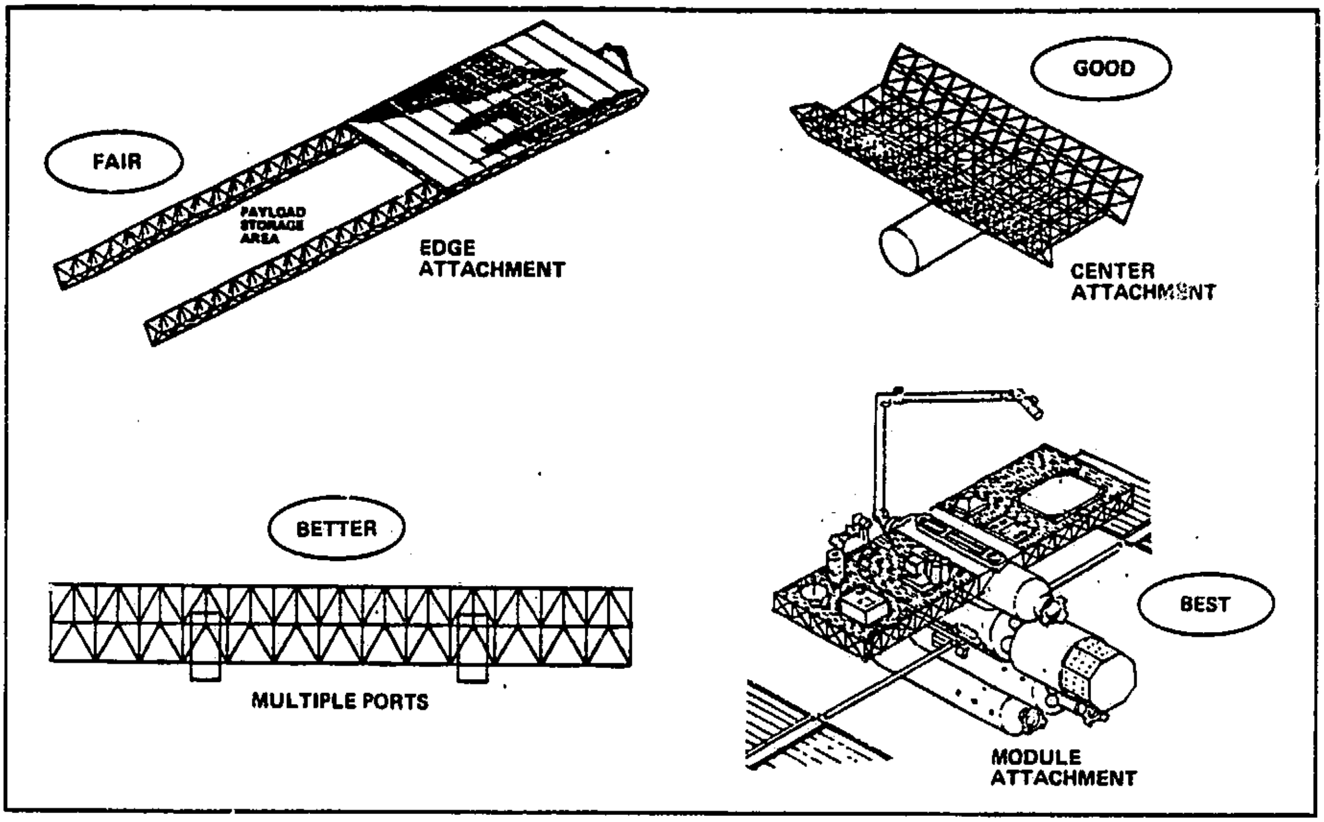


Figure 3.1-4 LSS-1 Space Station Interface Trade Study

scheme results in the highest loads and may require additional bracing to reduce the interface loads.

Since the Space Station is in its design infancy, the center mounted concept with auxiliary bracing (if required) was selected for this study. This design could easily be modified to a different attachment concept at a later date.

3.1.4 Structural Materials

Graphite/epoxy composites were chosen for the structural elements of LSS-1 and invar was chosen for the structural joints and fittings because of their low coefficient of thermal expansion (CTE) and their high specific strength. Although traditional materials such as aluminum are less expensive, the dimensional stability of graphite/epoxy makes it more desirable. Advanced composite materials such as metal matrix composites are also high strength, low CTE materials, but are currently being developed and are expensive. The recent discovery that organic materials may be significantly degraded when exposed to atomic oxygen in low Earth orbit may affect the choice of graphite/epoxy unless a means of protecting it from atomic oxygen can be devised. Additional research in this area is required to quantify this effect.

Thin aluminum sheets were selected for the hangar panels because of the lower cost and ease of manufacture. These panels do not need to carry structural loads and can be attached to the truss so that thermal expansion does not affect the truss. They can also be polished or coated to reflect solar heat.

3.1.5 Hangar Configuration

Figure 3.1-5 shows two candidate configurations for the hangar. The choice of the planar configuration was based primarily on qualitative assessments. Although the cylin-

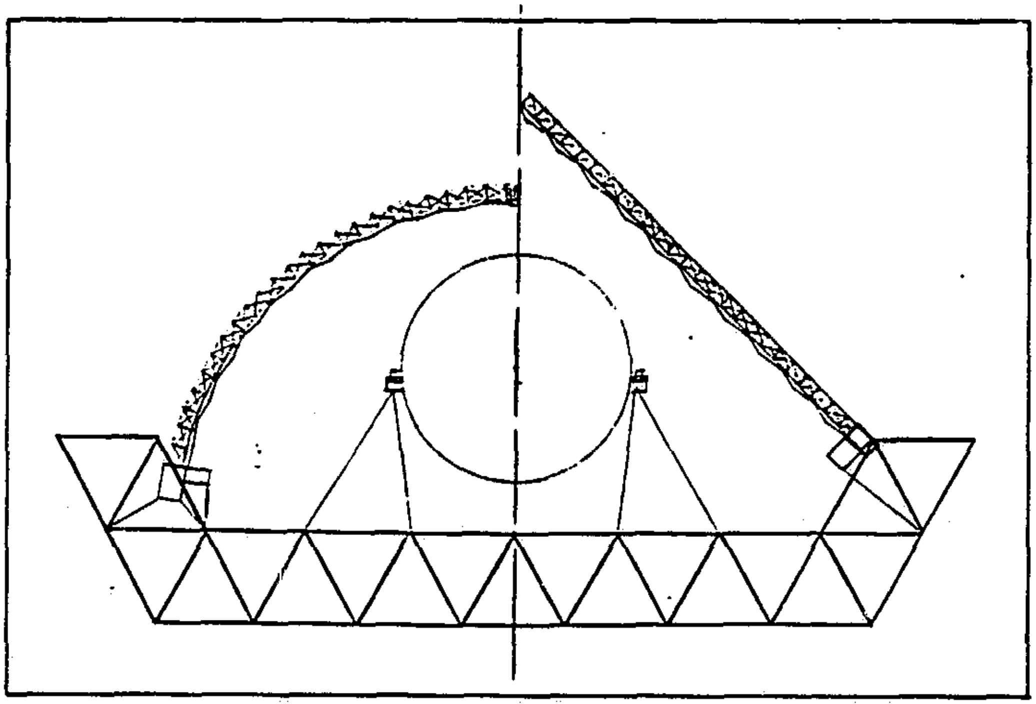


Figure 3.1-5 LSS-1 Hangar Configuration Trade Study

drical shape deployable roof maximizes the interior volume for a given roof height, the deployment of a curved extendable beam is technology not currently available. The planar configuration which uses deployable panels similar to the deployment of solar arrays was, therefore, selected for the hangar.

3.2 Operations Trade Studies

This section summarizes the operations trade studies completed during the LSS TDM contract.

3.2.1 EVA Crew Schedule

To the extent that a high level of LSS EVA construction performance will be required on what will approach a twenty-four hour per day basis, serious consideration must be given to the selection of the work-rest schedule. 1-G work-rest-sleep cycle data may not be a 1 for 1 application to 0-G work-rest-sleep cycles. Shifts should be limited to a duration that will preclude the development of task-specific fatigue or boredom. With the anticipated exposure to specific EVA construction tasks on a day-after day basis, shifts that seem to be suitable at the beginning of a mission may become long after a period of several weeks or months. In addition, the sleep periods should be arranged so that they will come at essentially the same time each day so that adjustment to (or in) the circadian rhythms will be facilitated. These two factors considered together are simply a trade-off between the necessary or desirable duration and numbers of sleep periods and the duration of the LSS EVA construction shifts.

The primary factors to be considered in the selection of the length and timing of the EVA construction shift relate to the nature of the activity required of the operators in the performance of their duties. Account must be taken of both the levels and varieties of the demands placed on operators in carrying out their tasks.

An important psychological factor underlying this distinction is the effect that different kinds of tasks exert on the operator's level of alertness. Passive tasks produce or contribute to decreased alertness whereas, at least up to some level of workload, active tasks tend to sustain or increase alertness. The variety of tasks also tends to promote alertness. However, moderately high workloads on tasks that require the simultaneous performance of psychologically disparate functions (mental calculations and code solving) tend to make operations vulnerable to losses in alertness. This is especially true for task combinations in which timing is critical.

If the operators have control over their rate of activity, they typically work at or near maximum rate for a period; they then take either an official or unofficial rest break, after which they resume their original rate. Thus the period of continuous work in most jobs is typically about two hours and is seldom longer than four hours.

This suggests that shifts on the order of four hours represent the duration of performance that should be expected as a matter of routine without encroaching on the maximum efficiency of the operator. When the level of performance necessary to satisfy the LSS mission requirements is substantially below the operators maximum capabilities, this figure can be increased. But, in determining how much it can be increased, the probability that an emergency might arise that would require maximum capabilities and the speed with which the operator would have to be able to exercise those capabilities becomes an important consideration.

Fortunately, except when their condition has reached a point of extreme deterioration, they can rather quickly rise to most any situation. The critical questions are, "How rapidly must they rise? how far? and for how long?"

In earth bound shift work it has been found that a deterioration in performance occurs during the night shift. Performance has been found to be slower, less accurate, and accidents are likely to be more frequent.

The ideal shift cycle would be one in which the total "daily" periodicity equals 24 hours, distributed in a manner to which humans are already adapted. The 90 minute day-night cycle of orbital flight makes this ideal rather difficult to attain in the operational situation.

Human ability to adapt to an atypical (non-earth) work-rest cycle has been found to take one week or more. Average times required are in the range of 2-3 weeks for complete adaptation. All reports seem to agree on the wide degree of variation in the rate and completeness of adaptation and the work out-put after adaptation. Experienced shiftworkers show some long-term adjustment as a result of prolonged experience with a particular shift system. It is possible that as little as a five day adaptation period may be required for these crewmembers to reach their normal functional level.

Efficiency during task performance is a major concern. Efficiency of performance follows a 24-hour rhythm. It is low upon arising, shows an initial ascent phase, a plateau in the middle of the day, and a terminal descent phase. Performance immediately upon getting up from a period of sleep is often poorer than it was just before retiring and is worse immediately after deeper stages of sleep. Over a long period of time these circadian periodicities in efficiency have direct implications on the performance levels to be expected of Space Station EVA personnel. In addition individual differences may affect operator shift performance by affecting the subjective health and motivation of the shift worker.

Initially, it would appear that a schedule should be selected that would require the operators to perform only during the high portion of their daily curve of efficiency. This would, in theory, provide on the order of 10 to 12 hours per day of high-level performance. However, the literature suggests that ten hours represents too long a period of work at one stretch to expect performance to be maintained without at least an increase in the probability of errors and/or decrements in performance.

Other factors affecting the work rest cycle include:

a. The number of crew members on board the Space Station.
b. The duty assignments or responsibilities of each crew member.
c. The need for time sharing of work space and facilities.
d. The need for equal division of task loading, rest, and sleep time.
e. The operator's observed pressure to complete the EVA mission.
f. The level of risk as perceived by the crew members.
g. Emergencies situations.
h. Recharge requirements for EVAS.
i. Mobility and dexterity of the EVAS.
j. Ease of EVAS operation.
k. Suit comfort.
l. Number of crew members involved in the EVA tasks.

The best work rest cycle should be one adjusted to duties, independent of the ambient sun-shadow cycle and not necessarily corresponding to the time pattern of the earth day-night cycle. This non-earth cycle should be one to which the astronaut should be able to adapt in a reasonable amount of time and with which they can maintain synchronization of their metabolic clock to ensure their best psychological and physiological performance.

The general conclusion reached is that humans are fairly well accustomed to a sleep-wakefulness cycle of a 24-hour duration and that they have diurnal variations in both performance and physiological functioning that coincide with this rhythm. When an atypical cycle is imposed, their physiological rhythms may be expected to show some adaptation to the non-earth periodicity, but adaptation is not likely to be complete nor to be uniform for all individuals. Concomitant decrements in performance, however, may not occur, especially if the sleep-wakefulness ratio is held constant. The performance decrement, whatever its degree, is precipitated by the imposition of atypical work-rest-sleep cycles and can be minimized in the following ways:

1) Avoid any non 24-hour work-rest-sleep cycle.

2) Establish permanent shift systems that maximize both short and long term crew adjustment. Where this is impossible, employ pre-flight, presynchronization periods for crews using the non 24-hour cycle proposed.

3) Coordinate pre-flight pre-synchronization with the abilities of the individual crew members to adapt (those who adapt least well should be kept close to their typical schedule).

Local (orbital adaptation can be accomplished by new crew members as they are rotated to the Space Station if they are not required to go on duty immediately upon arrival.

The results of this analysis indicates that the crew should follow a normal 24 hour (work-rest-sleep) cycle. The crew workday should be nominally 6 actual EVA hours as shown in figure 3.2-1. Suit care and work review will require several additional hours each day. The EVA crew should also average 10 minutes rest per hour of work, with a longer (15 min) lunch break in the middle of the work period.

Three operators per shift (2-EVA and 1-IVA) will be required, full time, during LSS EVA construction activities. The ability to operate more than 1 shift per day will be dependent on the Space Station crew size and other scheduled Space Station activities. Two or three shift operation could result in conflicts in the use of facilities and high noise levels while other crewmembers are trying to sleep. For the LSS TDM EVA construction activities it is recommended that 1 shift per day be utilized.

Operators are accustomed to working five days a week with short bursts of six or seven day activity. Requiring six or seven day weeks on a sustained basis will result in operator fatigue and a loss of efficiency. It is recommended that a 5 day LSS EVA

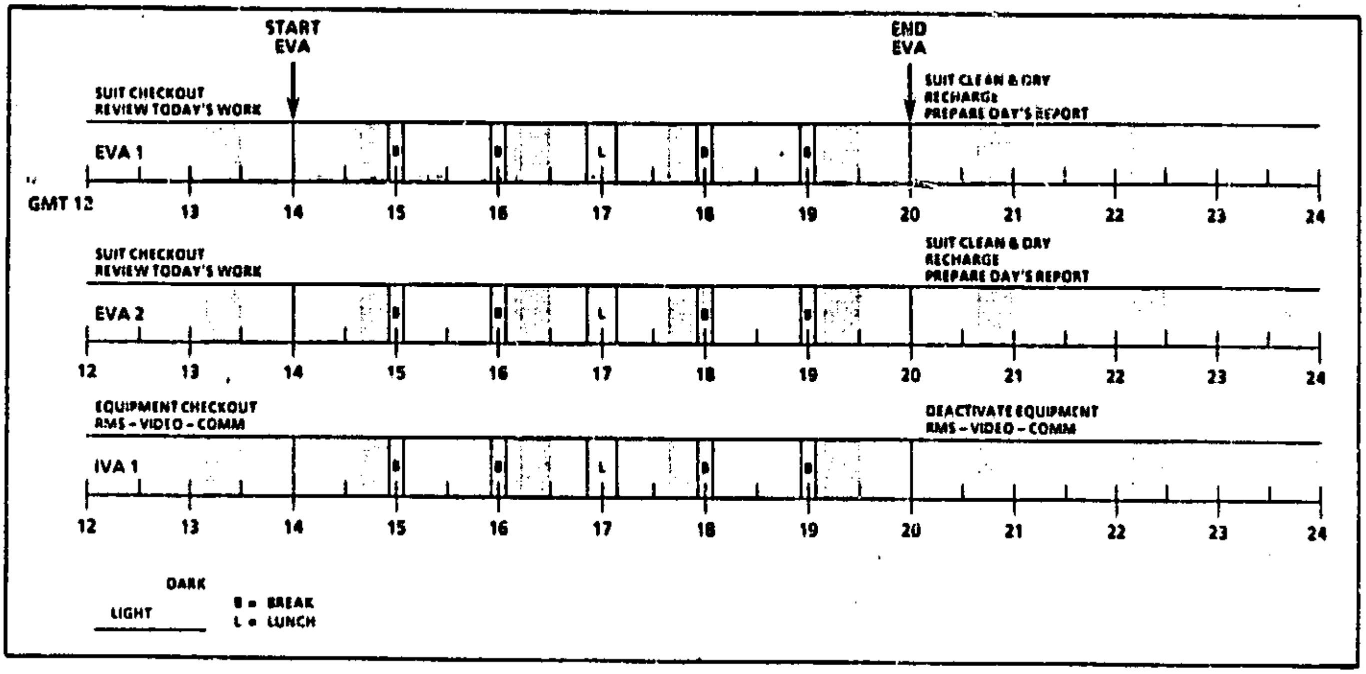


Figure 3.2-1 Typical Daily EVA Schedule

construction schedule, as shown in figure 3.2-2, be utilized allowing 1 IVA work day per week for paperwork and suit care and maintenance.

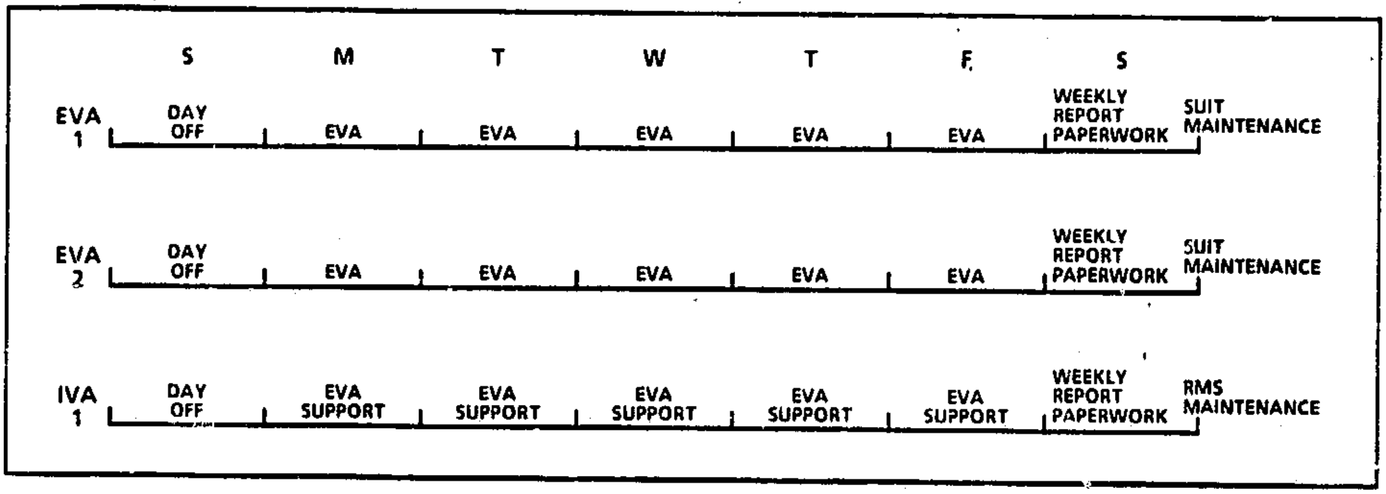


Figure 3.2-2 Typical Weekly EVA Schedule

3.2.2 EVA Personnel Restraints

In order to optimize efficiency during LSS EVA construction tasks, adequate restraint devices or systems must be provided. The LSS TDM EVA operators need adequate restraints to enable them to maintain their position, counteract torque, and aid in translation while accomplishing mission assembly, deployment, test, and operation. Currently on STS missions, in addition to the tethers used, the EVA operators stabilize themselves with one hand or try to wedge themselves into position with their feet. They also need to counteract the reactive torque that results from their EVA activities, and counteract the forces generated during torque requiring tasks (i.e., torquing nuts and bolts, hand cranking, parts alignment, and the application of force).

The Space Station must provide a restraint system for EVA personnel. The crewmembers need a restraint system to help counteract/provide torque and stabilize the EVA crewmembers at their work stations. During translation astronauts need a system to aid them while spanning long distances, plus a safety device (i.e., inertia reel) in case their tether fails or they loose their grip. The design of the restraint system will have a large impact on the final LSS TDM construction time lines. Restraint attachment, methods of restraint between work locations, number, and type of restraints all have an impact.

Strap tethers are simple to use and fairly inexpensive. Flexible tethers also tend to flop around during translation and other work activities. In addition they could be a hazard or damage delicate equipment if they strike it or get tangled in the equipment. strap tethers don't provide adequate restraint to counteract the torque forces generated during mission activities.

Wrist tethers are fast, convenient, and easy to use, see and reach. They, however restrict arm movement when attached to the Space Station or work area. They also get tangled up in equipment or closed in equipment or storage cabinets doors. This causes a safety hazard as doors and lids could get warped or broken from being closed on the restraint. Figure 3.2-3 shows an example of the type of wrist tethers used on STS flights.

Flexible waist tethers are attached close to the operator's CG. They require that the operator use at least one hand during construction activities to hold their position and counteract torque. Waist tethers are generally difficult for the operator to see and attach. They do not stabilize the operator because of the flexible straps.

Rigid waist tethers are also attached close to the operator's CG. They allow the operator to use both hands during construction activities rather than using them to hold his position and/or counteract torque. Rigid waist tether harnesses are generally difficult for the operators to see and secure. They do not stabilize the operator well as

Overview

Wrist and Waist Tethers are used to attach a crew member to a worksite or to tether tools which are not capable of being stowed during the work period.

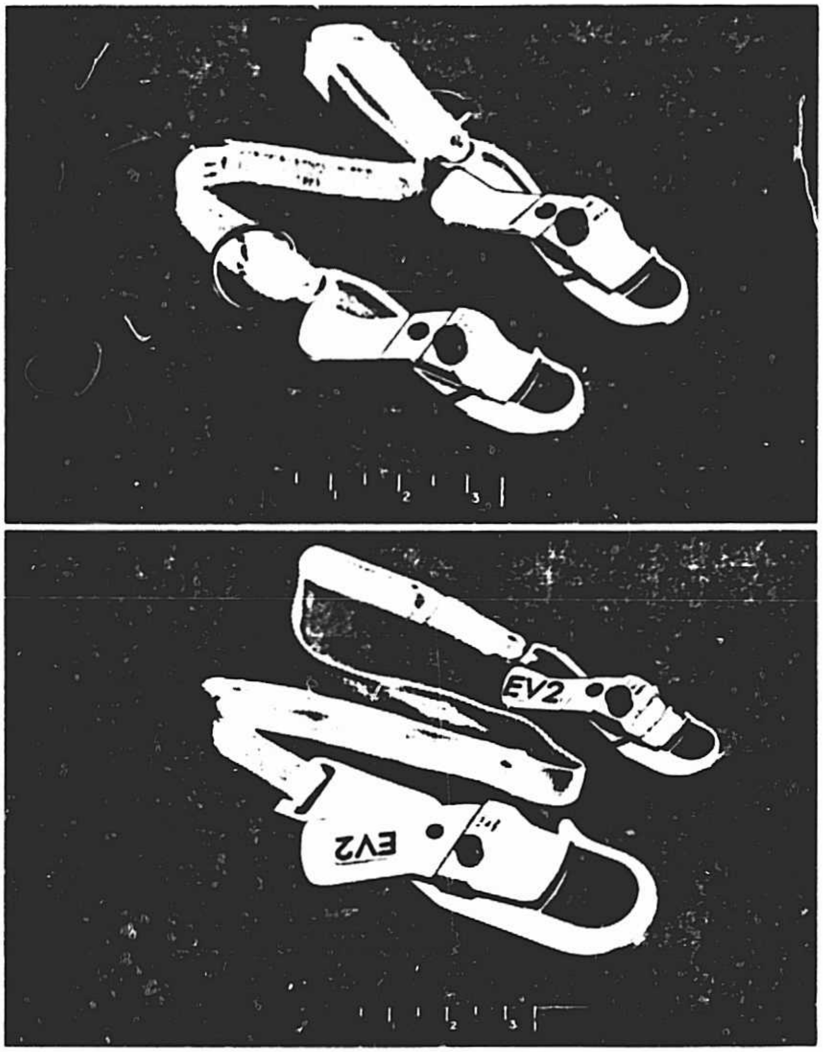


Figure 3.2-3 Wrist and Waist Tethers

the attach point is at the waist. This allows the operator to rotate around the waist when trying to apply torque or position himself. This type of tether mechanism requires more storage space and needs to be transported to the work site. Figure 3.2-4 shows an example of one type of waist restraint.

Safety lines are currently used on the STS EVA missions to keep the astronauts from drifting off during their EVA activities. The current safety line system could be a problem. Crewmembers could get tangled when translating long distances, when near other safety lines, or when around equipment and/or experiments. Currently on STS missions an inertia reel (see figure 3.2-5) is used to take up the slack in the safety line. During the STS-6 flight EVA the line got bound up when a test was conducted to

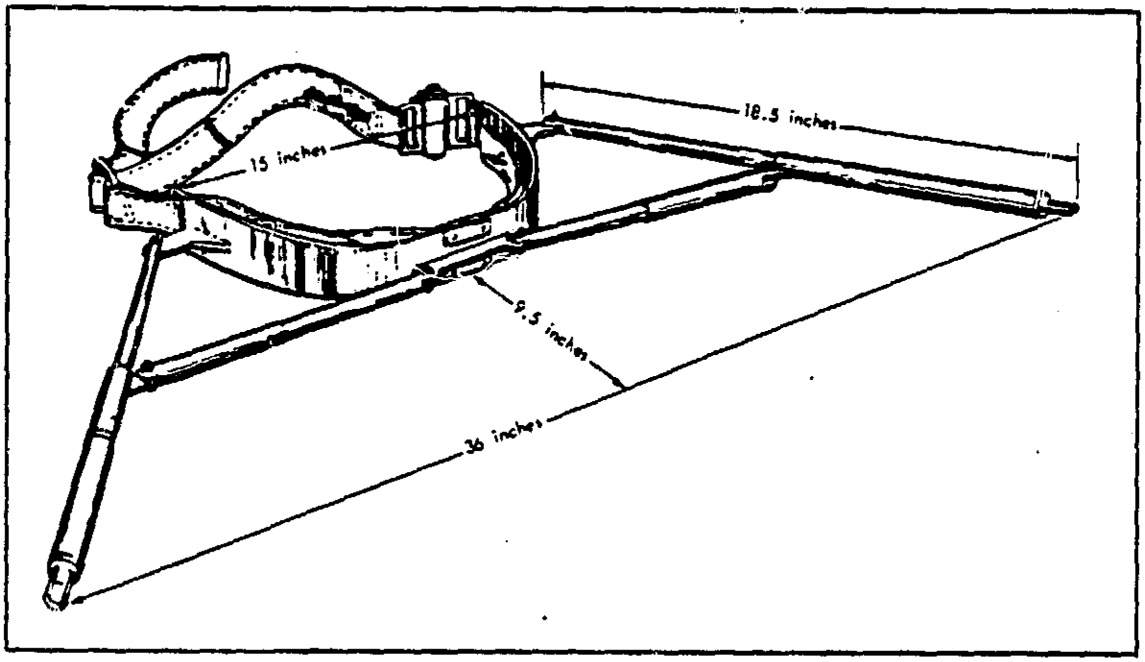


Figure 3.2-4 Restraint Belt

determine its retrieval capability. The current system is cumbersome. The large bulky reel has to be near the operator so that he can reach it and see it. The reel is attached to the operator by a snap. Tension from the reel keeps the safety line out toward the attach point on the work station. EVA operators have to be careful when passing or working near one another so that safety lines do not get crossed and/or tangled. The EVA crewmember also has to be careful so as not to become tangled in his own safety line.

Velcro holds well in shear but is not adequate in peel. However, when trying to apply torque it tends to work loose. The use of lots of velcro on the EVA suit creates a problem because crewmembers could inadvertently become secured when bumping into matching velcro. Also, loose tools, with velcro attachment patches, could stick to the suit in hard to reach places. There is also a contamination problem because of the outgassing of the adhesive that is used to secure the velcro to the desired surfaces. In addition long term usage causes hooks to break off resulting in loss of holding power and additional contamination from the small hook particles. Velcro is easy to attach in additional areas if needed at the work site. The use of velcro allows adding a variety of work positions to the construction area and facilitates the adding of temporary work stations.

Overview

The Fifty-Foot Safety Tether attaches the extravehicular crew member to the Cargo Bay door slidewire at all times when he is in the Cargo Bay.

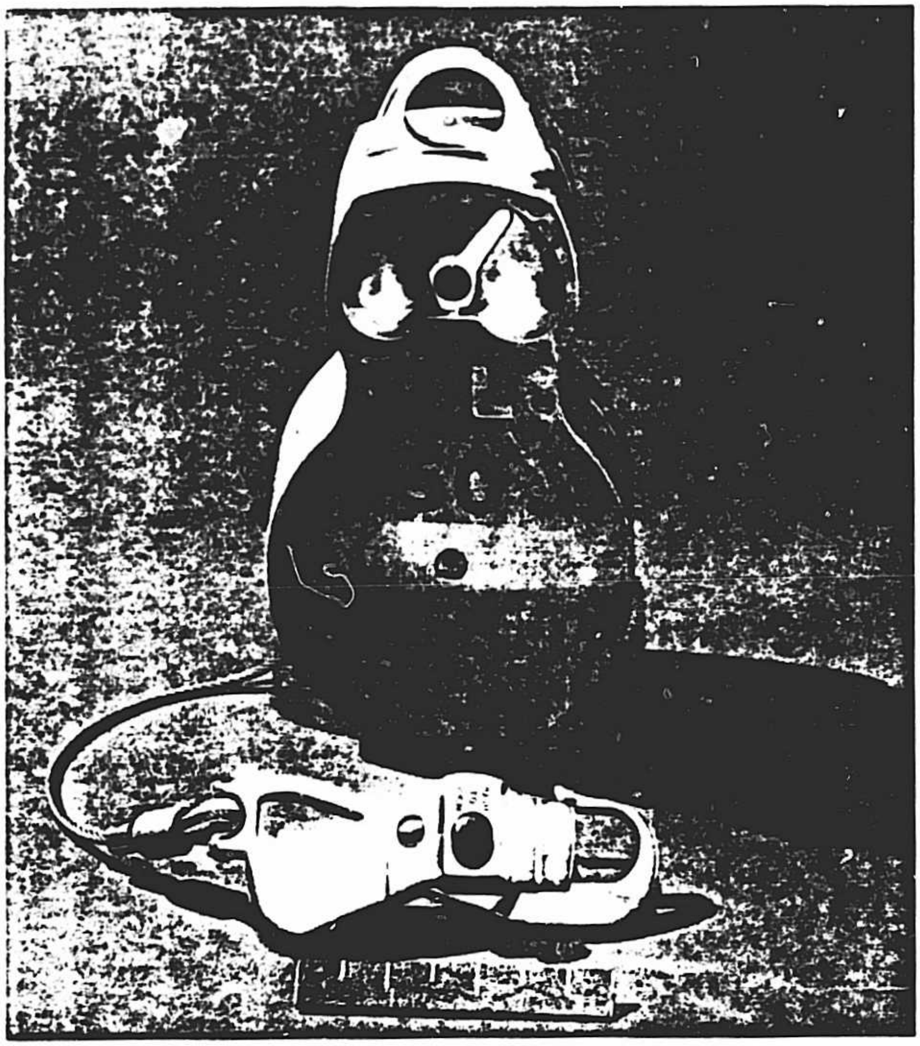


Figure 3.2-5 Fifty-foot Safety Tether for Crew Member

During the STS-6 flight a foot restraint was tested during work at the tool cabinet and during the hand cranking experiment. While the restraint was adequate for work at the tool cabinet, it did not appear to be rigid enough to provide a solid platform while hand cranking. The operator had trouble getting his feet into the foot restraint and had to have help in securing his heels in the foot restraint. In order to be effective, this type of platform for foot restraint would need to have attach points at the different work stations, and be adjustable for the 5th to 95th percentile operator.

Shoe restraints, such as those used on skylab flights, are fairly expensive and complex. Using them for EVA would require mating gridwork at all assembly locations. This would increase the weight requirement for EVA work stations. An emergency breakaway provision would be required in case they got hung up. Shoe restraints provide one of the best restraint methods for counteracting torque and maintaining operator position during assembly tasks. With a rigid gridwork they would free both hands for accomplishing tasks that required the use of both hands. One major major problem in the use of shoe restraints is the astronaut's inability to see his feet so that he can position them into the foot restraints. The requirement to meet the 5th percentile female to 95th percentile male anthropomotry for work stations requires that the grid work have a large adjustment range.

The shoe restraint design should be such that one or both feet can be secured while working at a task. Permanent grid work would be required at each work station with portable grid work available for temporary work areas. Addition of grid work at every work station would impose a weight penalty. The design would need to take into account all tasks to be accomplished as well as grid work location and adjustment. Mobile grid work would provide the operator flexibility in accomplishing construction tasks. It would require a quick and easy attachment method for the grid work. The grid work would need a storage location near the work station. This would increase operator timelines in that they would have to obtain the grid work, attach it to the work area, and then stow the grid work when the task was completed.

Providing a T-bar or other mechanical system that the operator wraps his legs around to stabilize himself during construction tasks would be fairly inexpensive. The problem with this method is that for long term usage the operator would experience fatigue in the muscles utilized to maintain this position. In addition the operator needs to concentrate on holding his position and if he relaxes his muscles or concentrates on the task he is working on to the exclusion of his restraint he would then drift away from his work and have to reposition himself.

Providing no restraint other than crewmembers holding on with their hands or wedging pars of their body into available crevices or wrapping around projections in the area is unacceptable. There will not always be adequate restraint locations with this method. In addition the operators will experience fatigue from holding their positions with muscle power and they have to provide a minimal concentration to maintain their position. Tasks requiring two hands would be impossible without some other restraint method.

The use of safety enclosures would enable the astronauts to work part of the time without tethers and/or safety lines. This would help speed up the completion of some tasks but would require the crewmembers stabilize themselves with the manual means described above. If the operator were in the middle of the open space it would be hard to get momentum to return to the work area or to where he could once again propel himself.

A rigid assemblable hangar would provide sunshade but could only be used for the construction of items small enough to fit inside the enclosed volume. If made of adequate materials it could also serve as a micro-meteroid shield. Time required for assembly or deployment of structure would add to operator timeline. It would require auxiliary lighting even during the sunny part of the orbit.

An inflatable rigidized hangar or work space should be light in weight for volume enclosed and easy to pressurize and rigidize. It could be hard to attach to the Space Station and could require auxiliary lighting even during the light part of the orbit. Again only items small enough to fit inside the hangar could be constructed. A box shape may be hard to achieve, however a cylinder should be easy to attain but would need to be large to provide adequate construction and storage space.

A safety net would provide an inexpensive method of keeping crewmembers and tools and/or equipment from drifting off. It would require deployment for each construction task, but could be made large enough to cover large space structures. It would not provide adequate sunshade and would create shadows on the work area during the sunny part of the orbit. The net could get tangled when operators try to deploy or stow it. In addition the operators could get tangled in the net depending on the mesh size. The net would require a storage area when not in use.

The restraint methods selected for the LSS-1 TDM construction activities are:

1. The flexible tethers that are currently used for the STS missions (figure 3.2-3).

2. The current safety line as shown in figure 3.2-5.

3. A shoe restraint with matching grid work.

4. The hangar that is part of LSS-1 will also serve as an operator restraint.

3.3 Mission Design

This section presents a description of some of the design details for the Construction/Storage/Hangar Facility (LSS-1). A more complete set of design drawings and parts list are contained in Appendix A.

3.3.1 Truss Platform

The top and end view of the LSS-1 truss structure are shown in figure 3.3-1. The truss is a deployable pentahedral truss (whose repeating elements are pentahedrons) made of graphite/epoxy tubes 50.8 mm (2.0 in.) in diameter and with a wall thickness of 3.175 mm (.125 in.). The typical strut length is 2.0 meters (78.74 in.) which results in a truss whose planform dimensions are 18.0 by 28.0 meters (59.04 by 91.84 ft.). The diagonal truss elements which form the pyramid of each pentahedron ore 2.236 meters (88.03 in.) long, resulting in a truss depth of 1.73 meters (68.19 in.). The truss is attached to the Space Station at a berthing port using a transfer tunnel which is also used for access to the platform. Also shown in the figure are support struts for a pair of structural rails which duplicate the longerons in the Orbiter payload bay for the storage of large payloads that are transported to the Space Station.

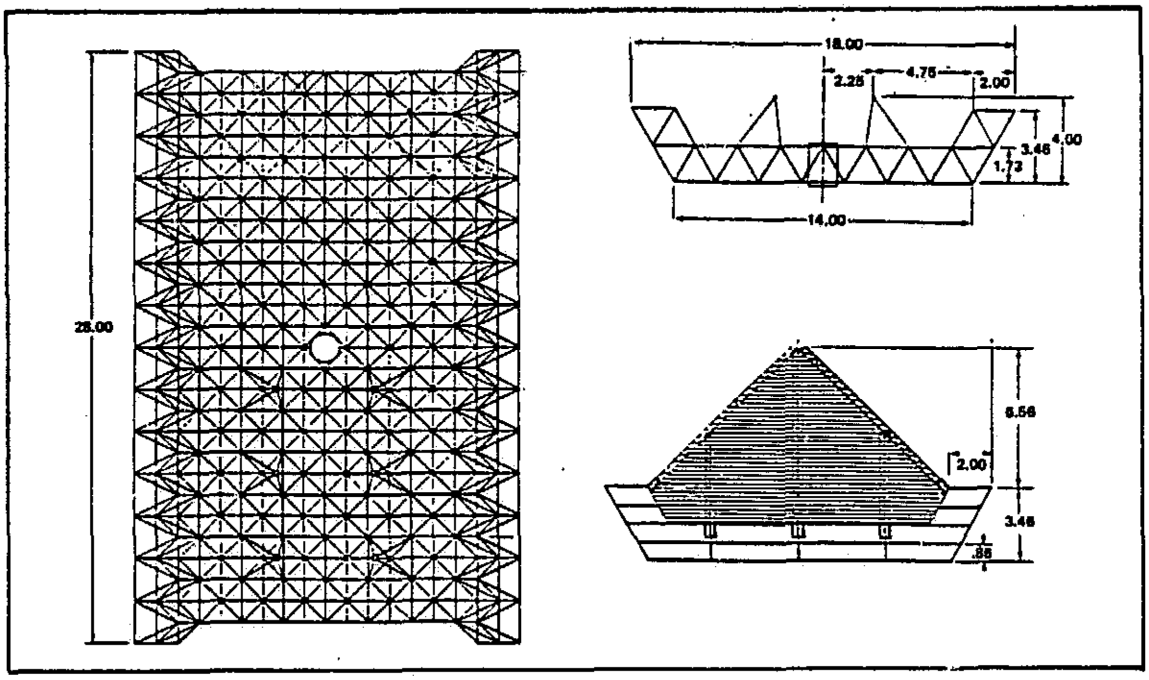


Figure 3.3-1 LSS-1 Pentahedral Truss Platform

The top view and side view of a typical pentahedral element of the truss is shown in figure 3.3-2 in both the deployed and stowed configurations. The numbers (e.g., -23) shown in the figure are part numbers. Knee joints in the center of each surface strut and pin joints at the cluster fitting end of each strut allow the truss to fold compactly for transport to orbit. The 2.0 by 2.0 meter truss element folds into a bundle whose dimension is 0.194 meters square. This results in a packaged truss whose dimensions are 2.72 by 1.75 by 2.24 meters (107.24 by 68.94 by 88.03 inches). Figure 3.3-3 shows the top view of the square base of one of the pentahedrans with the pulltruded graphite rods which form an "X" to provide shear stiffness. These rods are also hinged for packaging as shown in the stowed view with some of the struts removed for clarity.

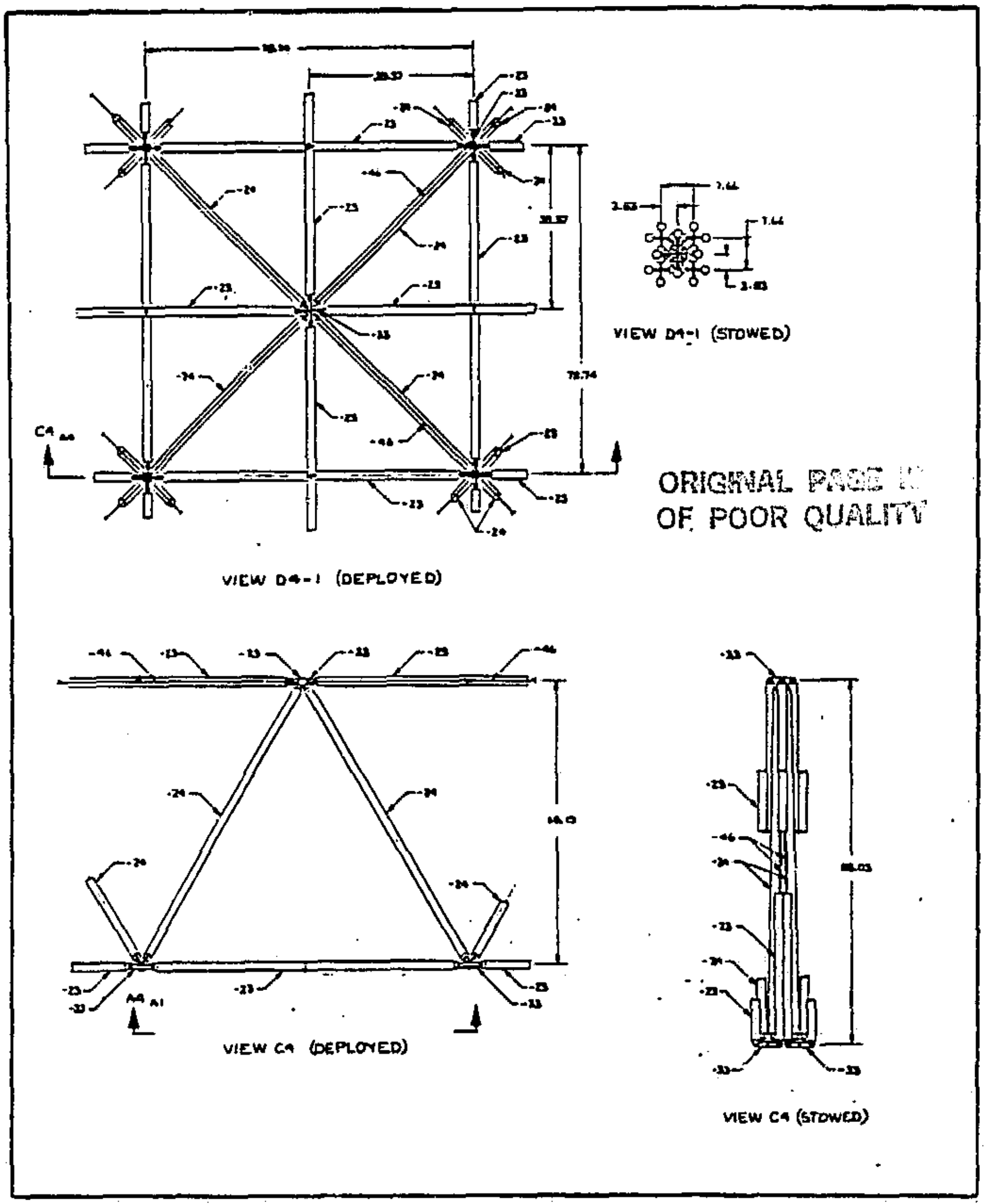


Figure 3.3-2 LSS-1 Platform Truss Element

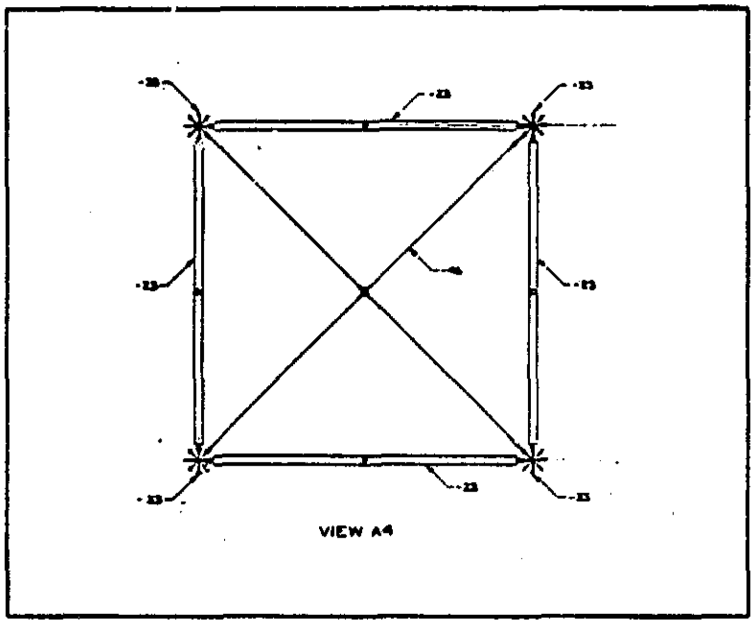


Figure 3.3-3 LSS-1 Truss Shear Ties

An end view of the platform truss at the junction of the planar truss with the "wing" is shown in figure 3.3-4 in both the deployed and stowed positions. The complex geometry of this area complicates the folding of the truss somewhat, but results in a stowed configuration which is only slightly skewed.

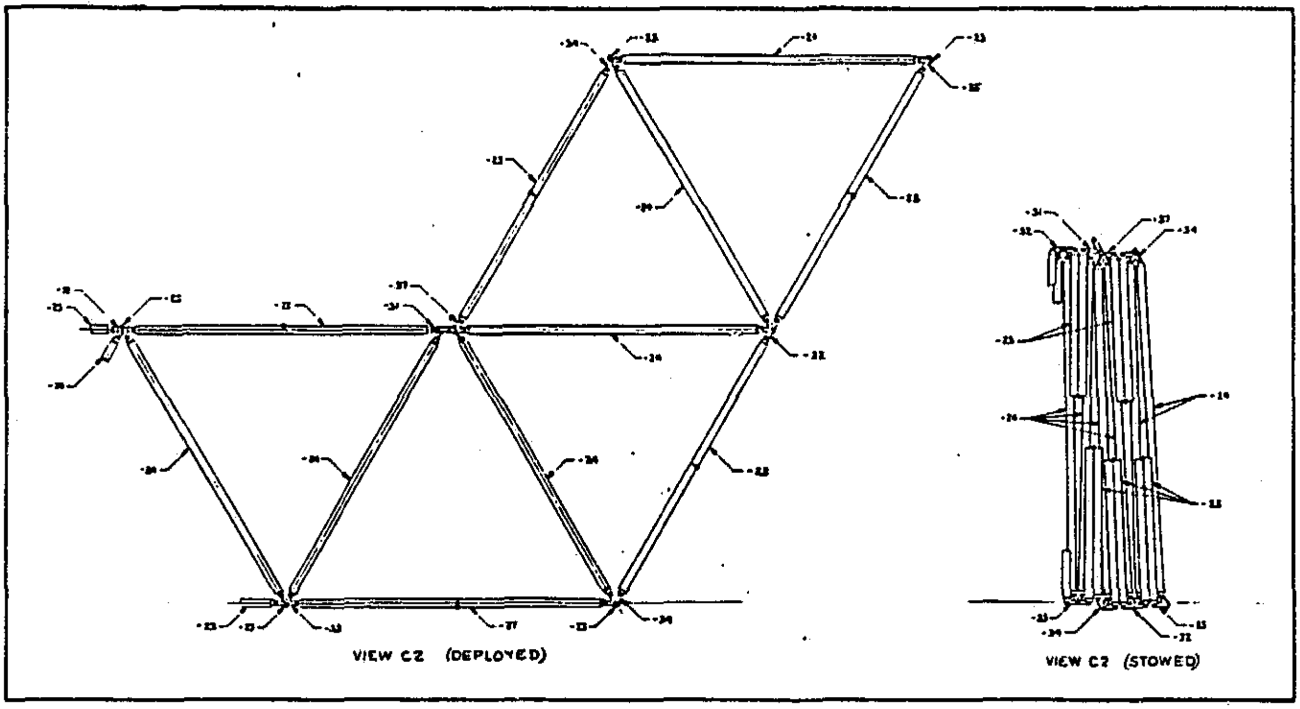


Figure 3.3-4 LSS-1 Truss Wing Junction

3.3.2 Transfer Tunnel

The truss structure for the construction platform is attached to a transfer tunnel, as shown in figure 3.3-5, which serves as the interface with the Space Station. It is packaged separately from the truss and attached to the Space Station first. Then the truss is deployed and attached to the transfer tunnel. It is 2.03 meters (80 in.) long and 1.788 meters (70 in.) in diameter (the diameter would be compatible with the diameter of the Space Station berthing port) and is made of aluminum with a thickness of 6.35 mm (.25 in.) for micrometeoroid and debris protection. Attachment points are built into the cylinder to accommodate the truss cluster joints in four places and the diagonal rods in four different places.

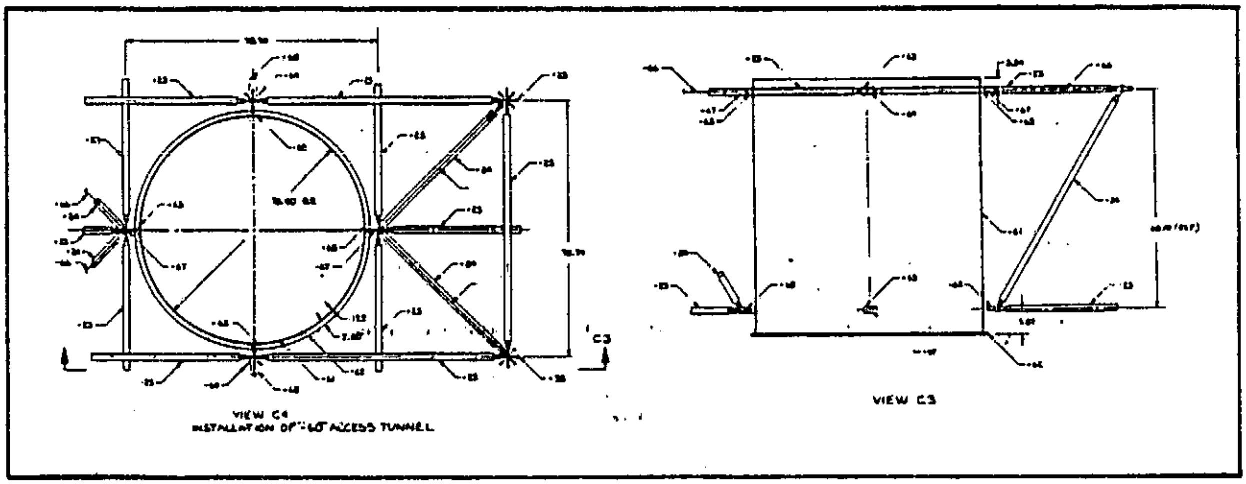


Figure 3.3-5 LSS-1 Transfer Tunnel

3.3.3 Payload Support Rails

A set of rails supported by three tripod support assemblies each are attached to the construction platform to provide a location for the storage of large objects transported to the Space Station. The rails duplicate the function and interface of the Orbiter payload bay longerons. The rails are equipped with standard Orbiter longeron attachment mechanisms. With the low g-levels anticipated at the Space Station, keel fittings are not required. For additional clearance between the payload and the platform, the payload can even be mounted in an inverted position on the platform rails.

3.3.4 Hangar

Figure 3.3-6 shows the LSS-1 platform with the hangar panels attached. The sides and bottom of the platform are fitted with fixed, lightweight panels which are attached to the truss via EVA to provide shielding from sunlight. The panels which form the "roof" and ends of the hangar are articulated and attach to coilable longeron deployable masts which are used to extend and retract the hangar in a manner similar to deployable solar arrays. This allows access to the interior of the construction platform using the Space Station remote manipulator. The hangar not only provides protection to the EVA crew from solar heat and light, but also contains the crew and equipment so that they will not drift away when working without tethers or other restraints. Hangar panels are made of thin corrugated aluminum sheets with a reflective surface on the outside for the reflection of solar light and heat.

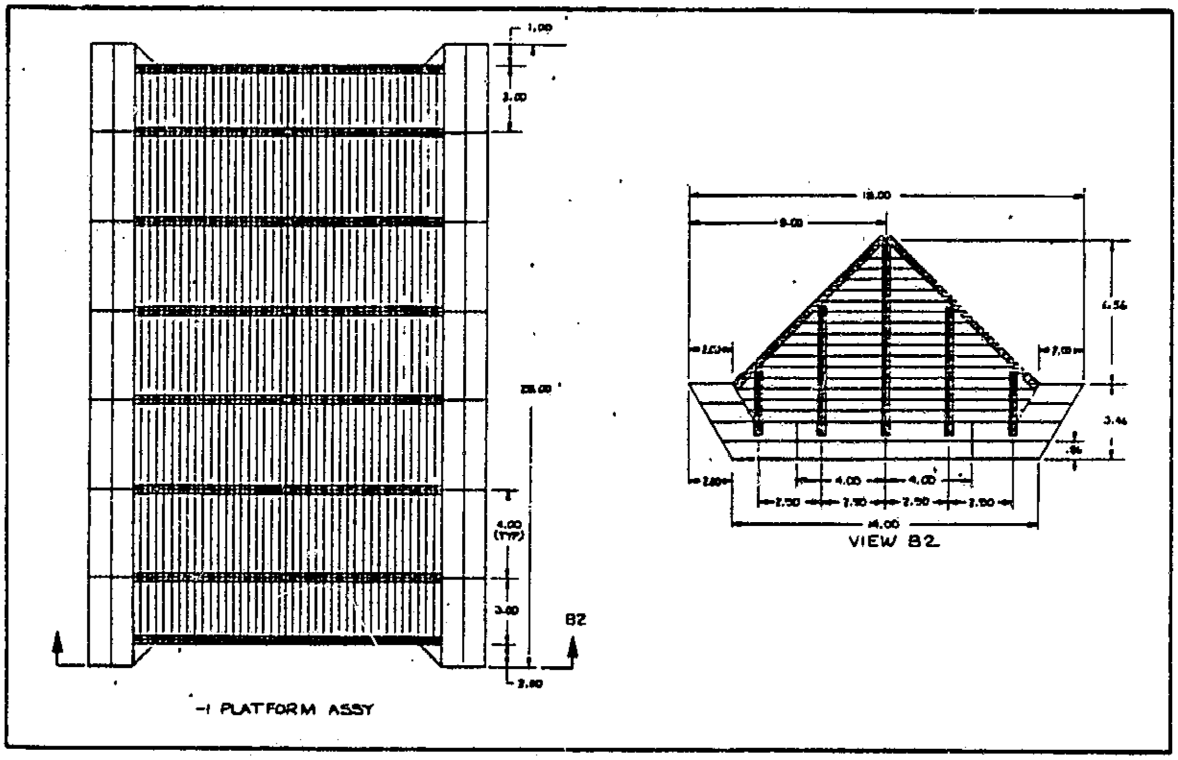


Figure 3.3-6 LSS-1 With Hangar Panels Attached

3.4 Operations Analysis

This section summarizes the analysis of the requirements for constructing the LSS-1 TDM on the Space Station.

3.4.1 Construction Method

In order to demonstrate all construction methods during the Space Station LSS TDM activity, different construction methods were considered for each mission.

Of the three construction methods considered deployment takes the least operator involvement but incurs the highest engineering and manufacturing costs. It also requires larger packaging and greater weight than individual components. Manual assembly of large space structures is labor intensive. This drives the on-orbit costs up (due to the high cost of EVA) while not reducing the engineering costs significantly.

A combination of deploy and manual assembly was chosen for construction of the LSS-1 TDM. This allows quick deployment of the platform with manual EVA addition of the hangar, floor, holding fixtures,and sunshield.

3.4.2 Functional Flow Analysis

Functional flow diagrams were prepared to identify the LSS TDM system organization and function. Utilizing preliminary design information, drawings, and mission data forms, a scenario of construction tasks was identified for each mission. This scenario was prepared to provide the first picture of the functions required to accomplish the LSS TDM objectives. As shown for LSS-1 in figure 3.4-1, it begins with the attachment of the transfer tunnel to a berthing port. The truss is then deployed and connected to the transfer tunnel. The payload support rails, floor panels, utilities, fixed and deployable hangar panels, etc. are then installed. Tests are conducted throughout this construction sequence to determine the dynamic characteristics, structural accuracy and thermal deformations of the structure. This construction scenario was then upgraded to a functional flow diagram in order to define the end to end construction and test operations for the LSS-1 mission. It was necessary to examine each of the proposed functions in terms of specifics regarding sublevel requirements for each function and in terms of the possible constraints that would affect the way in which each function was accomplished. The LSS-1 functional requirements analysis was thoroughly documented as seen in figure 3.4-2. In this analysis, each function was keyed to a specific construction objective. This made it easier to relate the functional flow diagrams to the LSS mission requirements.

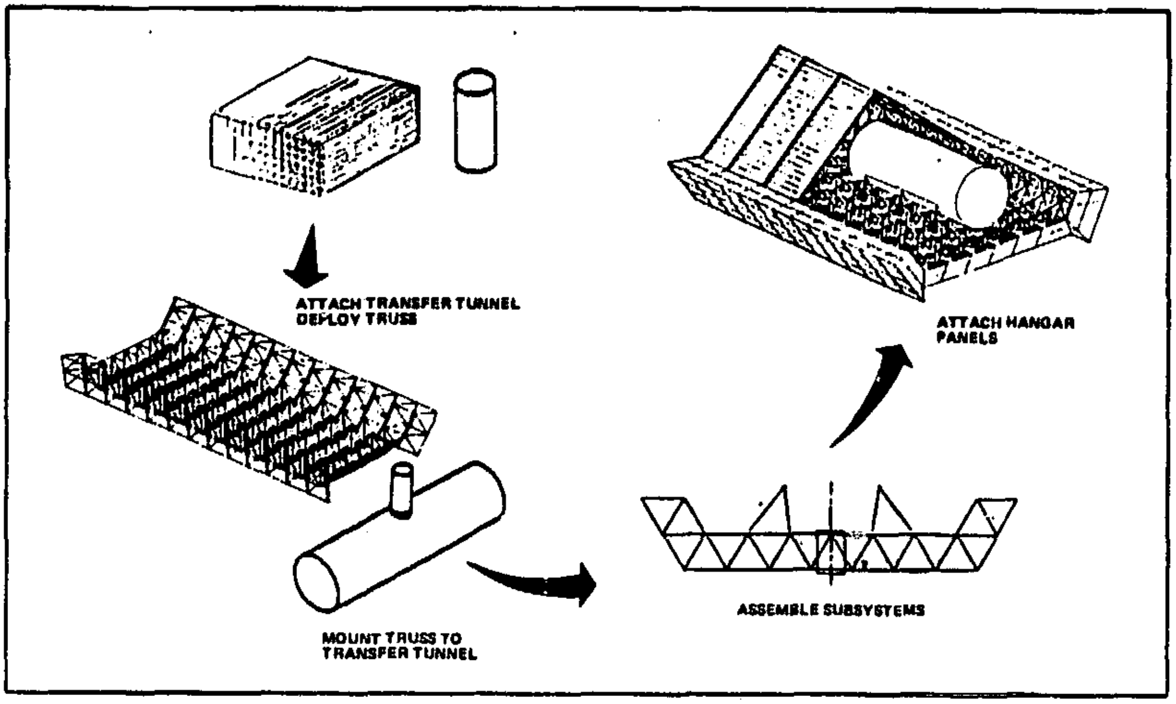


Figure 3.4-1 LSS-1 Construction Scenario

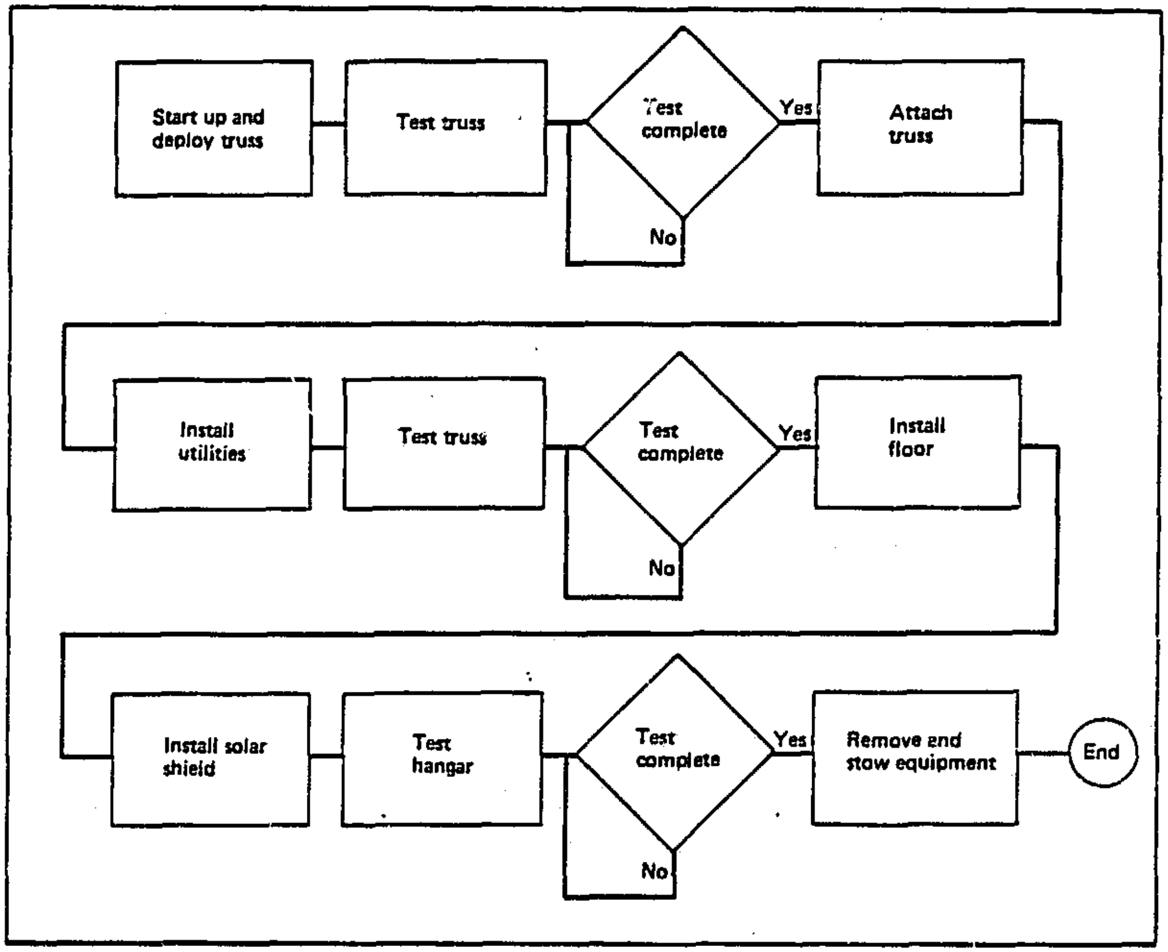


Figure 3.4-2 Construction/Storage/Hangar Facility (LSS-1) Functional Flow

3.4.3 Task Analysis

As the functional flow diagrams were being prepared, a preliminary task analysis was begun to further define the LSS TDM construction tasks. These were refined and updated as more detailed design data was generated. As the detailed time lines were evolved, task duration was considered. This combination generated a detailed timeline analysis.

3.4.4 Timeline Analysis

Timeline analysis was used to derive human performance requirements by showing the functional relationships between tasks as well as task loadings for the combinations of tasks.

Design details were coordinated with Boeing designers and used as a basis for the detailed task analysis and timelines.

The analysis indicates the estimated amount of operator's time which is occupied throughout the LSS construction tasks. These operator task load estimates were derived from neutral buoyancy simulation, task times from previous missions, and analysis of NASA video tape of STS-6, STS-11, and STS-13 missions. In addition, interviews with previous and current astronauts were reviewed for pertinent EVA data. A summary of the LSS-1 timeline is presented in figure 3.4-3 with the complete detailed timeline being presented in Appendix B.

	Hours
Start up and deploy truss	11.4
Test truss	5.0
Attach truss	1.5
Install utilities	7.0
Test truss	10.5
Install floor	7.0
Install solar shield	10.5
Test hangar	10.3
Remove and stow test equipment	4.8
Total	68.0

Figure 3.4-3 LSS-1 Timeline Summary

3.5 Development Activities

The technology development missions defined in this report will demonstrate the ability to construct large space structures on an early Space Station. However, precursor developments are required to advance the necessary technology and operational procedures required for on-orbit assembly or construction. These precursor activities involve the design, manufacture and test of structural components for the TDMs and the development of detailed procedures for their construction in space. Several testing arenas and types of tests can be used for these developments: ground tests in the laboratory, neutral buoyancy tests in a water tank and tests in space using the Space Shuttle.

Figure 3.5-1 summarizes the general areas where development activities for large space structures need to be conducted and the locations for each. In all cases, ground testing is the primary development testing arena, but all developments need to be demonstrated in space to verify the ground tests. Zero-g simulations which involve human interaction are most economically conducted in a neutral buoyancy simulator, subject to the limitations of the physical dimensions of the facility.

DEVELOPMENTS NECESSARY FOR LSS TDM	TESTS		
	GROUND	NEUTRAL BUOYANCY	SHUTTLE
ASSEMBLABLE JOINT	X	X	X
FOLDING DEPLOYABLE JOINT	X	X	X
MRS REFLECTIVE MEMBRANE SURFACE	X		X
MRS MEMBRANE SURFACE CONTOUR MEASURING SYSTEM	X		X
MRS MEMBRANE TENSIONING SYSTEM	X		X
MIRROR POSITIONING CONTROLS	X		X
DEPLOYABLE TRUSS BEAMS	X	X	X
TENSION STABILIZED BEAMS	X		X
CHERRYPICKER RMS	X		X
EVA ASSEMBLY OPERATIONS CAPABILITY	X	X	X
DYNAMIC TESTING	X		X
SURFACE ACCURACY MEASUREMENT	X		X
MODAL IDENTIFICATION TECHNIQUE	X		X

Figure 3.5-1 Precursor Technology Development

For the Construction/Storage/Hangar Facility in particular, a list of development tests was established for each type of test facility and is shown in figure 3.5-2. The

Ground Tests:
- Deployment (functional test)
- Accuracy measurements
- Dynamic tests
- Static Tests

Neutral Buoyancy Simulator (NBS) Tests:
- Deployment (operational test)
- Utilities routing and installation
- Install hangar panels
- Attach "floor" panels
- Simulate attachment of equipment or modules
- Replace interior member (simulation of repair)

Shuttle Flight Tests:
- Repeat NBS tests in space
- Measure structural accuracy (e.g., flatness)
- Measure thermal deformations
- Retract and stow structure

Figure 3.5-2 LSS-1 Development Tests

tests listed are designed to be conducted on a portion of the deployable truss so that hardware costs can be minimized while the basic characteristics of the structure can be determined.

3.5.1 Ground Tests

Ground tests conducted in 1-g can be used to determine the static, dynamic and thermal behavior of structural components and assemblies. For example, the nonlinear stiffness and damping of deployable joints must be determined because they may significantly affect the dynamic characteristics of the truss. Also, for some assembly level dynamic and functional tests, techniques for simulating zero-g are advisable (ie. air bearings or other distributed suspension systems). These suspension systems will more accurately represent the conditions in orbit and will also allow the measurement of the dimensional accuracy of the structure.

3.5.2 Neutral Buoyancy Simulator (NBS) Tests

Another technique for simulating zero-g is through the use of a neutral buoyancy simulator which relies on the buoyancy forces on an object submerged in water to counteract the force of gravity. These facilities are particularly useful for simulating tasks which must be accomplished by EVA astronauts and for developing assembly techniques. Manual or automatic deployment of a representative portion of the platform truss can be demonstrated. Once the truss is deployed, the installation of utilities, hangar panels and floor segments can be accomplished. Another task which will be important to the maintenance of large space structures is the replacement of components and structural elements in the event that they fail or become damaged. These maintenance and repair tasks can be demonstrated in a NBS.

3.5.3 Shuttle Flight Tests

Once the structural components and assemblies have been tested on Earth and the construction procedures and techniques have been developed and simulated, the next step is to demonstrate the functional aspects of the construction process in space. Structural assemblies of modest size can be constructed on orbit from the Shuttle cargo bay to verify the results of the Earthbound tests and simulations. To determine the accuracy and adequacy of these tests, it is advisable to duplicate the 1-g and NBS simulations as closely as possible in orbit so that the differences can be identified. It may be possible to compensate for these differences in future tests on Earth.

3.6 Programmatics

The LSS-1 programmatic analysis provides the necessary plans, schedules, and cost analysis to support the definition of this technology development mission. This is necessary to insure that the plans, schedules, and costs are given proper consideration in the development and analysis of the missions. Programmatic analysis was performed in two subtasks: (1) plans and schedules and (2) cost analysis.

3.6.1 Plans and Schedules

Our study of LSS TDM programmatics included considerations of program structure, hardware commonality, schedules, and program phasing. An important dimension of program structure is Program phasing. Schedules for LSS development were laid out using analogous experience with programs of similar size and complexity. Certain assumptions are implicit in these schedules:

(1) Significant technology advances will be carried at least to the proof-of-concept stage by technology advancement activities prior to initiation of phase C/D for each of the LSS TDM's. If the technology advancement is critical, a full technology demonstration may be required.

(2) Accordingly, program delays to solve technology immaturity problems will not be encountered.

(3) Shuttle launch service will be available on a timely basis for LSS buildup.

(4) End item fabrication and test activities are phased so that one set of tooling for each end item type, and one test crew, can accomplish the required fabrication and testing.

The schedule analyses keyed on the fabrication, test, and integration schedules incorporating assumptions (3) and (4).

Because the LSS TDM's will have their final assembly on the Space Station, it is seen as very important to validate, both mechanically and functionally on the ground before launch. This leads to the concept of a Ground Test Vehicle (GTV) All subsystems in the GTV will be flight or flight prototype hardware.

The GTV will initially serve in an integration role to prove out the proper operation of the subsystems, later it will serve to validate flight hardware interfaces at KSC before each flight article is launched. Finally, after the flight system is fully built up and in orbit, the GTV will serve as a "hangar queen" for simulation, training, and checkout of procedures, subsystems updates, and software changes before these are implemented in the flight system.

The program master schedule for LSS-1 was updated to reflect the Space Station 1992 IOC, and the combination of LSS TDM's 1 and 2. The expanded preliminary LSS-1 TDM program master schedule is shown in figure 3.6-1. The anticipated go-ahead is shown with design and development, fabrication and assembly, test and launch operations, and on orbit construction operations. The scheduled launch date for LSS-1 is shown in 1992. Facility availability, along with test plan submittal, is also shown. The LSS-1 TDM schedule reflects the start and completion dates for key milestone events, key reports, and customer reviews.

We have developed the LSS-1 master schedule that our analysis indicates will reduce risk to a minimum. This schedule has been formulated to ensure a timely flow. The scheduled task interrelationships are also shown in figure 3.6-1.

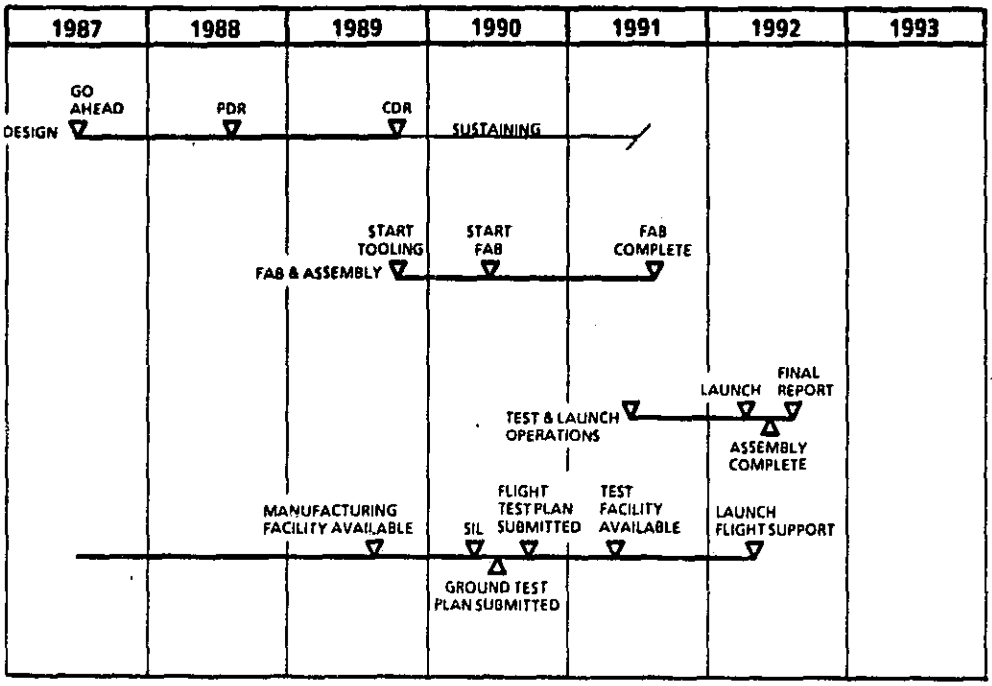


Figure 3.6-1 LSS-1 TDM Program Master Schedule

3.6.2 Cost Analysis

An analysis of the Construction/Storage/Hangar Facility was conducted during Phase I of this study (Reference 1) to determine the costs associated with its design, development, and manufacture. These costs were updated in Phase II to reflect maturity in the details of the design.

TDM costs were determined using the cost data base we have developed from experience with previous spacecraft. New equipment, hardware and development costs were defined using the Boeing Parametric Cost Model (PCM) cost analysis computer model and the RCA PRICE hardware acquisition model.

The groundrules provided by MSFC are:

- o Cost estimates are in FY-84 dollars, including fiscal year funding requirements.
- o Space Station ATP are FY-86 with initial launch in FY-90 and IOC in FY-91.
- o Cost estimates include all requirements unique to demonstrating the technology feasibility.

The additional groundrules and assumptions used are:

- o The Boeing PCM hardware cost model was used to estimate all structural/ mechanical items and all support costs i.e., SE&I, system ground test, tool & test equipment, program management, etc.
- o PCM was used to estimate all integration costs.
- o Design costs reflect the highly repetitive nature of the hardware.
- o The extendable masts for the hangar are 100% off-the- shelf.
- o Learning was assumed (88% of structural items).
- o Development quantity = 2

The development costs for the Construction/Storage/Hangar Facility are summarized in figure 3.6-2.

	PLATFORM	HANGAR
ENGINEERING ($M)	47.7	.5
TOTAL HARDWARE (2 UNITS)	33.8	8.7
TOTAL DEVELOPMENT ($M)	81.5	9.2
FLIGHT UNIT COST ($M)	7.81	2.77
1984 DOLLARS		

Figure 3.6-2 LSS-1 Development Costs

3.7 Space Station Resources Required

3.7.1 Accommodations

EVA activities require special equipment and/or procedures. These in turn will require accommodations in the basic space station design. The accommodation needs of the LSS TDM's were defined by analysis of both mission and space station requirements/capabilities. A detailed list of the space station architectural features, required for LSS-1 EVA construction activities are provided in figure 3.7-1.

Architectural Features

- EVA crew transfer corridors and work areas must be compatible with the dimensions and mobility of the EVAS.
- Proper storage and maintenance areas for EVAS items, spares and support equipment are necessary.
- Adequate handholds, translation rails, safety wires, and tether attachments to support egress, ingress, transfer, and other EVA construction activities are necessary.
- Crew safety from electrical, fluid, mechanical, and other station hazards must be considered.
- Viewing ports are required so that IVA crewmembers can observe all LSS EVA construction activities.
- All sharp edges, corners, and protrusions should be designed to meet EVA criteria.
- Floodlights to aid the EVA crewmembers visibility in areas of high EVA activity, such as the airlocks, LSS construction areas, etc., should be provided.
- Electrical power outlets must be available at EVA construction sites.

Airlock

- Provide two airlocks and support equipment that will handle a minimum of two crewmembers.
- One airlock shall have the capability of serving as a hyperbaric chamber for two crewmen.
- Provide an equipment airlock for the transfer of EVA tools, parts, and equipment.

Figure 3.7-1 Space Station Accommodation Needs

3.7.2 Operations

Scheduling of the Space Station facilities, activities, and personnel is of prime importance to minimize conflicts during LSS EVA construction activities. Communications, data equipment, and links required for EVA will need to be available and operational. All other missions and space station facility usage will require close coordination during EVA activity. Three crewmembers will need to be trained and available (2 EVA and 1 IVA) during construction activities. Figure 3.7-2 shows the Space Station operations that need to be scheduled to avoid conflict with LSS-1 construction activities.

Scheduling
- **Communications**
  - **CCTV**
  - **Intercomm**
  - **Links**
- **Data**
  - **Processing**
  - **Handling**
- **Missions**
  - **Limited constructions or servicing without platform**
  - **RMS usage**
  - **Facilities (briefing room)**
- **Crew members**
  - **2 EVA**
  - **1 IVA**

Figure 3.7-2 Space Station Operations LSS-1

3.7.3 Crew Support

The operations analysis data from previous NASA studies was examined to define the necessary crew skills for performing basic Space Station operations. . The studies identified 7 basic crew skills. The seventh skill (spacecraft systems) was further defined, as shown in figure 3.7-3, to breakout the skills required to accomplish the Space Station missions.

1. **No special skill required**
2. **Medical/biological research**
3. **Physical sciences research**
4. **Earth and ocean sciences research**
5. **Engineering**
6. **Astronomy research**
7. **Spacecraft systems**
   - a) **Spacecraft systems operations—data**
   - b) **Spacecraft systems operations—electronics**
   - c) **Spacecraft systems operations—mechanisms**
   - d) **Spacecraft systems operations—fluids**
   - e) **Space Station subsystems operation and maintenance**
   - f) **EVA MRMS operations**
   - g) **EVA work station operations**
   - h) **MOTV and OMV piloting**
   - i) **Teleoperator piloting**

     Skill Levels
     1) **Task trainable**
     2) **Technical**
     3) **Professional**

Figure 3.7-3 Space Station Skill Type

The operations analysis data from the LSS TDM studies was examined to define the necessary crew skills for performing the LSS construction and testing operations. It was determined that six of those skills identified in figure 3.7-3 are required for LSS construction and testing activities. These six skills are shown in figure 3.7-4.

Engineering
Spacecraft systems operations—data
Spacecraft systems operations—electronics
Spacecraft systems operations—mechanisms
Space Station subsystems operation and maintenance
EVA MRMS operations

Figure 3.7-4 LSS TDM Skills Required

These six skill requirements were then further refined as shown in the example in figure 3.7-5. This figure identifies the crew skill title, the Space Station location where this skill is most often utilized, and the LSS TDM tasks that the person with this skill would be expected to perform, and the basic requirements for this skill.

Job Title	Work Location
Engineering	IVA in command center EVA LSS construction areas

Basic Tasks

Primary function is to supervise construction and test of LSS Technology Development missions.

Maintain voice and visual contact with other EVA and IVA crewmembers as required.

Requirements

Supervisory skills

Advanced training in properties of metals and composites for LSS TDMs

Advanced skills in mechanical, and electrical, diagnostics, troubleshooting and repair.

Training in computer hardware and software.

EVA proficient.

Figure 3.7-5 Crew Skill Descriptions

At this point in time, it is too early to define the skill mix required for each of the LSS Technology Development mission crewmembers. During the early missions, no doubt, each crew person will be cross-trained for more than one crew skill. As the Space

Station activity and number of crewmembers increases with time, it is likely that some of the crewmembers can become more and more specialized to the point to where they would be trained for only one skill.

To facilitate the generation of crew skill utilization statistics, it was necessary to create a set of tables that allocated the various crew skills to the various LSS TDM operations.

The numbers shown in the crew skills allocations represent the percent of operation duration time each skill is required. These percentages were estimated from the data used to calculate the operation time. Particular attention was paid to the crew skill descriptions in figure 3.7-5 in making sure that the proper crew skills were utilized for each operation. Figure 3.7-6 gives a summary of the crew skills applied to the LSS-1 construction/storage/hangar facility.

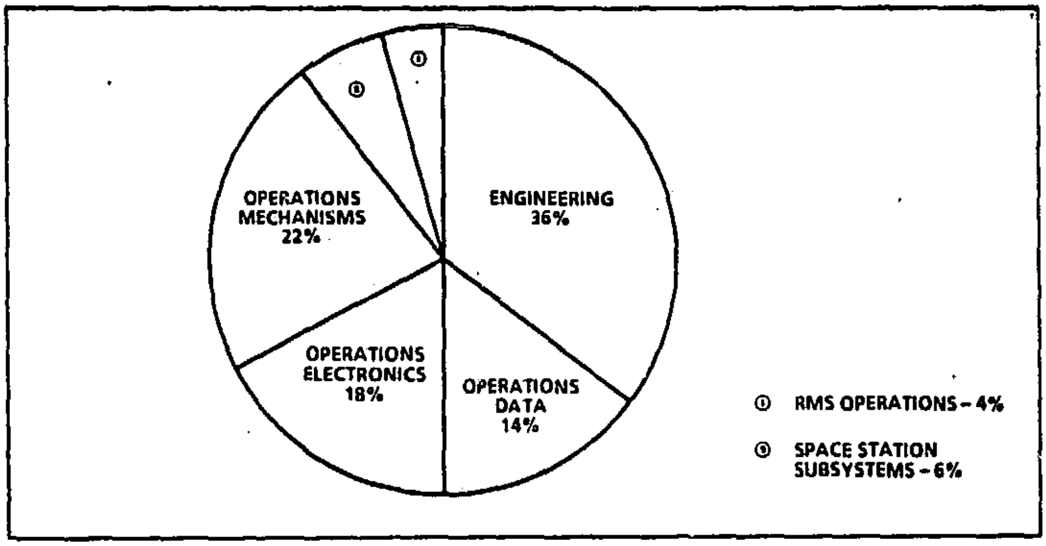


Figure 3.7-6 LSS-1 Crew Skill Support

3.7.4 Special Equipment

During the definition and analysis of the LSS-1 TDM, special equipment requirements were considered. The required support equipment, instrumentation, data systems, and small tools identified during this study are listed in figure 3.7-7. Some common equipment is envisioned to remain on the Space Station for use with other missions.

Support Equipment Docking tunnel Miscellaneous constraints and hold-downs Articulated test equipment holding fixture
Instrumentation Structural dynamics (acceleration, strain, loads, etc.) Thermal response (thermocouples) Position/deflection (precision laser ranging, corner reflectors)
Data Systems Recording Storage and retrieval Manipulation (EDP)
Small Tools LSS-1 construction tool kit

Figure 3.7-7 LSS-1 Special Equipment

3.8 Potential Problems and Concerns

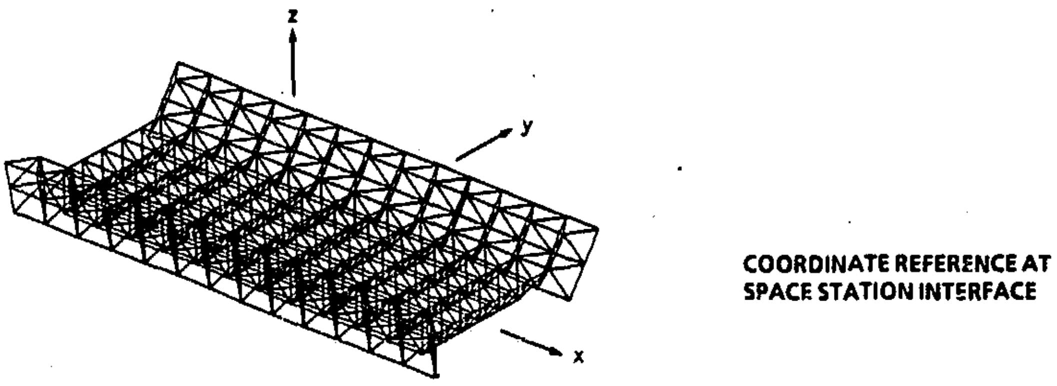
Several areas of concern must be considered when constructing the Construction/Storage/Hangar facility at the Space Station. The additional mass and inertias of the structure as well as its structural dynamic characteristics must be accommodated by the Space Station control system. The dynamic loads resulting from events such as Orbiter docking and thruster firings must also be accounted for. Large Space Structures attached to the Space Station will also increase the drag due to their size. The large size of the structures may also influence the thermal balance of the Space Station and interfere with communication paths.

These and other concerns raised by the construction of large space structures affect a wide range of technologies and subsystems and need to be carefully considered in the design of the Space Station as well as in the design of the construction project. The results of initial investigations of some of these concerns are presented in the following sections.

3.8.1 Mass and Inertia

The control system of the Space Station must be designed to accommodate growth from the earliest configuration to the most advanced configuration. The mass and inertias of each Space Station component and any large space structures construction projects must be calculated to assess their contribution to the total mass and inertias.

The mass properties of the Construction/Storage/Hangar Facility with and without the hangar panels are shown in figure 3.8-1. The center of mass location is given in relation to the Space Station interface which is at the center of the platform. The inertias are given relative to the center of gravity. The location of the platform will determine to what extent the additional mass and inertia will affect the Space Station. Since the mass of LSS-1 is less than 1/3 of the mass of a single Space Station module, it is unlikely that it will cause a major influence on the total mass and inertia.



WITHOUT HANGAR		WITH HANGAR	
MASS	= 3300 kg	MASS	= 7000 kg
Z-C.G.	= .4 m	Z-C.G.	= 4.1 m
I_{XX}	= 78,000 kg-m^2	I_{XX}	= 231,000 kg-m^2
I_{YY}	= 130,000 kg-m^2	I_{YY}	= 441,000 kg-m^2
I_{ZZ}	= 201,000 kg-m^2	I_{ZZ}	= 485,000 kg-m^2

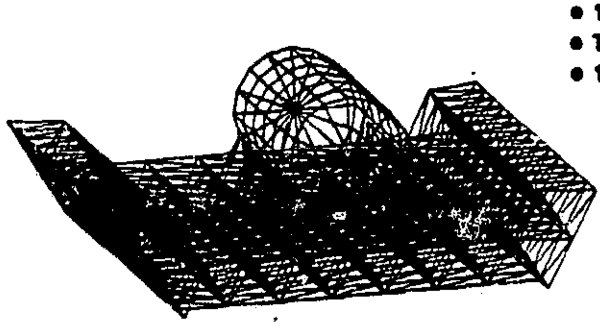
Figure 3.8-1 LSS-1 Mass Properties

3.8.2 Dynamic Loads

An analysis was conducted to determine whether the accelerations imposed on the Space Station by such events as Orbiter docking, attitude control or station keeping thrust would cause excessive loads of deflections. A NASTRAN finite element model of the construction platform including a 14,500 kg "payload" attached to the payload rails was exposed to a unit acceleration in the x, y and z directions. The structure was cantilevered from a rigid transfer tunnel at the center of the truss and the payload was kinematically supported on the payload rails.

The loads in the truss members near the transfer tunnel showed them to be buckling critical. The maximum acceleration which this platform configuration can withstand is 0.48 g's. The maximum deflections which occur with this acceleration level are shown in figure 3.8-2. The maximum deflections which occur at the corner of the platform are 15 mm (.57 in) or less. These deflections are judged to be acceptable. However, the "weak link" is probably the Space Station module wall near the berthing port to which the transfer tunnel is attached. On the other hand, the low thrust propulsion systems and soft docking techniques proposed for the Space Shuttle will produce accelerations well below the 0.48 g's used in this analysis (probably on the order of 0.01 g's). If the Space Station module loads are still too high, additional bracing members can be used to distribute the loads.

ANALYSIS
- 846 D.O.F. NASTRAN MODEL
- 14,500 kg (32,000 lb) "PAYLOAD"
- TRUSS ATTACHED TO RIGID TRANSFER TUNNEL
- 1-g LOADS APPLIED IN X, Y & Z DIRECTIONS



ANALYSIS
- BUCKLING CRITICAL
- ALLOWABLE LOAD FACTOR = 0.48g

DEFLECTIONS (.48g)

LOAD DIRECTION	MAX. DEFLECTION
X	13. mm (.51 in)
Y	12. mm (.48 in)
Z	15. mm (.57 in)

Figure 3.8-2 LSS-1 Truss Deflections

3.8.3 Structural Dynamic Characteristics

The same NASTRAN finite element model used in the loads and deflection analysis was reduced to 120 dynamic degrees of freedom and used to determine the dynamic characteristics of the Construction/Storage/Hangar Facility (without hangar). The resulting frequencies listed in figure 3.8-3 show that the truss is very stiff, even with a 14,500 kg payload attached. With the hangar panels attached, the first mode frequency will be approximately 2.0 Hz. As mentioned in the discussion of the truss loads in Section 3.8.2, the flexibility of the Space Station side of the interface could contribute significantly to the overall flexibility of the platform system.

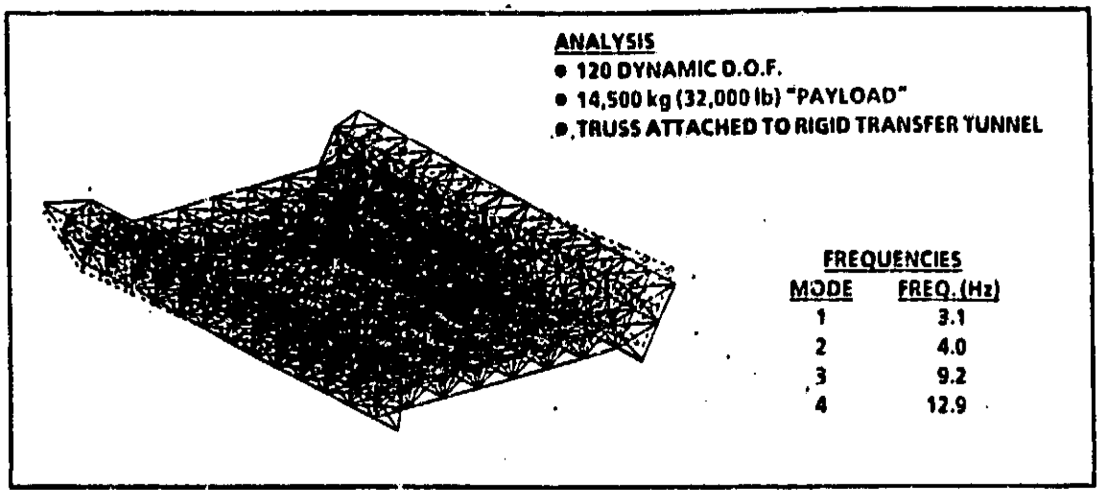


Figure 3.8-3 LSS-1 Dynamic Characteristics

3.8.4 Drag

Another concern created by LSS construction is the increased frontal area which increases the rate of orbital decay due to drag. The orientation of the structure can have a pronounced effect on the drag. For instance, if the planform of the platform is oriented perpendicular to the flight path, the frontal area of the Space Station will be increased more than if it was oriented with the end of the platform toward the flight path.

The drag force on a body in low Earth orbit is a function of its ballistic coefficient (area per unit mass). Figure 3.8-4 shows the area of LSS-1 in the x, y and z directions and the corresponding area/mass ratio treating the platform as an isolated body. The important thing, however, is the effect that the additional area and mass have on the Space Station drag. Using an estimate of the maximum exposed area and mass of the Space Station, the influence of LSS-1 was estimated in terms of the percent increase in area/mass ratio as shown in the figure. For these calculations, it was assumed that the two areas are additive, when in reality, some shadowing may occur.

	X-DIR	Y-DIR	Z-DIR
LSS-1 AREA (m^2)	102.	303.	504.
AREA/MASS RATIO (m^2/kg)	.015	.043	.072
% INCREASE FOR SPACE STATION	-1	7	16.4

ASSUMPTION: TDM AREA ADDS TO SPACE STATION AREA

Figure 3.8-4 LSS-1 Drag Effects

4.0 PASSIVE MICROWAVE RADIOMETER, LSS-3

This section is a self-contained description of the tasks relating to the development of a Passive Microwave Radiometer technology development mission, LSS-3. Included in the study are design and operations trades, detailed structural design of the mission, an analysis of the operations required to perform the mission, precursor technology developments which can be accomplished on Earth or with Shuttle flights, and the programmatics of the mission. In addition to these topics, the accommodations which the Space Station must provide to the TDM are identified and, conversely, some of the problems and concerns which the TDM may impose on the Space Station are considered.

4.1 Design Trade Studies

The design topics relating to the microwave radiometer which were subjected to trade studies include the configuration, the type of members and joints, and the reflector surface material and its control. Each trade is discussed individually in this section.

4.1.1 Truss Ring Configuration

The three types of reflector support structure shown in figure 4.1-1 were considered for this TDM. Two ring trusses, one made up of trapezoidal elements (box ring truss) and

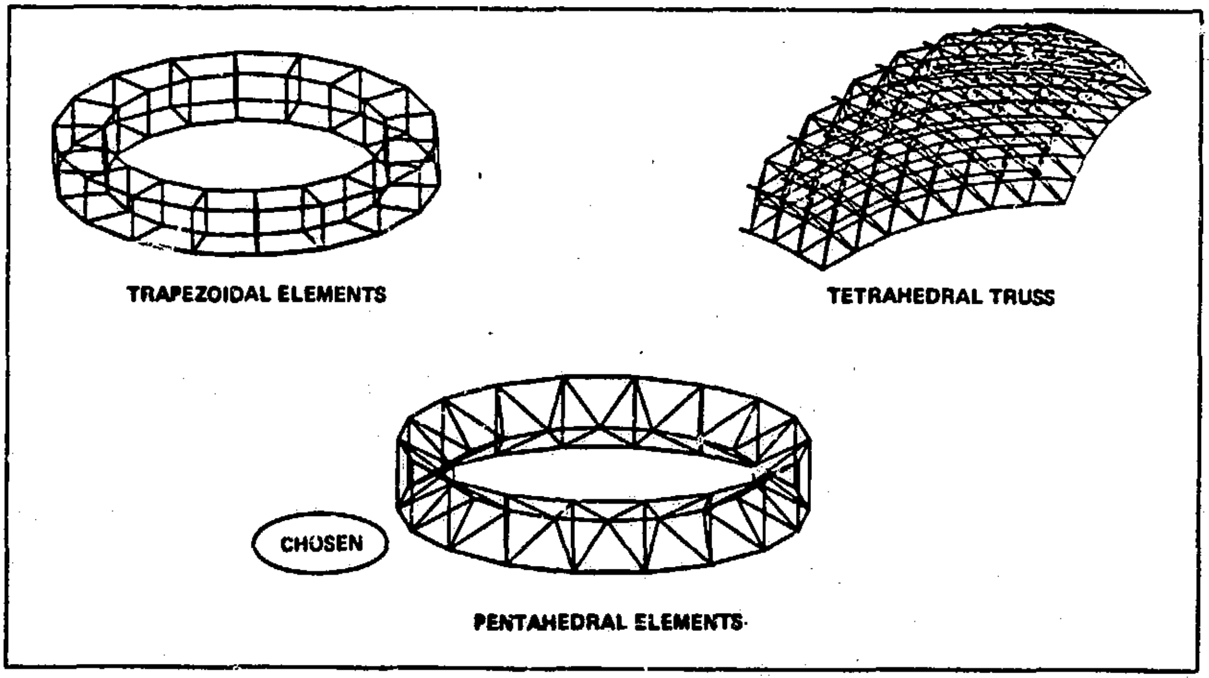


Figure 4.1-1 LSS-3 Reflector Support Structure Concepts

one consisting of pentahedral elements, and a continuous tetrahedral truss were evaluated based on characteristics such as mass, stiffness and number of structural elements and joints. Additional factors such as ease of on-orbit construction were also used to evaluate the configurations.

Figure 4.1-2 summarizes the results of the trade study. Under the assumption that the tetrahedral truss is a deployable concept, the length and diameter of the members was varied to arrive at a baseline configuration. Packaging dimensions and the requirement for a sufficiently large number of "hard points" for proper reflector control led to the 12 ring baseline configuration. The resulting weight and complexity (number of elements and joints) quickly eliminated it from further consideration.

TRADE ITEMS	OPTIONS BOX RING TRUSS	 PENTAHEDRAL RING	 TETRAHEDRAL TRUSS
			(12 RINGS)
MASS (KG)	887.	774.	3486.
STIFFNESS (1ST MODE FREQ., HZ)	1.08	.85	2.25
NUMBER OF ELEMENTS	144	144	3852
NUMBER OF JOINTS	72	54	901 CLUSTER 2556 KNEE
DIAMETER (M)	[illegible]	103.	115.
OTHER CONSIDERATIONS			
EASE OF CONSTRUCTION	FAIR	GOOD	COMPLEX
		CHOSEN	

Figure 4.1-2 LSS-3 Reflector Support Structure Trade Study

The two ring configurations are comparable in mass, stiffness and complexity. The pentahedral truss ring is 13 percent lighter than the box truss using similar structural elements. The stiffness of the box truss is higher based on a NASTRAN analysis of the dynamic characteristics of each configuration. However, the stiffness of the pentahedral truss ring can be increased by increasing the diameter of the cables which provide shear stability in the square faces of the pentahedral truss elements. The pentahedral truss is smaller in overall diameter since the reflector can be attached at the outside diameter while it must be attached to the inside diameter of the box ring truss. The biggest advantage of the pentahedral truss, however, is in the ease of on-orbit construction. It is significantly easier to construct a pyramid truss module (from a fixed base) than it is to construct a cubic module. The tip of a pyramid aligns itself while shear ties must be added and adjusted to stabilize and align a cube (or trapezoidal element). For these reasons, the pentahedral ring truss was selected for LSS-3.

4.1.2 Truss Members

Three types of truss members were considered for the truss elements: cylindrical tubes, nestable tapered tubes and deployable beams. The factors which led to the selection of nestable tapered tubes for the truss ring are packaging (cylindrical tubes are very inefficient for packaging) and complexity (deployable beams are complex and, therefore, expensive). Nestable tapered tubes require on-orbit assembly of the two halves but can be packaged efficiently for delivery to orbit.

4.1.3 Truss Member End Joints

Figure 4.1-3 shows the four truss member end joint concepts evaluated for the ring truss elements. Truss assembly requires the use of "side entry" joints for both assembly and for potential replacement of members. All four candidates are "side entry" joints. The strengths and weaknesses of each are discussed individually in the following paragraphs.

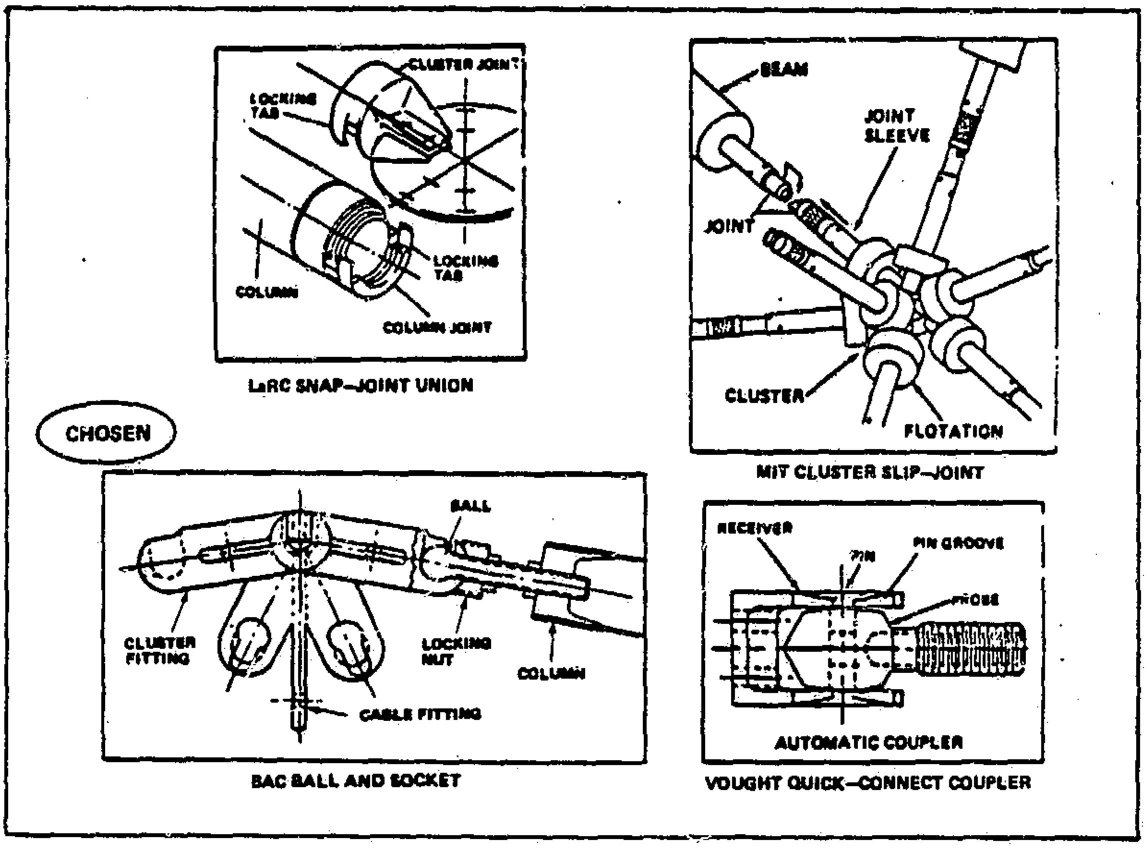


Figure 4.1-3 LSS-3 Truss Member End Joint Trade Study

Snap-joint union - This joint requires complex machining and, to minimize joint "slop", it must be machined very accurately. Accurate strut alignment is required for latching and opposite ends of the strut must be accurately aligned with respect to each other to permit truss assembly.

Cluster slip-joint - The cluster slip-joint also requires precision machining to minimize joint slop. High alignment accuracy is required to slide the joint sleeve into place, and high end-to-end alignment accuracy is required to allow truss assembly.

Quick-connect coupler - This joint can be assembled from the side, from the end, or from other angles. Although the slop accommodation is potentially better than the previous two concepts, the fit of the pin within its hole determines the amount of slop in the joint. As in the previous joints, the end-to-end alignment must be accurate.

Ball and socket - The geometry of the ball and socket joint does not require high alignment accuracy for latching or for end-to-end alignment. The slop in the joint is eliminated by the locking nut. Although strut length is pre-set on the ground, it is feasible to adjust the strut length on-orbit.

The ball and socket joint was selected for the LSS-3 truss ring because of its ability to eliminate all joint slop, its tolerance to slight strut misalignment for initial latching, and its potential for being manufactured from low CTE (coefficient of thermal expansion) materials such as invar or graphite/epoxy. The ball ends of the struts also eliminate the necessity to index the strut torsionally before latching. The biggest deterrent is the necessity for a tool (wrench) to lock the joint.

4.1.4 Truss Member Center Joint

To achieve high packaging density, the use of nestable tapered struts is proposed for the truss members. The center joint which joins the two halves is the subject of this trade study. The two concepts which were considered for this trade are shown in figure 4.1-4. The interlocking joint consists of a series of interlocking fingers on each half of the strut which rely on the flexing of the fingers to slide over and latch to a machined ring on the opposite half of the strut. The ring clamp concept is similar to those commonly used in the aerospace industry to join cylindrical structures.

The interlocking joint is operationally simpler since there are no extra parts required. It does, however, require high alignment accuracy and an axial force to latch.

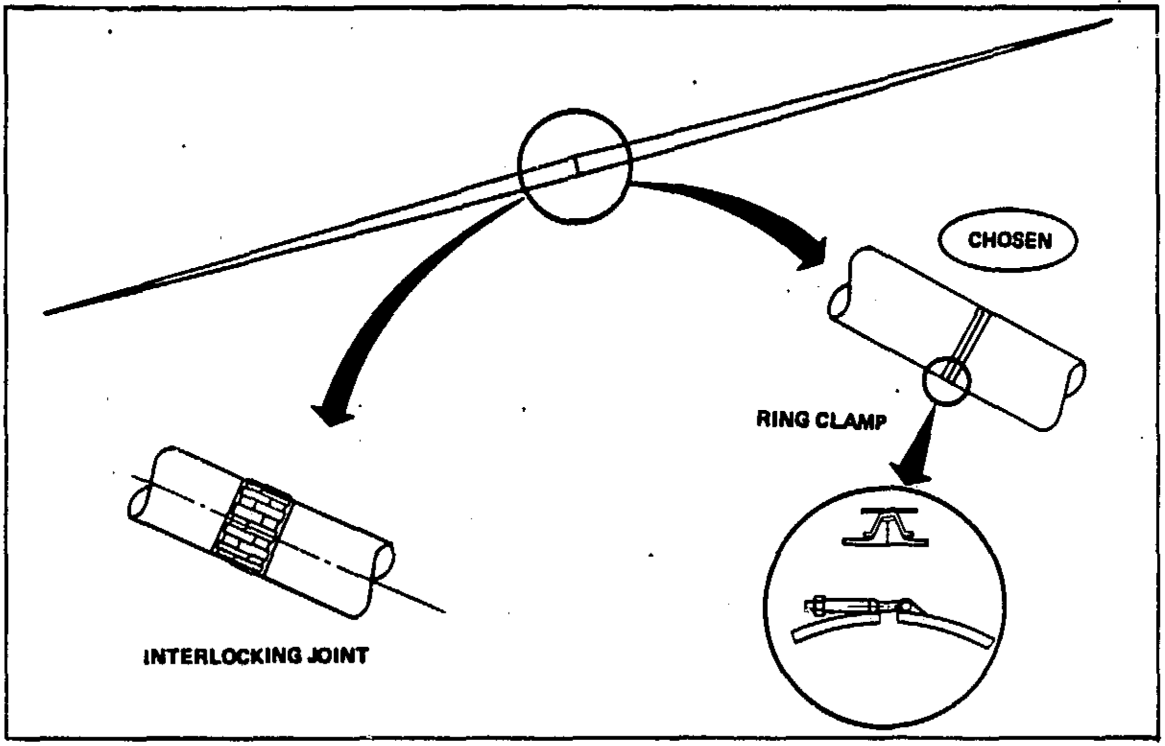


Figure 4.1-4 LSS-3 Truss Member Center Joint Trade Study

The manufacturing process is fairly complex and requires accurate machining to assure proper fit and minimum joint slop. The disassembly of this joint is also very inconvenient since all of the latched fingers must be lifted simultaneously to disengage the two halves of the joint.

Although the ring clamp is an extra part to contend with in the assembly process, the manufacturing simplicity, off-the-shelf technology, self-aligning ability, joint slop elimination and ease of disassembly make it our choice for the center joint for LSS-3 truss members.

4.1.5 Feed Array Supports

The three types of masts shown in figure 4.1-5 were considered for use as feed array support beams: a coilable longeron (Astromast-type) deployable mast, a cable-stiffened mast (consisting of a structural central tube which carries axial loads and outrigger cables which provide increased bending stiffness), and a deployable mast with folding longerons.

Figure 4.1-6 gives a quantitative and qualitative comparison of the three types of masts. The coilable longeron mast has high packaging efficiency, but is the heaviest of

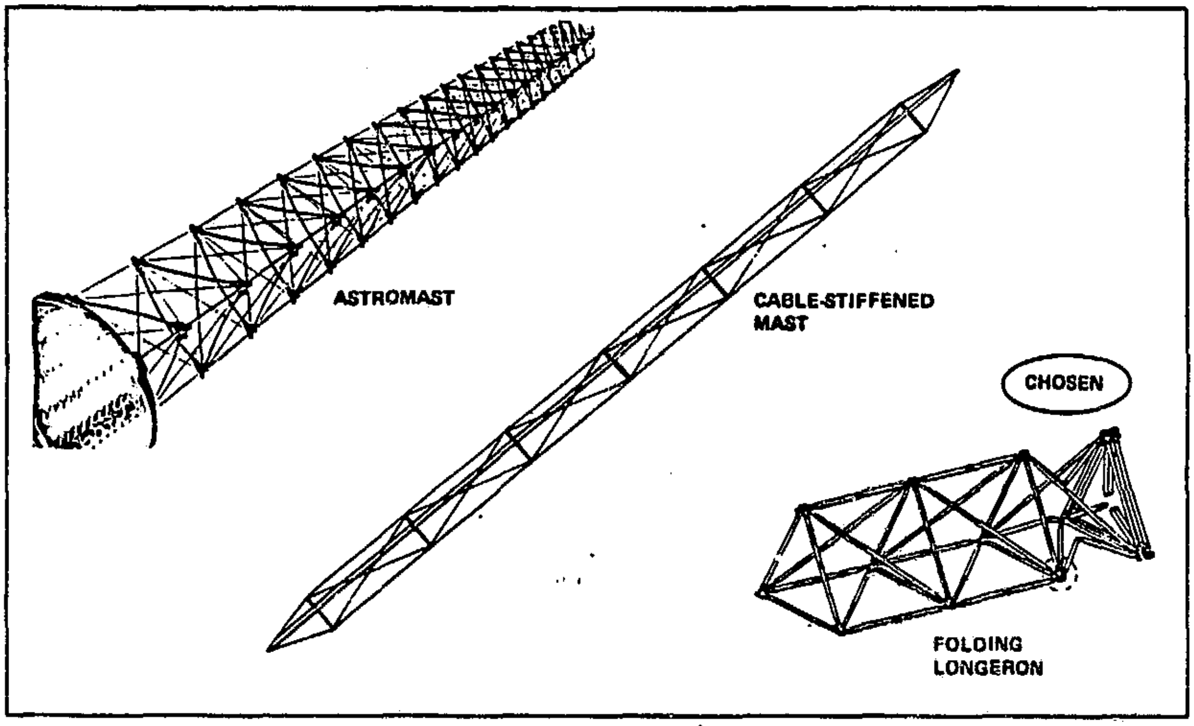


Figure 4.1-5 LSS-3 Feed Array Support Mast Concepts

TRADE ITEM	ASTROMAST	TENSION-STIFFENED MAST	FOLDING LONGERON MAST (CHOSEN)
MASS, KG	320.	150.	56.
BENDING FREQUENCY (PIN-PIN), HZ	.14	.25 - .40	.32
PACKAGING EFFICIENCY	HIGH	LOW	HIGH
COMPLEXITY	HIGH	LOW	HIGH

Figure 4.1-6 LSS-3 Feed Array Support Mast Trade Study

the three and has the lowest bending frequency based on pinned end conditions. The cable stiffened mast is somewhat less complex than the other two but has poor packaging efficiency since it consists of seven hinged sections which fold into a 11.5 meter long bundle after the cable spreaders are folded along the central tube. Its bending stiffness depends upon the cable parameters and spreader length. The folding longeron mast made of graphite/epoxy material is the lightest, has good frequency characteristics and is efficiently packaged for delivery to orbit. This type of mast was, therefore, selected for use as the feed array supports.

4.1.6 Feed Array Truss Beam

The three generic types of deployable beams considered for the feed array truss beams are shown in figure 4.1-7. Two of the concepts have a triangular cross-section while the third has a square cross-section. Comparisons were made on the basis of weight, stiffness, number of elements and joints, and other intangible factors such as the ability to accommodate the microwave sensor assemblies.

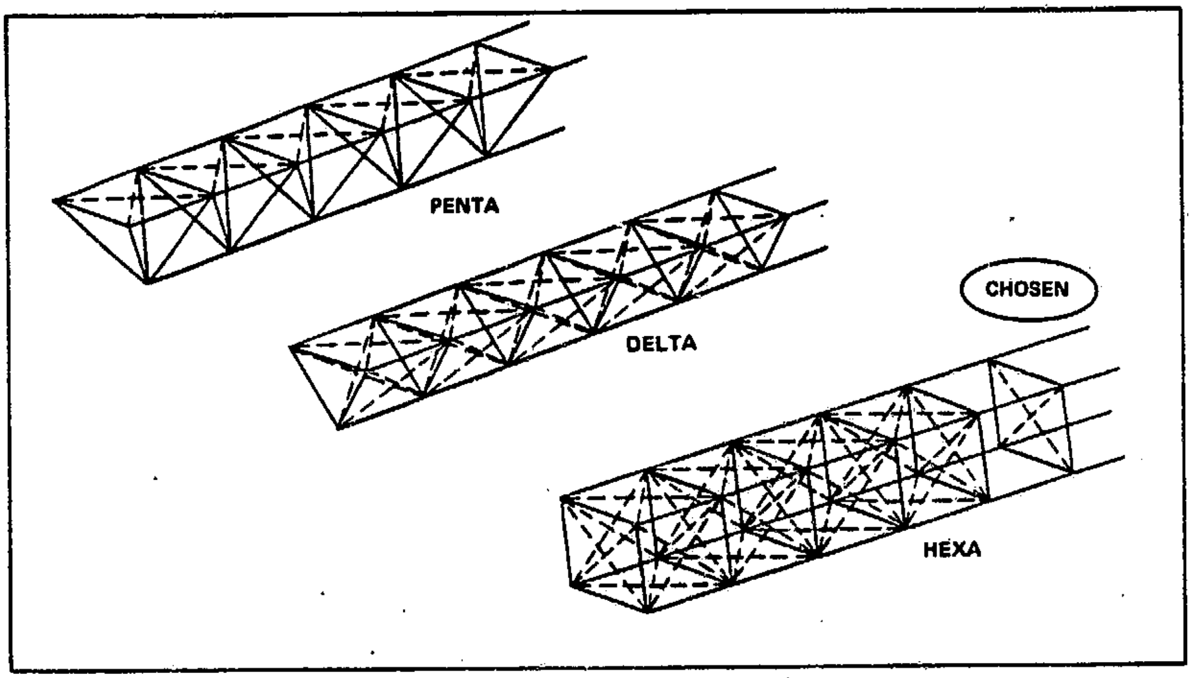


Figure 4.1-7 LSS-3 Feed Array Truss Beam Concepts

Figure 4.1-8 shows a comparison of the characteristics of the three deployable truss beam types. Ignoring the weight of the joints, a mathematical expression was derived for a stiffness-to-weight parameter (I'). This non-dimensional parameter involves the equivalent area moment for the beam (I), the material density (ρ), the length of a typical member (L) and the weight per unit length (w). The stiffness-to-weight parameter shown is:

$$I' = I*\rho/(W*L^2)$$

Although the hex-truss beam is the heaviest, it has the highest stiffness-to-weight ratio (a measure of its bending frequency-squared). Its square modular shape also provides good accommodation for the feed horn assemblies, while the triangular cross-section of the other two truss beams would require the feed assemblies to be mounted externally. This causes the mass to be offset from the elastic axis of the beam and would result in undesirable lateral/torsional coupling. Therefore the hex-truss configuration was selected for the feed array truss beam.

	CHOSEN		
	PENTA	DELTA	HEXA
NUMBER OF ELEMENTS PER BAY			
W/O DIAGONALS	9	6	8
W/ DIAGONALS (1)	10	9	13
NUMBER OF JOINTS PER BAY	3	3	4
STIFFNESS/WEIGHT PARAMETER			
h = ℓ			
W/O DIAGONALS	.0749	.1069	.125
W/ DIAGONALS	.0648	.0626	.0664
WEIGHT/UNIT LENGTH			
W/O DIAGONALS	8.90Aρ	6.24Aρ	8Aρ
W/ DIAGONALS	10.32 Aρ	10.65 Aρ	15.07 Aρ
FEED HORN ASSEMBLY ACCOMMODATION	POOR	POOR	GOOD

Figure 4.1-8 LSS-3 Feed Array Truss Beam Trade Study

4.1.7 Reflector Surface

A review of the literature indicates that there are two basic types of flexible reflector surfaces: mesh and membrane. Mesh types include woven metallic mesh and knitted metallic mesh. Membranes include materials such as aluminized kapton or aluminized mylar. Based on articles in Reference 2, a knitted metallic mesh system was selected. The mesh consists of gold-plated molybdenum wire with an areal density of 0.043 kg per square meter.

4.1.8 Reflector Shape Control Mechanism

Three types of reflector control schemes were considered for LSS-3: The bootlace catenary system, the distributed control catenary system and the electrostatic control method. These three schemes are shown schematically in figure 4.1-9. The distributed control catenary system was somewhat arbitrarily selected for use as the reflector control method. The electrostatic control method appears to be complex and heavy, while the bootlace system is judged to be intolerant of local variations in reflector shape.

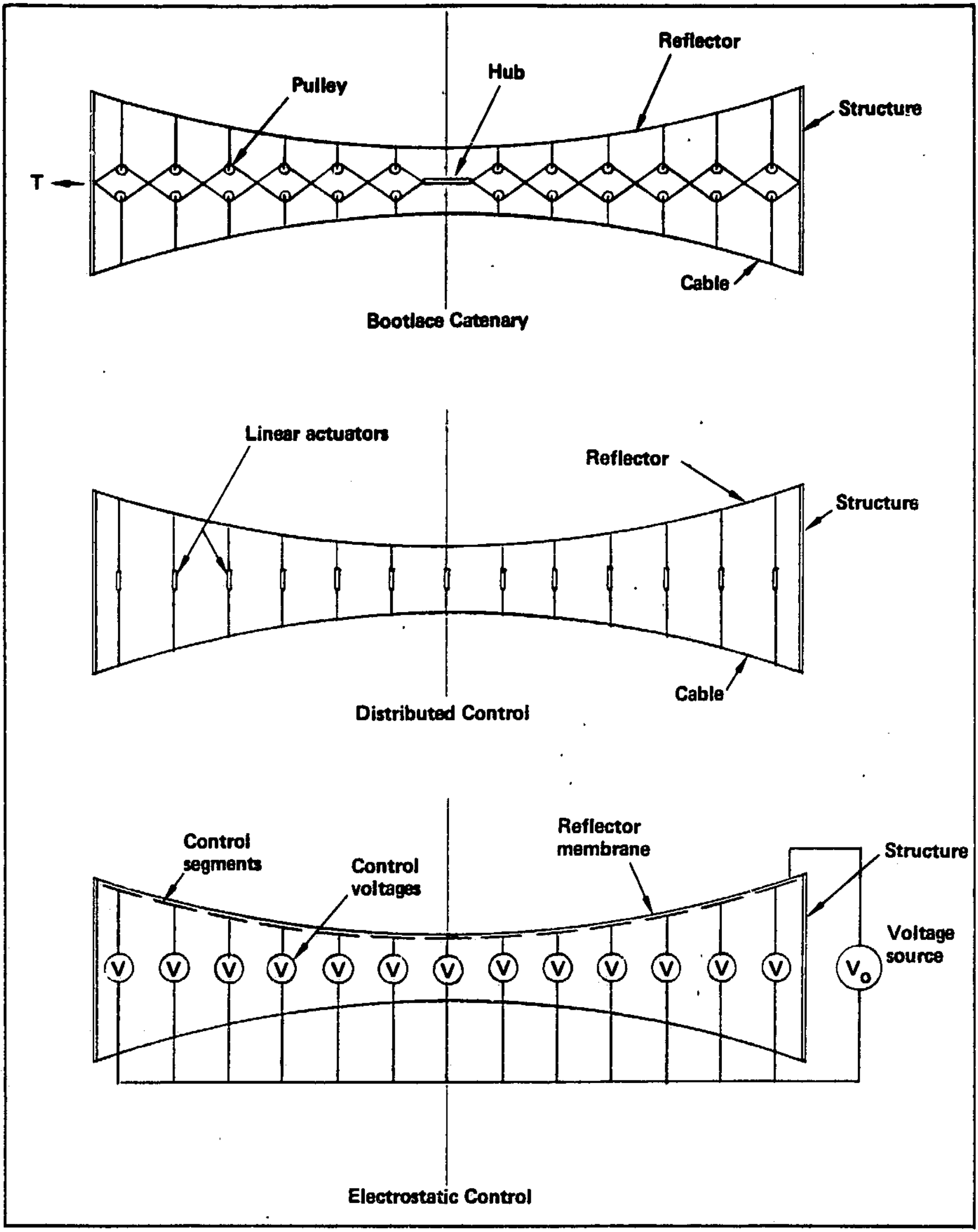


Figure 4.1-9 LSS-3 Reflector Control Options

4.2 Operations Trade Studies

This section summarizes the trade studies completed during the LSS-3 construction analysis.

4.2.1 EVA Crew Schedule

The results of our analysis indicates that the workday should be 6 actual EVA hours.

Three operators per shift (2-EVA and 1-IVA) will be required, full time, during LSS EVA construction activities. The ability to operate more than 1 shift per day will be dependent on the Space Station crew size and other scheduled Space Station activities. Two or three shift operation could result in conflicts in the use of facilities and high noise levels while other crewmembers are trying to sleep. For the LSS TDM EVA construction activities it is recommended that 1 shift per day be utilized.

It is recommended that a 5 day LSS-3 EVA construction week be adopted with 1 IVA day for paperwork and suit maintenance and care.

4.2.2 EVA Personnel Restraints

The restraint methods selected for the LSS-3 TDM construction activities are:

1. The flexible tethers that are currently utilized for the STS missions.

2. The current safety line.

3. A shoe restraint with matching grid work.

4. The hangar that is part of LSS-1 will also serve as an operator restraint.

4.3 Mission Design

Some of the design details for the Passive Microwave Radiometer (LSS-3) are discussed in the following paragraphs. The detailed design drawings can be found in Appendix A.

4.3.1 Reflector Support Structure

The 103 meter diameter reflector support structure is a truss ring made of tapered strut elements 18 meters in length, forming a series of pentahedral truss elements as shown in figure 4.3-1. The struts are made of graphite/epoxy material and use a unique method of manufacture. 260 graphite/epoxy fiber bundles run longitudinally and are evenly spaced around the circumference, resulting in a structural element which has a constant cross sectional area even though it tapers from .305 meters (12. inches) in diameter at the center to .025 meters (1.0 inch) diameter at the end. Then a single helical wrap bundle is used to stabilize the longitudinal fibers. The center joint and the end joint are bonded with the longitudinal fibers during manufacture. With the joints included, the mass of each 18. meter strut is 5.7 kg (12.5 lbs) and can be efficiently nested for transport to orbit.

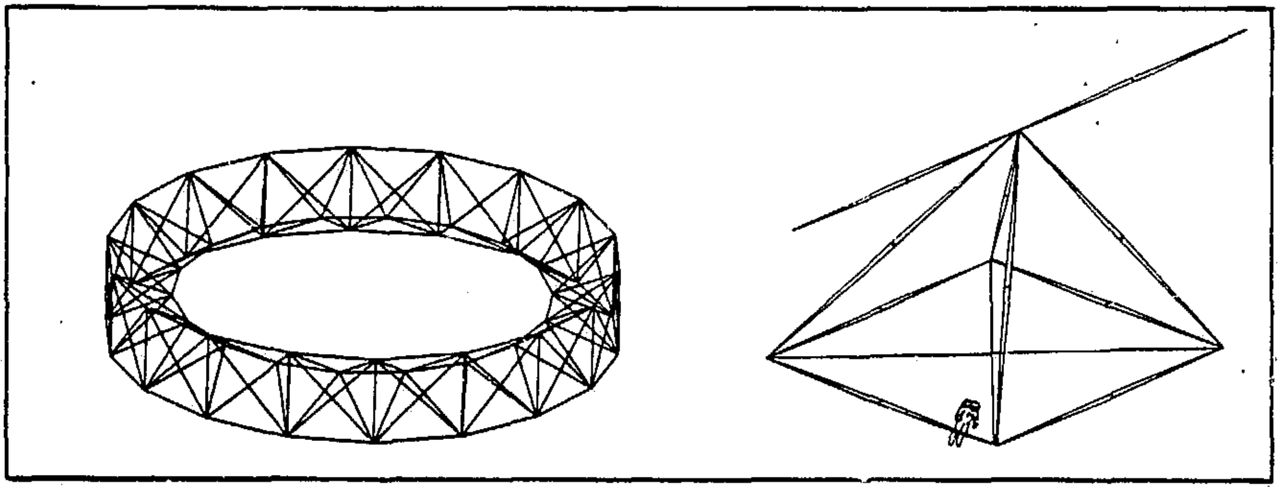


Figure 4.3-1 LSS-3 Reflector Support Structure

The center and end joints are shown in figure 4.3-2. The center joint is a ring clamp joint which produces a no-slop connection which does not require accurate angular alignment about the strut axis during assembly. The end joint is a ball and socket joint which also allows all slop to be eliminated and does not require angular alignment. The primary adjustment nut is designed to allow an astronaut to accomplish the initial connection and tightening with a gloved hand. Final tightening of the lock nut requires a

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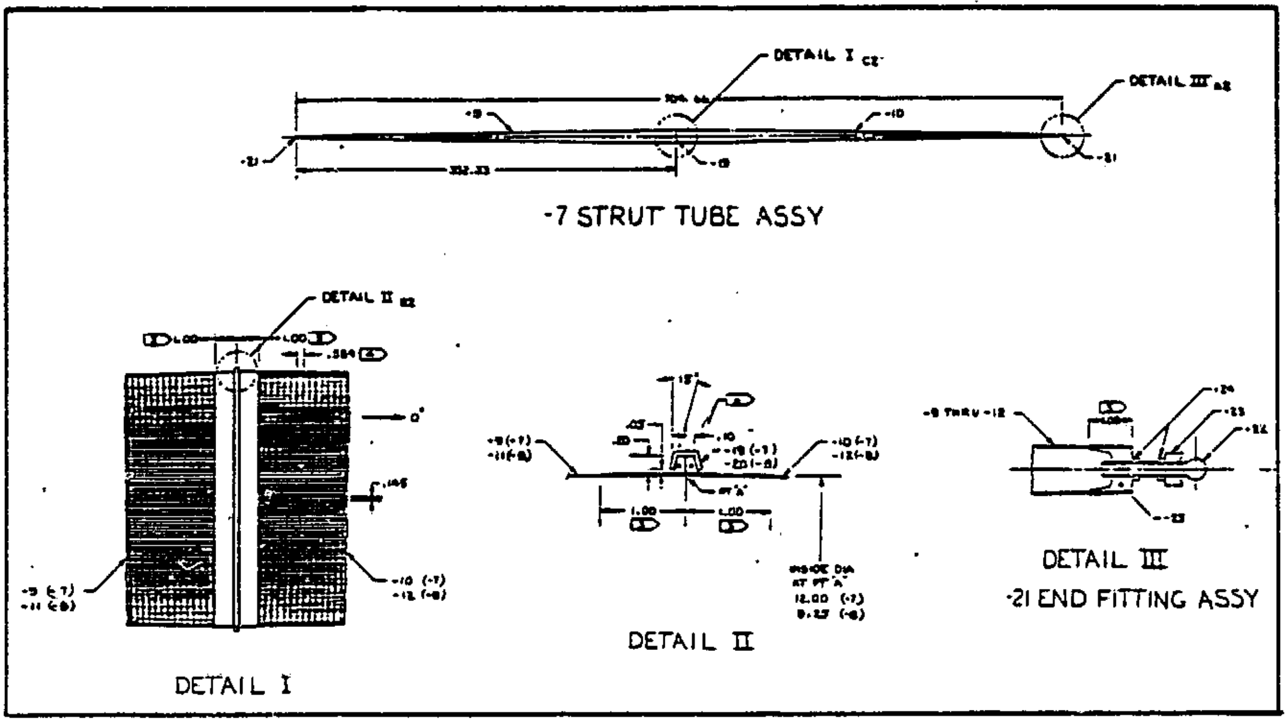

Figure 4.3-2 LSS-3 Ring Truss Member Joints

wrench. The cluster fittings, shown in figure 4.3-3, are made of Invar investment castings with final machining to provide the accuracy necessary in the sockets.

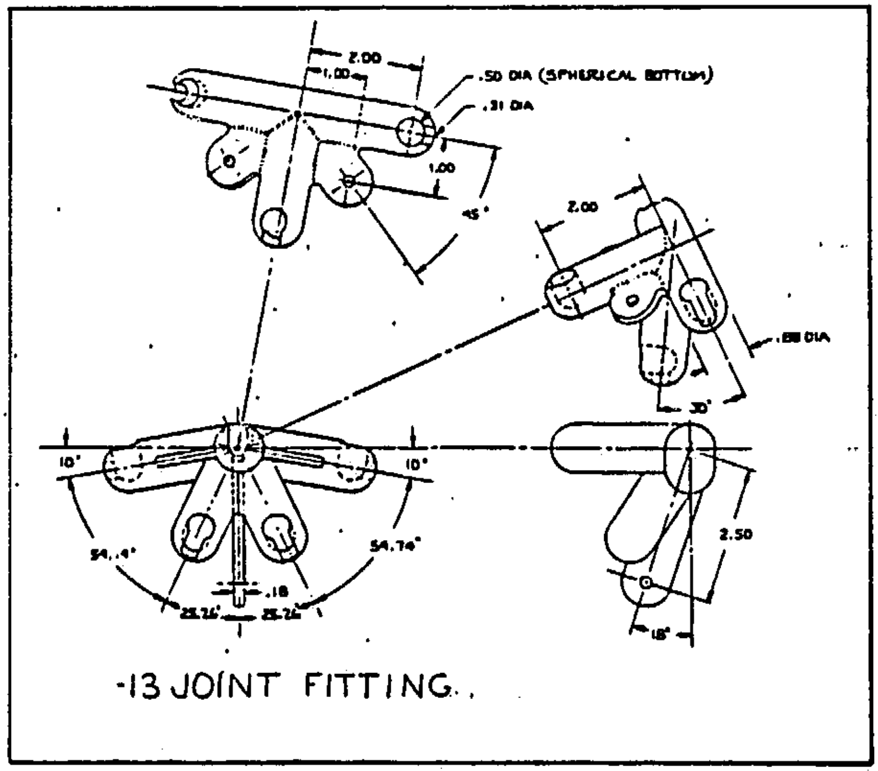

Figure 4.3-3 LSS-3 Ring Truss Cluster Joint

4.3.2 Feed Array Structure

The feed array structure is a deployable box beam truss as shown in figure 4.3-4. The elements are .0508 m (2.0 in.) in diameter and are made of graphite/epoxy laminate. Although the longeron tubes are all the same length, the hinge fittings on the bottom of the truss are approximately .1016 meters (4.0 in.) longer than those on the top so that the box beam curves in a 79.3 meter circular arc. The "tee" plates and "angle" plates in the joints are made of laminated graphite/epoxy and the tube end fittings are injection molded graphite/epoxy.

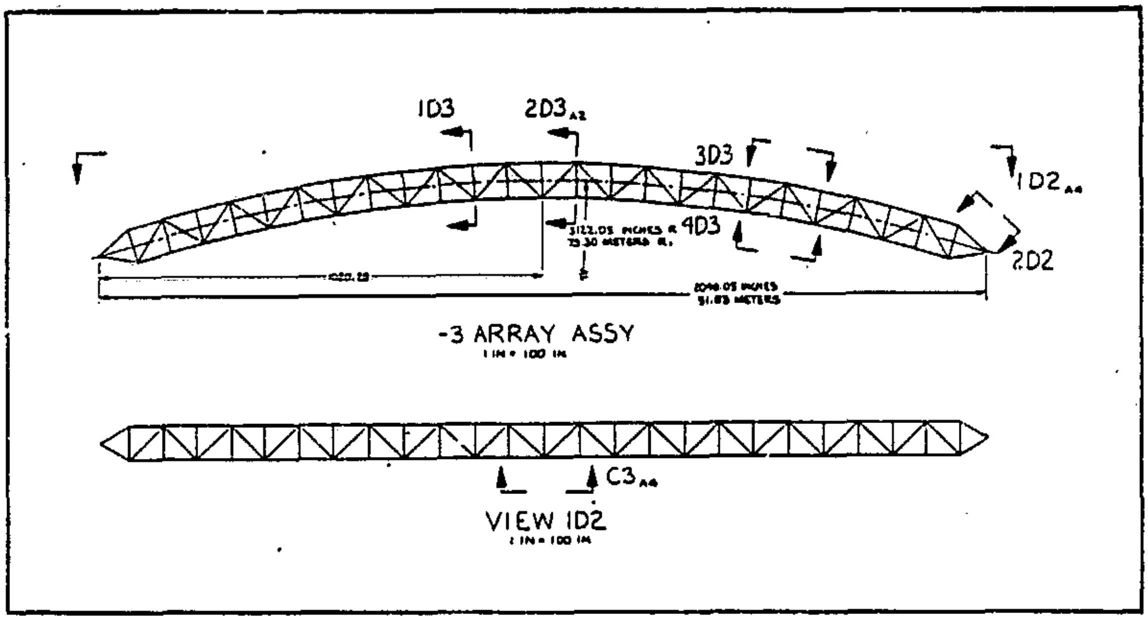

Figure 4.3-4 LSS-3 Feed Array Structure

Figure 4.3-5 shows the packaging scheme for the box truss. The diagonal members on the sides of the truss beam telescope to allow the truss to fold at the hinged joints. The packaged dimensions of the feed truss are 2.0 x 4.0 x 2.1 meters.

4.3.3 Feed Support Structure

The feed support masts are deployable truss beams with a triangular cross section as shown in figure 4.3-6. As in the feed array truss, the structural elements are graphite/epoxy tubes .0508 meters (2.0 in.) in diameter.

Figure 4.3-7 shows the packaging method for these masts. The longeron tubes are hinged at the center of each bay and fold inward as shown. The cross section of the packaged mast is triangular with a base of 2.0 meters and a height of 2.0 meters. The 79.3 meter length becomes 4.5 meters when packaged.

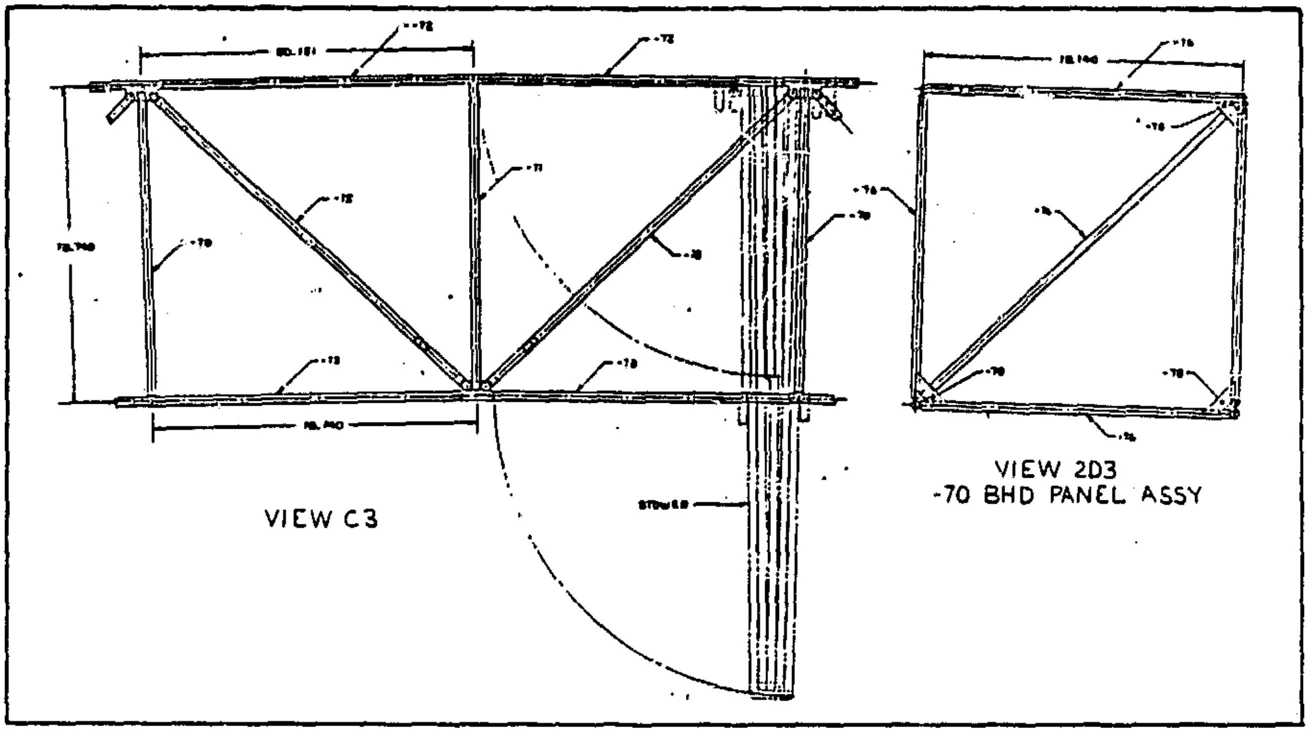

Figure 4.3-5 LSS-3 Feed Array Packaging Concept

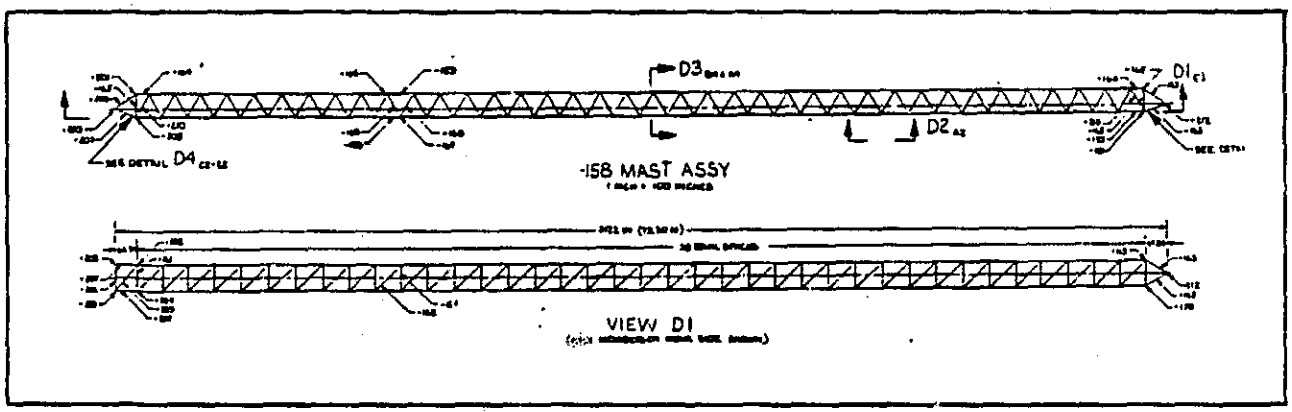

Figure 4.3-6 LSS-3 Feed Support Mast

4.3.4 Reflector System

The reflector surface is a light weight knitted wire mesh made of gold plated molybdenum wire embedded in a plastic film. It is divided into 18 gores with 25 panels each (fig. 4.3-8) with reinforcing cables at the boundary of each panel and gore. The mesh is attached to the top of the truss ring at eac of the 18 cluster joints around the circumference. The radial reinforcing cables are mirrored bv radial control cables. The radial reinforcing cables are mirrored by radial control cables attached to the corresponding cluster fittings around the bottom of the truss ring. Between the mesh surface

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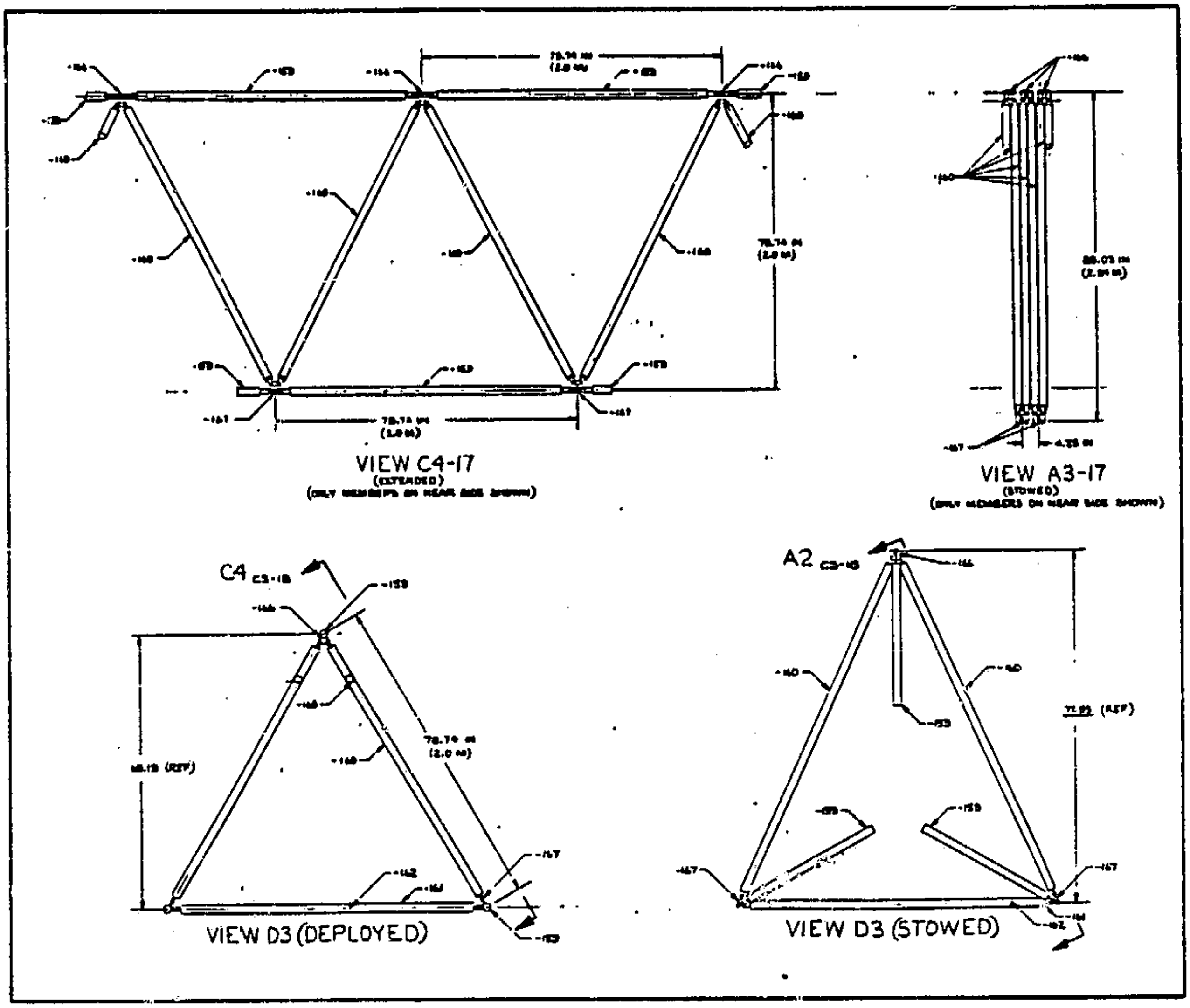


Figure 4.3-7 LSS-3 Feed Support Mast Packaging Concept

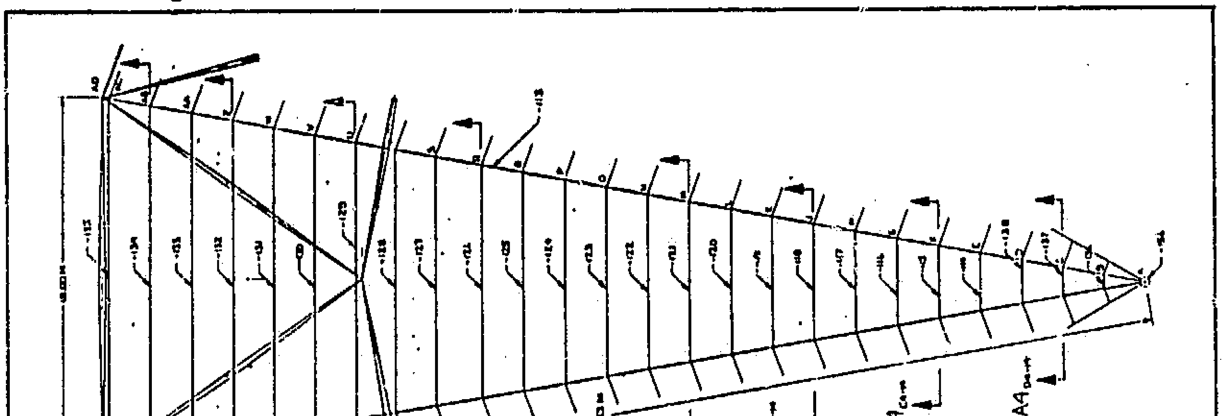


Figure 4.3-8 LSS-3 Reflector Surface

and the radial control cables are vertical drop cables, as shown in figure 4.3-9, which control the shape of the reflector surface. Each drop cable and radial cable contains a linear actuator which can apply tension to its cable in response to the surface control system. A typical linear actuator capable of a .0508 m (2.0 in.) stroke is shown in figure 4.3-10. The control of the surface contour will require a sophisticated measurement and control system to orchestrate the many actuators.

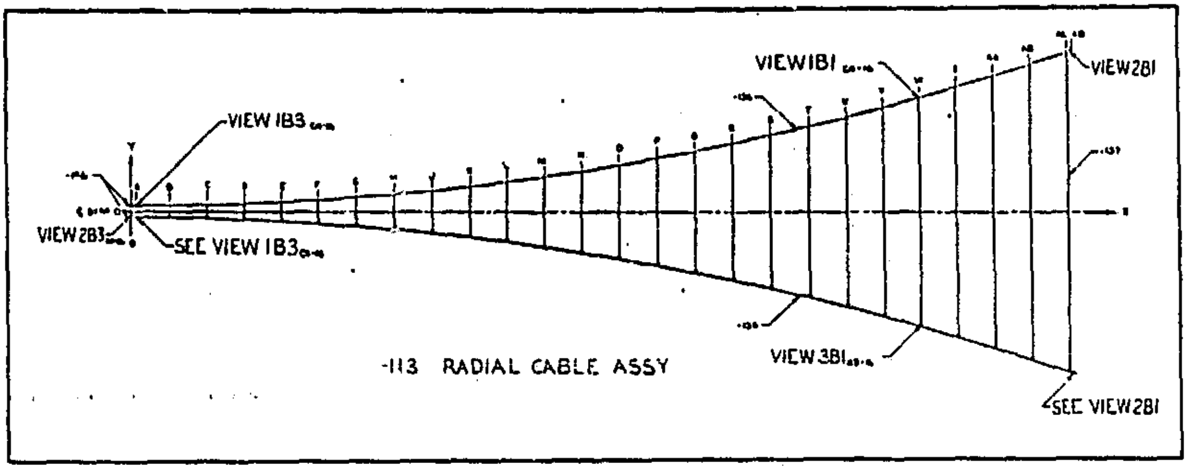


Figure 4.3-9 LSS-3 Reflector Control Cable System

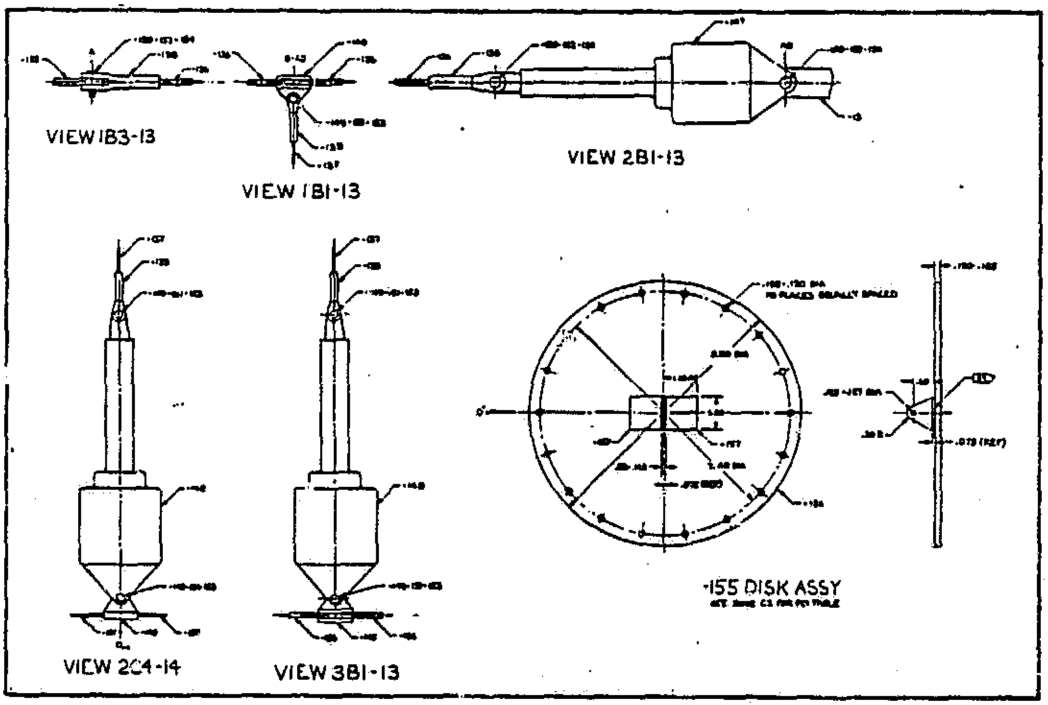


Figure 4.3-10 LSS-3 Reflector Control Linear Actuator

4.3.5 Construction Fixture

The construction of the radiometer structure will require a fixture to provide stability and alignment for the structural components. The construction fixture shown in figure 4.3-11 attaches to the "wings" of the construction platform and consists of a pair of tee-section rails supported by a series of quadrupods along their length. The rails are

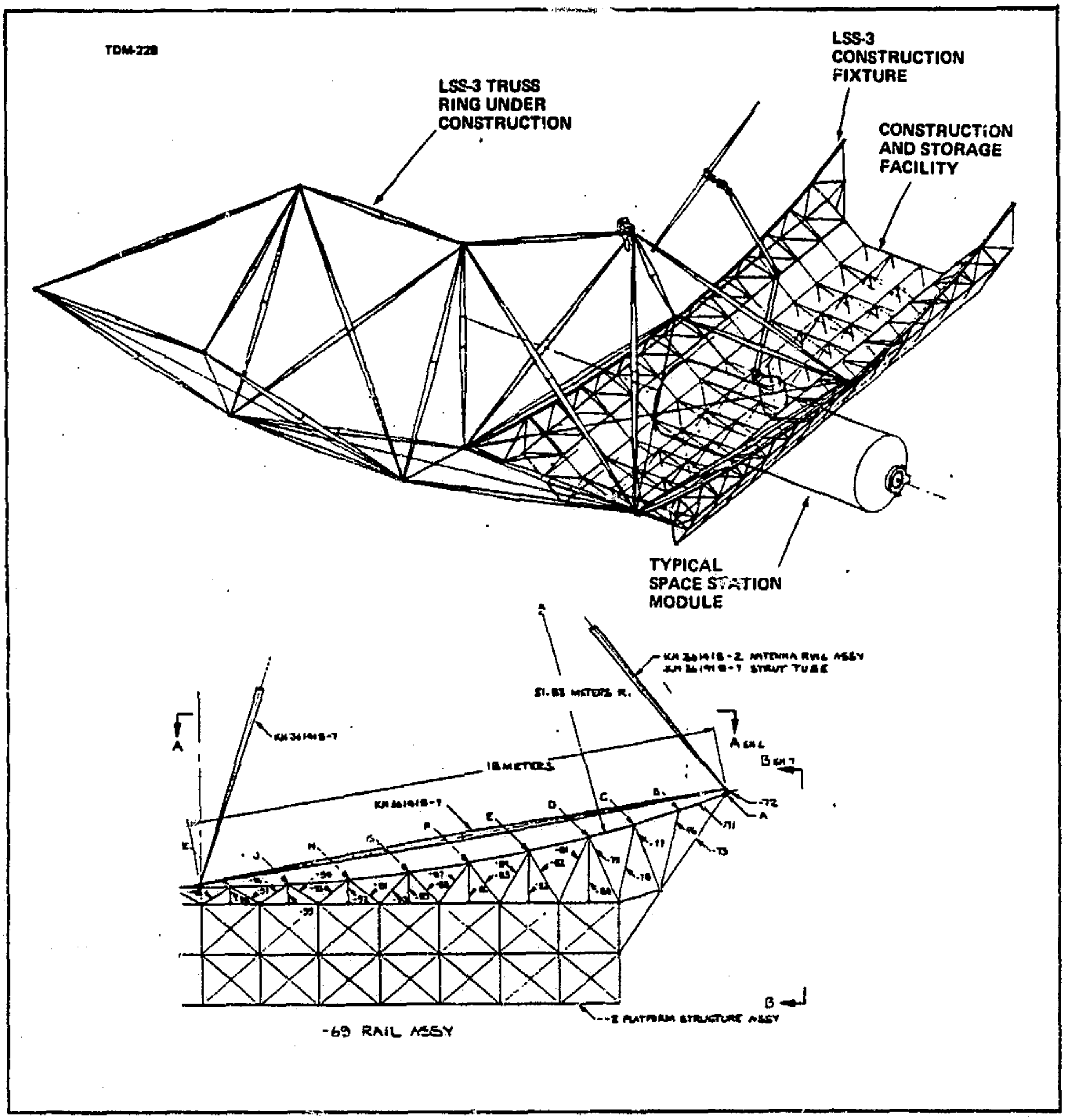


Figure 4.3-11 LSS-3 Construction Fixture

curved in a circular arc compatible with the radius of the radiometer truss ring structure. Attached to the rails are wheeled carriages (fig. 4.3-12) to which the truss ring cluster fittings can be attached. The rails are long enough to support two bays of the truss ring so that one bay can be anchored to the platform while another bay is under construction. Upon completion of the second bay, the truss ring is allowed to move circumferentially until it is supported by the newly constructed bay. The next bay can then be constructed in the area vacated. Thus the construction of the truss ring always occurs in one area of the construction platform which is convenient to the stored structural components and reduces the translations required for both structural components and personnel. This concept also supports the use of fixed and mobile work stations which ease the construction tasks.

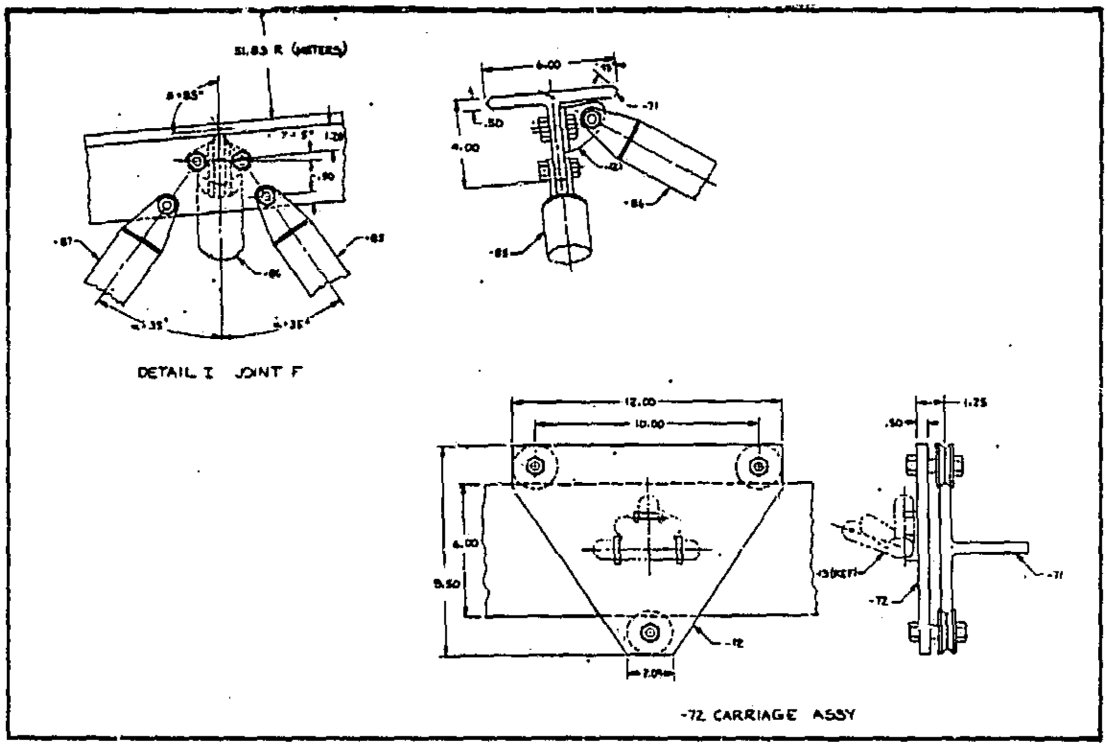


Figure 4.3-12 LSS-3 Construction Fixture Rails and Carriage

4.4 Operations Analysis

This section summarizes the analyses of the requirements for constructing the LSS-3 on the Space Station.

4.4.1 Construction

In order to demonstrate all construction methods during the space station LSS TDM activity, different methods were considered for each mission.

EVA assembly was chosen for construction of the LSS-3 TDM. Of the three construction methods considered, manual assembly requires the most operator EVA. This drives up the on-orbit construction costs due to the high cost of supporting EVA activities. These costs, plus the fact that engineering costs are not significantly reduced, makes this type of construction as expensive as the other methods (even though there are lower fabrication costs).

4.4.2 Functional Flow Analysis

Functional flow diagrams were prepared to identify the LSS TDM system organization and function. Utilizing preliminary design information, drawings, and mission data forms, a scenario of construction tasks was prepared for the microwave radiometer, LSS-3. This scenario was prepared to provide a picture of the construction tasks required to accomplish the LSS-3 TDM objectives. Figure 4.4-1 shows the microwave radiometer construction sequence. First, the construction holding fixture is assembled on the

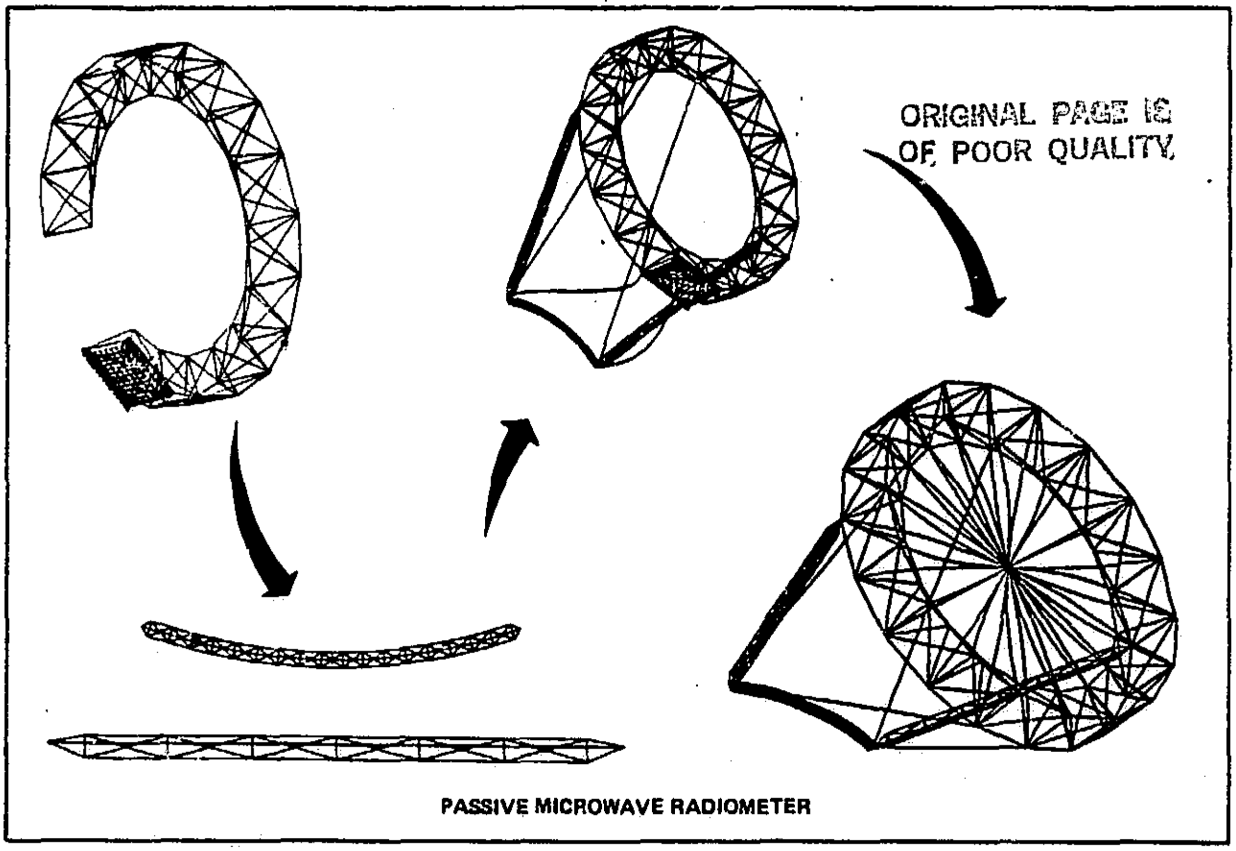


Figure 4.4-1 LSS-3 Construction Sequence

platform. Then each pentahedral module is assembled and indexed on the fixture until the truss ring is completed. Next, the feed array beam and its support beams and bracing cables are deployed and attached. The reflector mesh and its control cables are then installed. During construction, structural accuracy, dynamic characteristics and thermal deflections tests are planned to verify the characteristics of the structure and construction techniques. The LSS-3 functional flow diagrams were then prepared and are documented as shown in figure 4.4-2.

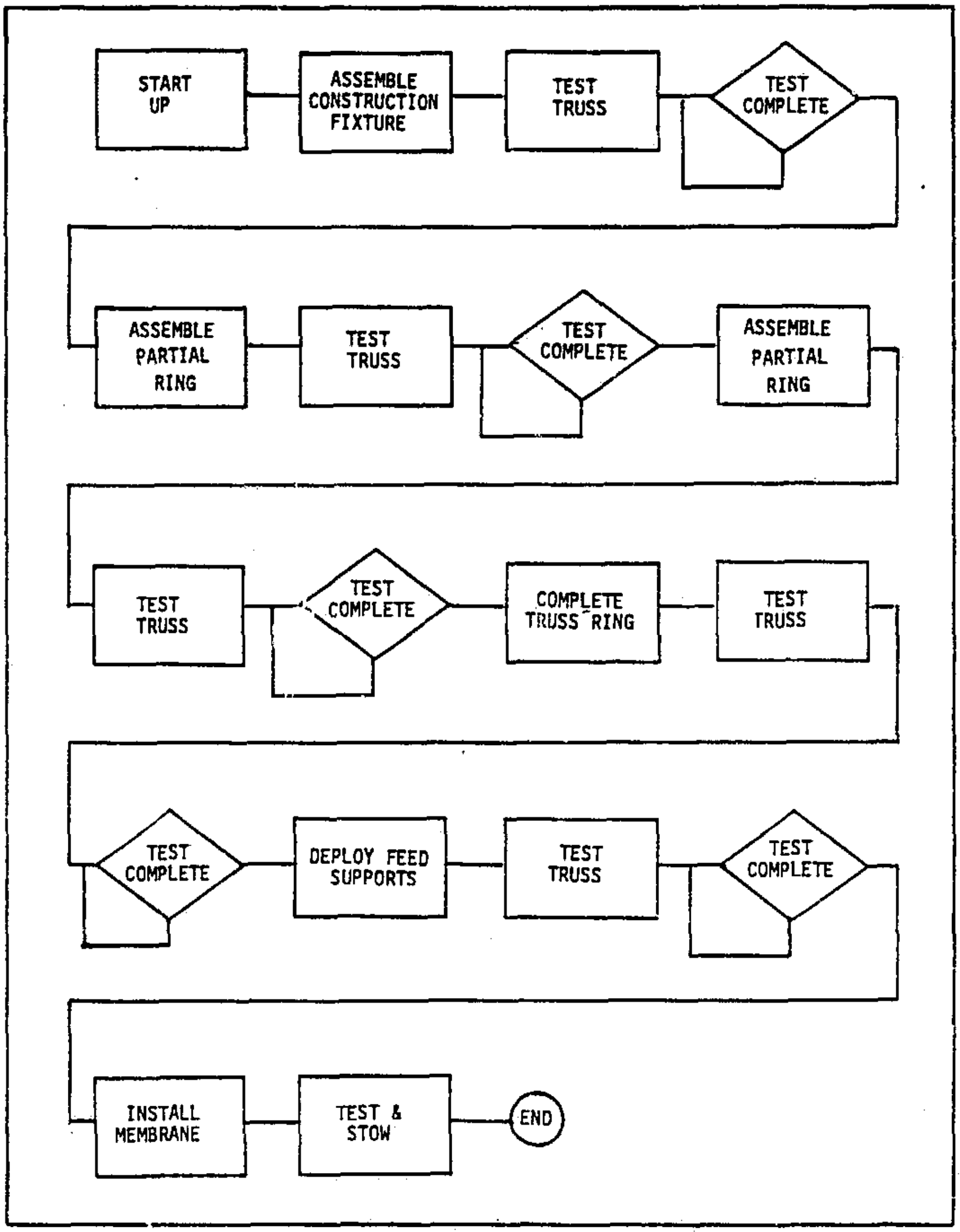


Figure 4.4-2 LSS-3 Functional Flow

4.4.3 Task Analysis

As the functional flow diagrams were being prepared, a preliminary task analysis was begun to further define the LSS TDM construction tasks. These were refined and updated as more detailed design data was generated. As the detailed timelines were evolved, task duration was considered. This combination generated a detailed timeline analysis.

4.4.4 Timeline Analysis

Timeline analysis was used to derive human performance requirements by showing the functional relationships between tasks as well as task loadings for the combinations of tasks. Design details and operator requirements were coordinated with Boeing designers and were used as a basis for the detailed task analysis and timelines.

The analysis indicates the estimated amount of operator's time which is occupied throughout the LSS-3 construction tasks. These operator task load estimates were derived from neutral buoyancy simulations, task times from previous missions, and analysis of NASA video tapes of STS-6, STS-11, and STS-13 missions. In addition, interviews with previous and current astronauts were reviewed for pertinent EVA data. A summary of the LSS-3 timeline is presented in figure 4.4-3 with the complete detailed timeline being presented in Appendix B.

Task	Hours
Start up	8.7
Assemble construction fixture	9.7
Test construction fixture	14.8
Assemble partial truss ring	15.5
Test truss	13.7
Assemble partial truss ring	14.0
Test truss	13.7
Complete truss ring	2.0
Test truss	13.9
Deploy feed supports	14.6
Test truss	12.3
Install membrane	8.5
Final test and stow	14.9
Elapsed hours	156.3
25% contingency	39.1
Total hours	195.4

Figure 4.4-3 LSS-3 Construction Timeline Summary

4.5 Development Activities

The technology development missions defined in this report will demonstrate the ability to construct large space structures on an early Space Station. However, precursor developments are required to advance the necessary technology and operational procedures required for on-orbit assembly or construction. These precursor activities involve the design, manufacture and test of structural components for the TDMs and the development of detailed procedures for their construction in space. Several testing arenas and types of tests can be used for these developments: ground tests in the laboratory, neutral buoyancy tests in a water tank and tests in space using the Space Shuttle.

Figure 4.5-1 summarizes the general areas where development activities for large space structures need to be conducted and the locations for each. In all cases, ground testing is the primary development testing arena, but all developments need to be demonstrated in space to verify the ground tests. Zero-g simulations which involve human interaction are most economically conducted in a neutral buoyancy simulator, subject to the limitations of the physical dimensions of the facility.

DEVELOPMENTS NECESSARY FOR LSS TDM	TESTS		
	GROUND	NEUTRAL BUOYANCY	SHUTTLE
ASSEMBLABLE JOINT	X	X	X
FOLDING DEPLOYABLE JOINT	X	X	X
MRS REFLECTIVE MEMBRANE SURFACE	X		X
MRS MEMBRANE SURFACE CONTOUR MEASURING SYSTEM	X		X
MRS MEMBRANE TENSIONING SYSTEM	X		X
MIRROR POSITIONING CONTROLS	X		X
DEPLOYABLE TRUSS BEAMS	X	X	X
TENSION STABILIZED BEAMS	X		X
CHERRYPICKER RMS	X		X
EVA ASSEMBLY OPERATIONS CAPABILITY	X	X	X
DYNAMIC TESTING	X		X
SURFACE ACCURACY MEASUREMENT	X		X
MODAL IDENTIFICATION TECHNIQUE	X		X

Figure 4.5-1 Precursor Technology Development

For the Passive Microwave Radiometer in particular, a list of development tests was established for each type of test facility and is shown in figure 4.5-2. The test program

Ground Tests
    Full scale tests
        – Assembly (1 or 2 bays)
        – Packaging
        – Static, dynamic and thermal
    Scale model tests
        – Assembly (full ring truss)
        – Static and dynamic
        – Install reflector and control cables
Neutral Buoyancy Simulator (NBS) Tests—(scale model)
    Assemble ring truss
    Install mesh reflector surface
    Deploy section of feed truss
    Install feed assembly in truss
Shuttle flight tests:
    Ring truss:
        – Repeat NBS tests in space
        – Measure structural accuracy
        – Measure thermal deformations
        – Dynamic tests
    Feed truss and feed support beams:
        – Deploy
        – Accuracy measurements
        – Dynamic tests
        – Install feed modules in feed truss

Figure 4.5-2 LSS-3 Development Tests

outlined makes use of full scale tests to provide data on structural components, and subscale model tests to determine the characteristics of larger assemblies. Many of the tests and assembly demonstrations can be accomplished first in a 1-g environment, again in a neutral buoyancy simulator and, finally in space.

4.5.1 Ground Tests

Static, dynamic and thermal tests of full scale components are required to determine their behavior in response to the expected environment of space. Many of these tests can be conducted in 1-g laboratory conditions. Portions of the assembled structure can also be tested in full scale to determine the effect of joints, cable pretension, etc. on the behavior of the structure. However, because of the large size of the complete structure, the overall static, dynamic and thermal characteristics of the radiometer structure will initially have to be determined analytically. Verification of the analytical tools can be accomplished through the use of scale model test/analysis correlation. The scale models will also provide data on the assembly procedures and techniques which are required for on-orbit construction.

To reduce the effect of gravitational forces, special suspension systems will be required to distribute the forces over the structure. They may take the form of air cushions, air bearings, soft springs or an active suspension system which is computer controlled. These suspension systems will more accurately represent the conditions in orbit and will also allow the measurement of the dimensional accuracy of the structure.

4.5.2 Neutral Buoyancy Simulator (NBS) Tests

Zero-g activities which require human involvement are best simulated in a neutral buoyancy simulator which uses the buoyant forces on objects submerged in water to simulate the weightless conditions of space. Within the dimensional limitations of the NBS facility, several radiometer assembly tasks can be demonstrated. The deployment of a section of both the feed array truss beam and the feed support beam, the joining of these two beams and the attachment of the support beam to the ring truss can be accomplished. Procedures necessary for the deployment of mesh reflector surfaces and their control cables can be developed. Due to the length of the ring truss members (18 meters), demonstration of the assembly of the truss ring will require the use of scaled structural elements and construction fixture (perhaps 1/5th scale). The NBS facility can also be used to demonstrate the installation of subsystem components and the routing of utilities.

4.5.3 Shuttle Flight Tests

After the structural components and assemblies have been tested on Earth and the construction procedures and techniques have been developed and simulated, the next step is to demonstrate the functional aspects of the construction process in space. Structural assemblies of modest size can be constructed on orbit from the Shuttle cargo bay to verify the results of the Earthbound tests and simulations. To determine the accuracy and adequacy of these tests, it is best to duplicate the 1-g and NBS simulations as closely as possible in orbit so that the differences can be identified. It may then be possible to compensate for these differences in future tests on Earth.

4.6 Programmatics

The LSS-3 programmatic analysis provides the necessary plans, schedules and cost analysis to support the definition of this technology development mission. This is necessary to insure that plans, schedules, and costs are given proper consideration in the development and analysis of the missions. Programmatic analysis was performed in two subtasks: (1)plans and schedules and (2) cost analysis.

4.6.1 Plans and Schedules

The program master schedule for LSS-3 was updated to reflect the Space Station 1992 IOC and TDM launch date in 1994. The expanded preliminary LSS-3 TDM program master schedule is shown in figure 4.6-1. The anticipated go-ahead is shown in 1988, along with the design and development, fabrication and assembly, test and launch operations, and on orbit construction operations. Facility availability, along with test plan submittal, is also shown. This schedule reflects the start and completion dates for key milestones, key reports, and customer reviews.

We have developed the LSS-1 master schedule that our analysis indicates will reduce risk to a minimum. This schedule has been formulated to ensure a timely flow. The scheduled task interrelationships are also shown in figure 4.6-1.

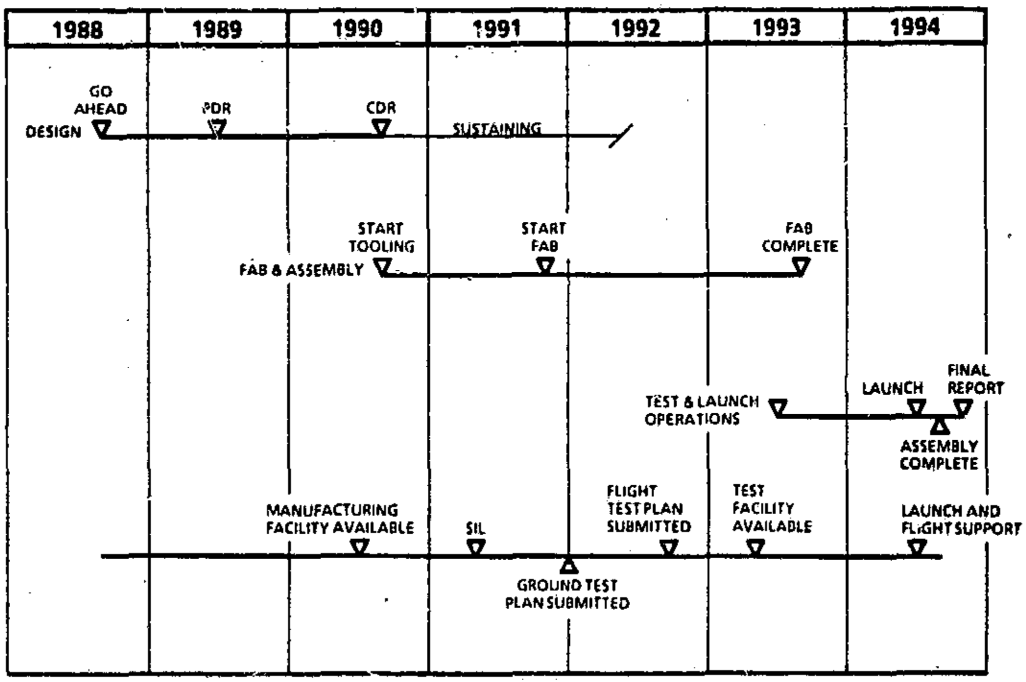


Figure 4.6-1 LSS-3 Master Program Schedule

4.6.2 Cost Analysis

An analysis of the Passive Microwave Radiometer was conducted during Phase I of this study (Reference 1) to determine the costs associated with its design, development, and manufacture. These costs were updated in Phase II to reflect maturity in the details of the design.

TDM costs were determined using the cost data base we have developed from experience with previous spacecraft. New equipment, hardware and development costs were defined using the Boeing Parametric Cost Model (PCM) cost analysis computer model and the RCA PRICE hardware acquisition model.

The ground rules provided by MSFC are:

- Cost estimates are in FY-84 dollars, including fiscal year funding requirements.
- Space Station ATP are FY-86 with initial launch in FY-90 and IOC in FY-91.
- Cost estimates include all requirements unique to demonstrating the technology feasibility.

The additional ground rules and assumptions used are:

- The Boeing PCM hardware cost model was used to estimate all structural/mechanical items and all support costs, i.e. SE&I, system ground test, tool & test equipment, program management, etc.
- PCM was used to estimate all integration costs.
- Design costs reflect the highly repetitive nature of the hardware.
- The electronics package for the Passive Microwave Radio-meter was not priced.
- Learning was assumed (88% of structural items).
- Development quantity = 2

The development costs for the Passive Microwave Radiometer are summarized in Figure 4.6-2.

ENGINEERING ($M)	20.2
TOTAL HARDWARE (2 UNITS)	100.7
TOTAL DEVELOPMENT ($M)	120.9
FLIGHT UNIT COST ($M)	37.86

DOES NOT INCLUDE MICROWAVE SENSORS AND ELECTRONICS
DOES NOT INCLUDE CONSTRUCTION FIXTURE

1984 DOLLARS

Figure 4.6-2 LSS-3 Development Costs

4.7 Space Station Resources Required

4.7.1 Accommodations

LSS TDM EVA activities require special equipment and/or procedures. These in turn will require provisions for accommodations in the basic Space Station design. The accommodation needs of the LSS-3 TDM were defined by analysis of both mission and Space Station requirements/capabilities. A detailed list of the Space Station architectural features, required for LSS-3 EVA construction and test activities is provided in figure 3.7-1 previously shown in section 3.7.

4.7.2 Operations

Scheduling of the Space Station facilities, activities, and personnel is of prime importance to minimize conflicts during LSS EVA construction activities. Communications, data equipment, and links required for EVA will need to be available and operational. All other missions and space station facility usage will require close coordination. This scheduling could be critical during the LSS-3 truss ring construction. Figure 4.7-1 shows the Space Station operations that need to be scheduled to avoid conflict with LSS-3 construction activities.

Scheduling
- **Communications**
  - **CCTV**
  - **Intercomm**
  - **Links**
- **Data**
  - **Processing**
  - **Handling**
- **Missions**
  - **Shuttle, OTV, and OMV docking and operations**
  - **RMS usage**
  - **Facilities (briefing room)**
- **Crew Members**
  - **2 EVA**
  - **1 IVA**

Figure 4.7-1 LSS-3 Space Station Operations

4.7.3 Crew Support

The LSS-3 crew skills were identified as explained in Section 3.7.3. The numbers shown in the crew skill support (fig. 4.7-2) represent the percent of operation duration time each skill is required. These percentages were estimated from the data used to calculate the operation time. Particular attention was paid to the crew skill descriptions in figure 3.7-5 in making sure that the proper crew skills were utilized for each operation.

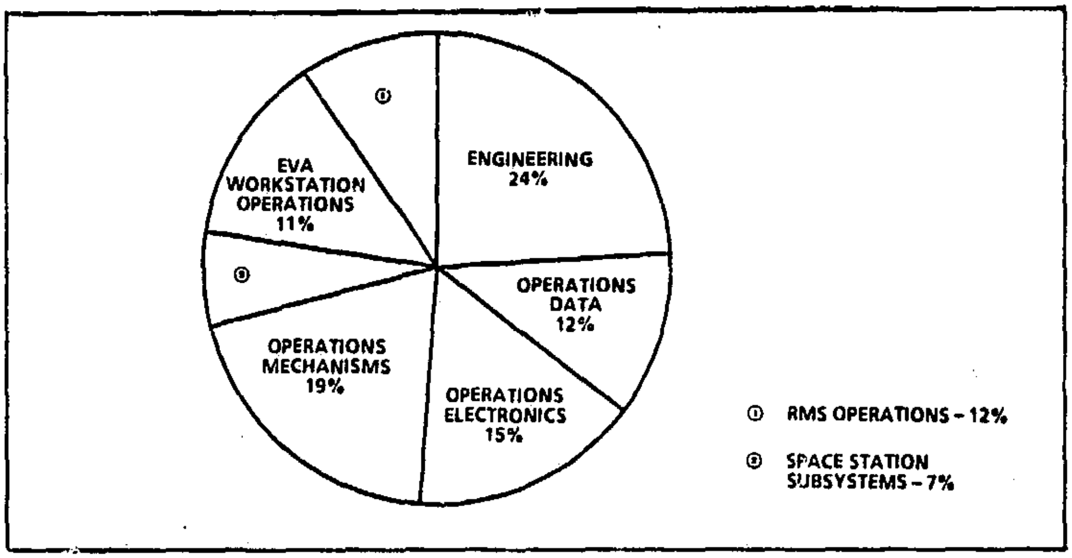


Figure 4.7-2 Crew Skill Support

4.7.4 Special Equipment

During the definition and analysis of the LSS-3 TDM, special equipment requirements were considered. The required support equipment, instrumentation, data systems, and small tools identified during this study are listed in figure 4.7-3. The construction

Support Equipment
- **Construction fixtures**
- **Miscellaneous constraints and hold-downs**
- **Articulated test equipment holding fixture**
- **Strut alignment and assembly fixture**

Instrumentation
- **Structural dynamics (acceleration, strain, loads, etc.)**
- **Thermal response (thermocouples)**
- **Position/deflection (precision laser ranging, corner reflectors)**

Data Systems
- **Recording**
- **Storage & retrieval**
- **Manipulation (EDP)**

Small Tools
- **LSS-3 construction tool kit**

Figure 4.7-3 LSS-3 Special Equipment

fixtures and strut alignment and assembly fixture are good examples of special equipment that will need to be supplied with the LSS-3 mission hardware. Some common equipment is envisioned to remain on the Space Station for use with other missions.

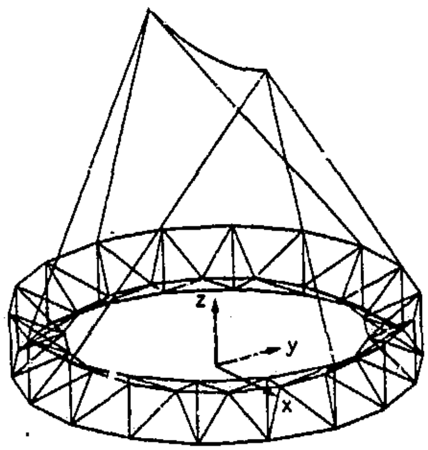
4.8 Potential Problems and Concerns

Several areas of concern must be considered when constructing the Passive Microwave Radiometer at the Space Station. The additional mass and inertias of the structure as well as its structural dynamic characteristics during and following its construction must be accommodated by the Space Station control system. The dynamic loads resulting from events such as Orbiter docking and thruster firings must also be accounted for. Large Space Structures attached to the Space Station will also increase the drag due to their size. The large size of the structures may also influence the thermal balance of the Space Station and interfere with communication paths.

These and other concerns raised by the construction of large space structures affect a wide range of technologies and subsystems and need to be carefully considered in the design of the Space Station as well as in the design of the construction project. The results of initial investigations of some of these concerns for LSS-3 are presented in the following sections.

4.8.1 Mass and Inertia

The mass properties of the Microwave Radiometer structure are shown in figure 4.8-1. Although all the structural components are delivered in one Shuttle flight, the distribution of the mass will change as the structure is assembled. The location and orientation of the radiometer will determine to what extent the additional mass and inertia will affect the Space Station. The center of mass and inertias shown in the figure are measured relative to the coordinate origin located at the center of the bottom plane of the truss ring.



MASS = 2846 kg

Z-C.G. = 27.5 m

I_{xx} = 4.64×10^6 kg-m²

I_{yy} = 5.6×10^6 kg-m²

I_{zz} = 4.93×10^6 kg-m²

Figure 4.8-1 LSS-3 Mass Properties

Although the radiometer structure is light, the distance between the center of mass and the point where the truss ring is attached to the construction platform is large (51.5 meters). Therefore the contribution of the radiometer to the Space Station inertias can be significant.

4.8.2 Loads and Deflections

One of the analyses performed was to determine the structural deformation of the ring truss due to the pretension in the guywires which support the feed array structure. A NASTRAN finite element model of the radiometer structure was used to determine these deflections. It was determined that a pretension of 500 Newtons is required in each of the guywires to prevent them from becoming slack under an acceleration of

0.1 g's in the lateral direction. With this pretension, the truss ring deforms approximately 0.1 meters (3.9 in) and varies around the circumference of the ring as shown in figure 4.8-2. The deflections shown are measured relative to the base of the feed support masts. Although these deflections are more than the accuracy required by the reflector surface, they can be reduced by increasing the shear stiffness of the ring. The linear actuators which control the reflector surface contour can also be used to provide the required surface accuracy.

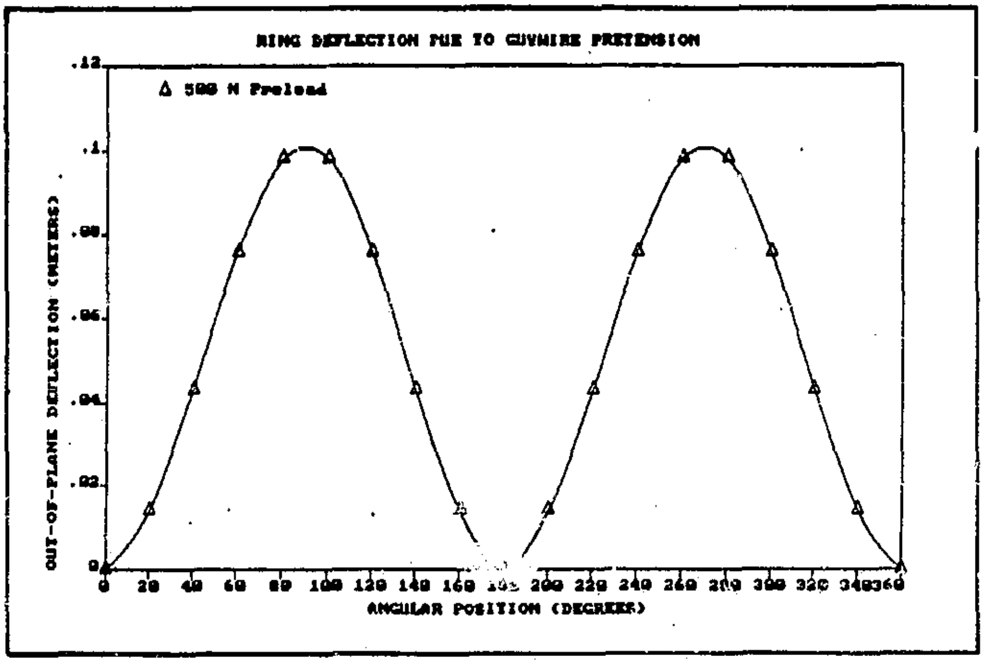


Figure 4.8-2 LSS-3 Ring Deflection Due to Guywire Pretension

4.8.3 Structural Dynamic Characteristics

One of the primary concerns relating to the construction of large space structures on the Space Station is the flexibility of the structure both during and after construction. Therefore a NASTRAN finite element model was used to assess this concern for LSS-3. Mode shapes and frequencies were calculated at several stages during the assembly of the truss ring. As more and more segments of the ring are constructed, the modal frequencies of the cantilevered structure get lower and lower as shown in figure 4.8-3. After 17 of the 18 bays are constructed, the first mode frequency of the truss (whose mode shape is shown in the figure) is less than 0.1 Hz. Upon completion of the 18th bay, the frequency increases to approximately 0.25 Hz. because the ring is now continuous. The curves plotted show the trends associated with different types of motion, therefore they cross over each other as more bays are completed.

The frequencies of the radiometer structure after the feed system and reflector are added are shown in figure 4.8-4. The tension-only characteristics of the guywires were modeled by using half of their cross-section properties. The first column shows the cantilevered frequencies of the completed structure without the reflector installed. The ring was cantilevered at the four points adjacent to one of the feed support masts (point A on the figure) for these results. The next two columns contain the structural

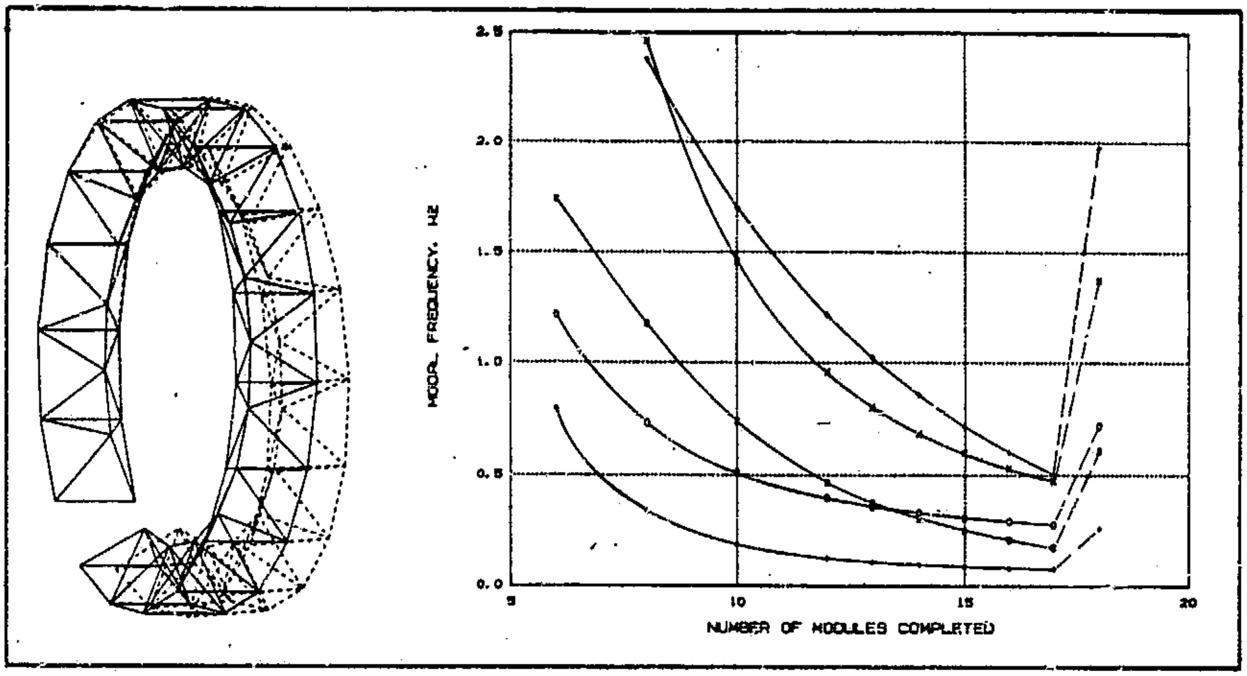
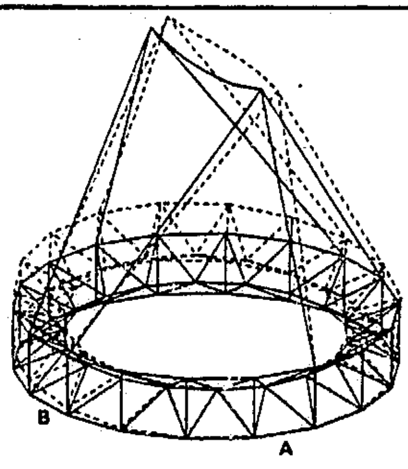


Figure 4.8-3 LSS-3 Structural Dynamics During Build-up



	FREQUENCY, Hz		
MODE	NO REFLECTOR A	W/REFLECTOR A	W/REFLECTOR B
1	.197	.195	.191
2	.236	.217	.281
3	.378	.328	.287
4	.493	.475	.433
5	.660	.602	.661

A = CANTILEVERED AT POINT A
B = CANTILEVERED AT POINT B

Figure 4.8-4 LSS-3 Structural Dynamics After Build-up

frequencies with the mass of the reflector included. The reflector mass was distributed around the ring, therefore the membrane modes are not included in the analysis. The first of these two columns use point A as the cantilever location while the second of these two columns uses point B (midway between the feed support mast attachment points) which is a more flexible mounting position.

4.8.4 Drag

Another concern created by LSS construction is the increased frontal area which increases the rate of orbital decay due to drag. The orientation of the structure can have a pronounced effect on the drag. For instance, if the plane of the ring is oriented perpendicular to the flight path, the frontal area of the Space Station will be increased more than if it was oriented with the edge of the ring toward the flight path.

The drag on a body in low Earth orbit depends on its ballistic coefficient (area per unit mass). Figure 4.8-5 shows the area of LSS-3 in the x, y and z directions and the corresponding area/mass ratio tor the radiometer alone. The effect that the radiometer has on total Space Station drag properties is shown in the last line of the table, expressed as the percent increase of the Space Station area/mass ratio due to LSS-3. For these calculations, the shadowing effects which may occur were neglected, and the areas were assumed to be additive. Due to the size and light weight of the radiometer, it has a significant effect on Space Station drag properties, particularly when the reflector is broadside to the flight path. This orientation results in a 455. percent increase in the area/mass ratio and must be avoided if at all possible.

	X-DIR	Y-DIR	Z-DIR
LSS-3 AREA (m^2)	885.	898.	7854.
AREA/MASS RATIO (m^2/kg)	.311	.316	2.76
% INCREASE FOR SPACE STATION	38.	38.	455.

ASSUMPTION: TDM AREA ADDS TO SPACE STATION AREA

Figure 4.8-5 LSS-3 Drag Effects

5.0 PRECISION OPTICAL SYSTEM, LSS-4

This section is a self-contained description of the tasks relating to the development of a Precision Optical System, LSS-3. Included in the study are design, operations and cost trades, preliminary structural design of the mission, an analysis of the operations required to perform the mission, precursor technology developments which can be accomplished on Earth or with Shuttle flights, and the programmatics of the mission. In addition to these topics, the accommodations which the Space Station must provide to the TDM are identified and, conversely, some of the problems and concerns which the TDM may impose on the Space Station are considered.

5.1 Design Trade Studies

The design considerations which were subjected to trade studies for the Precision Optical System include the structural configuration, the size and shape of the primary mirror segments, and the method of assembly. Each trade is discussed individually in this section.

5.1.1 Primary Mirror Support Truss

The most efficient planar truss and one which accommodates a segmented mirror configuration very well is the tetrahedral truss. It can also be made to provide a spherical or parabolic surface. The tetrahedral truss was, therefore, selected as the primary mirror support truss. The subject of this trade study is to determine the method which will be used to construct the primary mirror support structure on-orbit.

Figure 5.1-1 shows the three candidate construction techniques considered for the precision optical system primary mirror support truss. The assemblable concept relies on in-space assembly while the deployable concept requires on-Earth assembly and checkout with little human intervention on-orbit. The modular concept combines these two methods by high precision manufacture of the mirror support frame with mirrors attached on the ground. The primary mirror support truss is divided into seven modules which support seven hexagonal mirror segments each. The individual modules are sized so that they fit within the Orbiter bay diameter with the mirrors attached. Truss elements in the upper surface of each module (called the mirror support frame) are

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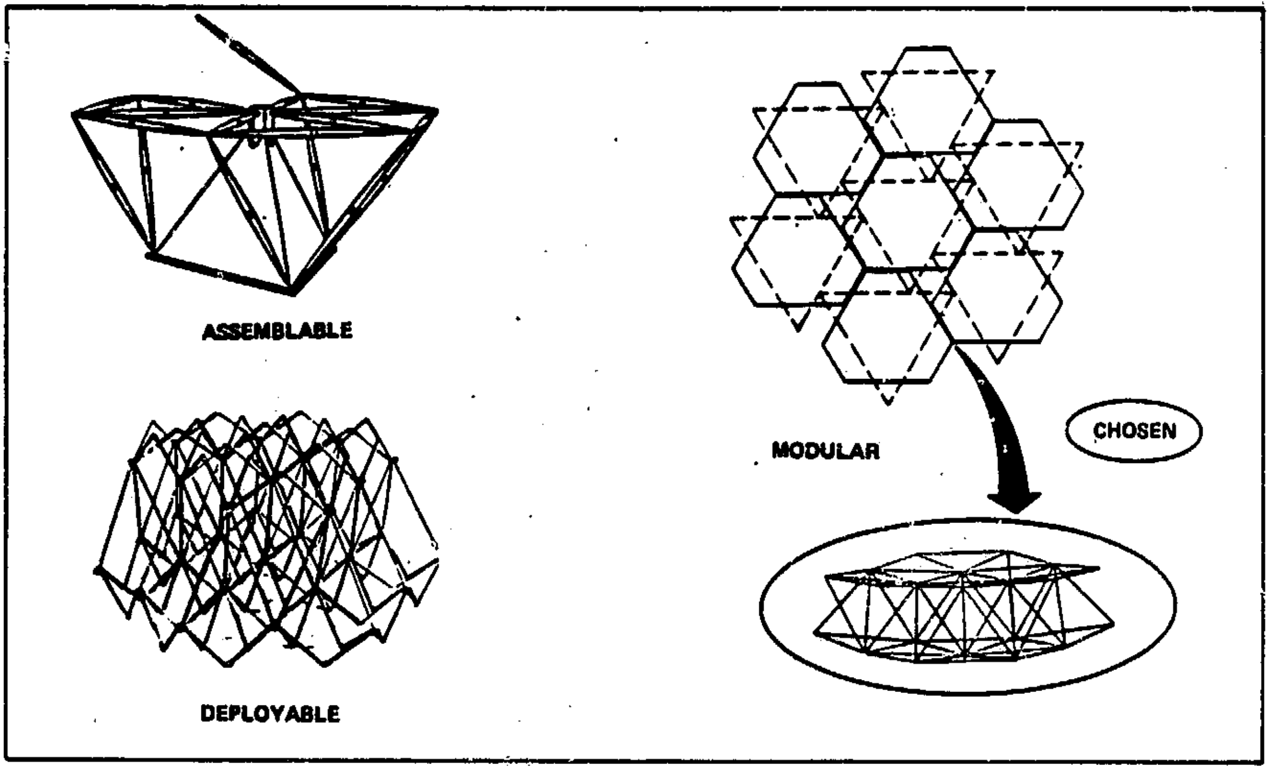

Figure 5.1-1 LSS-4 Primary Mirror Structure Concepts

rigidly bonded together on the ground and the mirrors are attached to it. The backing truss (the bottom surface of the truss and the diagonal elements) is semi-deployable for efficient packaging in the Orbiter. The bottom truss surface elements are also rigidly bonded together on the ground with the diagonal elements made so that they deploy from the bottom truss surface. Each module is deployed and assembled at the Space Station and then connected to the adjacent module, as shown in the figure, to form the primary mirror array. The outlines of the mirror support frames are shown as a solid lines in the figure while the outlines of the bottom truss frames are dotted. The size of the mirror array can be easily increased by adding more mirror modules.

The trade study results in the form of quantitative and qualitative comparisons of each assembly concept are shown in figure 5.1-2. A NASTRAN finite element analysis of each of the concepts was conducted to determine their dynamic characteristics. In this analysis, all joints were assumed to have no slop. Therefore, the analysis of the assemblable and deployable concepts are identical. The first mode frequency of the modular truss is somewhat lower than the other two because each module is attached to the adjacent module at three points. The mass of each truss concept is nearly equal. A qualitative comparison of the time required to assemble the primary mirrors and their support structure shows that the modular approach takes less time than the other two.

TRADE ITEM	ASSEMBLABLE TRUSS	DEPLOYABLE TRUSS	CHOSEN MODULAR TRUSS
PRIMARY FREQUENCY (TRUSS + MIRRORS) (Hz)	15.0	15.0	9.5
TRUSS MASS (Kg)	159.0	159.0	161.0
EVA ASSEMBLY TIME (TRUSS + MIRRORS)	HIGH	MEDIUM	LOW
ACCURACY (AS ASSEMBLED)	MEDIUM	MEDIUM	HIGH
JOINT REQUIREMENTS	• SIDE LATCH • SELF ALIGNING • ZERO SLOP	• DEPLOYABLE (AUTO) • LOCK-ABLE	• SOME DEPLOYABLE (MANUAL) • SELF ALIGNING • ZERO SLOP
COST ON-ORBIT ($M)	39.3	36.5	27.8

Figure 5.1-2 LSS-4 Primary Mirror Structure Trade Study

This is based on the fact that much of the assembly and adjustment work for the modular concept is accomplished on the ground. The assemblable concept requires a large amount of EVA to build the structure and attach the mirrors. For the deployable concept, the time required to deploy the structure is short, but the attachment of the mirrors to the structure is not only time consuming but also risky. The as-built accuracy of the modular concept is judged to be higher than the other concepts. The results of the assemblable vs. deployable vs. modular cost trade (discussed in more detail in Section 5.3) are also summarized in the table, with the modular concept being the least expensive. Based on these trade study comparisons, the modular concept was chosen for the precision optical TDM.

5.1.2 Primary Mirror Segment Size

Using the modular support structure concept, two sizes of mirror segments can be accommodated as shown in figure 5.1-3. With seven mirror segments per module, the size of each mirror segment is approximately 1.5 meters in diameter. A single mirror approximately 4.0 meters in diameter can also be used.

The size of the segmented mirrors was determined by both mirror manufacturing technology and cost. Large mirrors are more difficult to manufacture, but the smaller mirrors will require more position control mechanisms which will add to the total cost. Also, based on the design goal of 15 to 25 kg per square meter for lightweight mirrors, large diameter mirrors would be too fragile to withstand the boost environment and may not retain their proper shape. A report on mirror technology (NASA CR 166493) applicable to the Large Deployable Reflector (LDR) concludes that the "optimum size

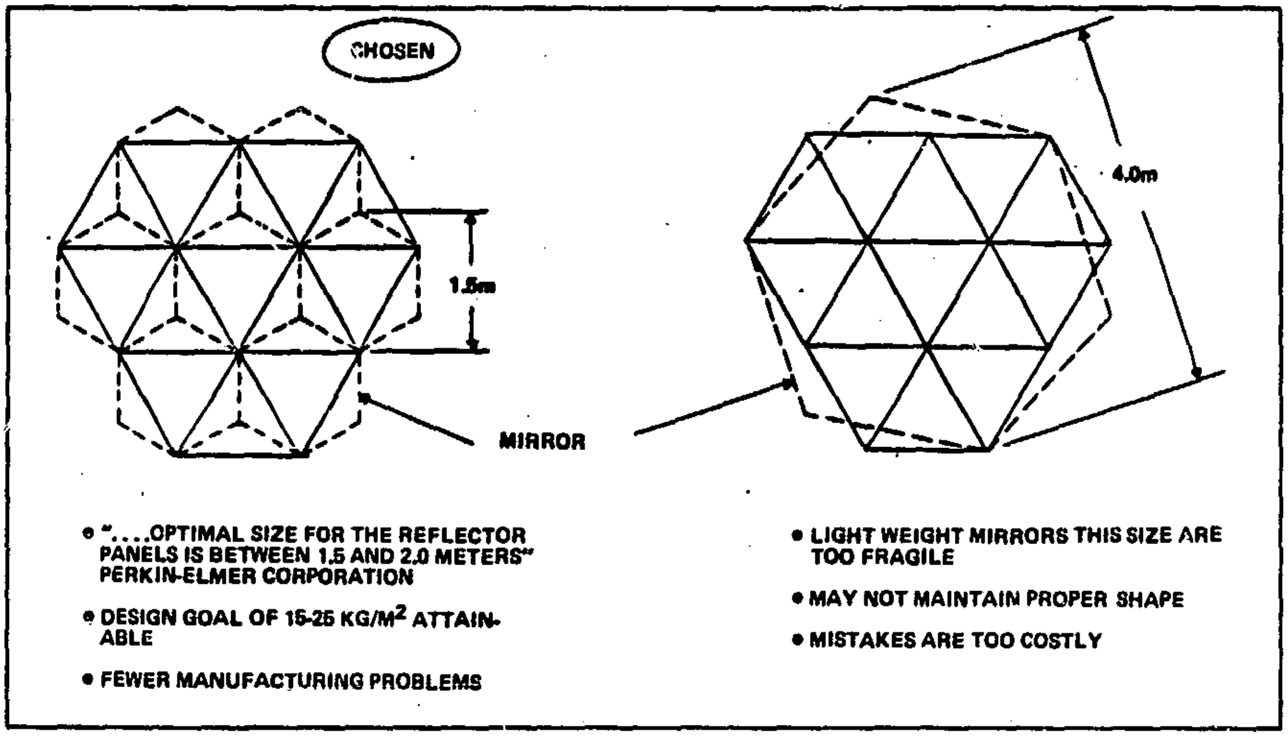

Figure 5.1-3 LSS-4 Primary Mirror Size Options

for the reflector panels is between 1.5 and 2.0 meters." Therefore the 1.5 meter mirrors were selected for LSS-4.

5.1.3 Secondary Mirror Supports and Light Shield

Two candidate secondary mirror support concepts are shown in figure 5.1-4. The LSS-4 configuration defined in Phase I of this study is shown on the left. The secondary mirror is supported by radial truss beams attached to a hexagonal truss ring which, in turn, is supported by six extendable masts attached to the primary mirror support truss. These masts also support the light shield panels. The figure on the right shows NASA's strawman LDR (Large Deployable Reflector) concept which employs a tripod secondary mirror support structure and a separate light shield.

The configuration of the secondary mirror support structure was changed from the initial LSS-4 concept to the tripod support structure concept. The purpose of the secondary mirror support structure is to provide accurate alignment of the secondary mirror with respect to the primary mirror. The inherent stiffness of the tripod support is a definite advantage over the parallel support beam concept. It is also lighter and much less complex. The fact that the light shield is separate from the secondary mirror supports is also an advantage since disturbances which may affect the light shield will not be transmitted directly to the secondary mirror.

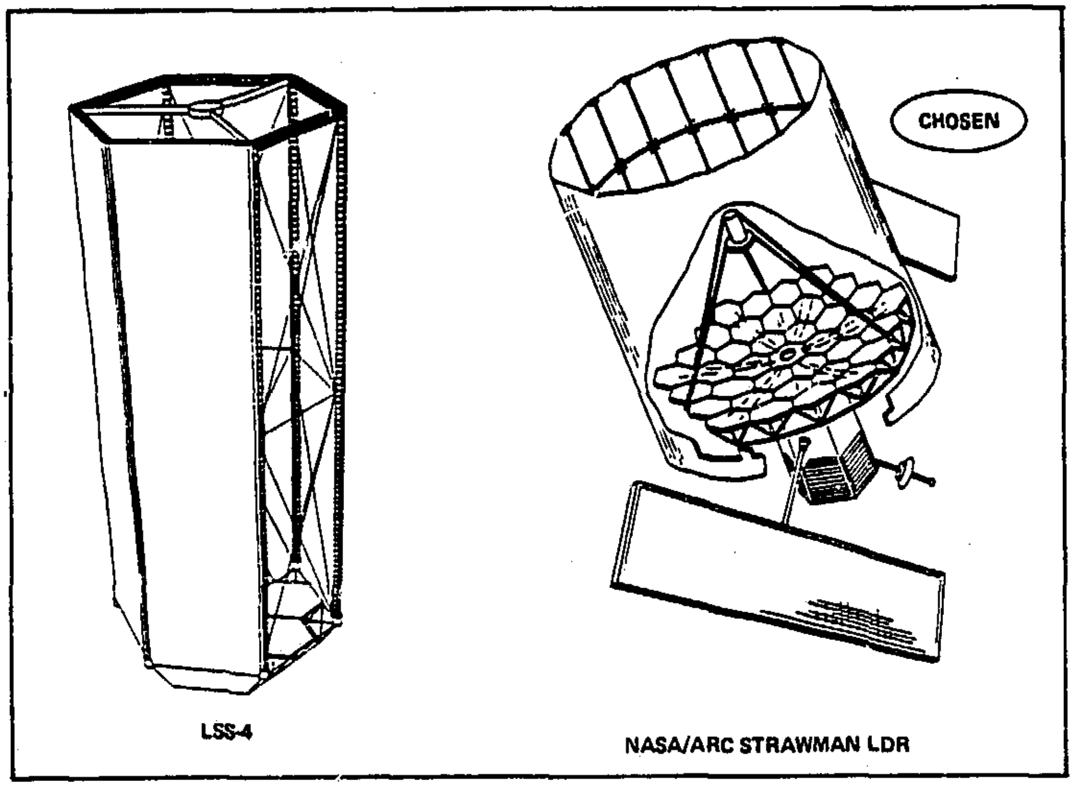

Figure 5.1-4 LSS-4 Secondary Mirror and Light Shield Trade

5.1.4 Cost Trade Study

Although the choice of space system designs can be based on considerations such as structural efficiency, weight, performance, simplicity, etc., the cost of the system is a very important item. Many factors contribute to the overall cost of a large space system. Design, development, test and manufacturing are some of the items which immediately come to mind when costs are being determined. However, the cost of transportation to orbit and, in the case of the TDMs defined in this study, the costs involved in the on orbit construction need to be considered.

With this in mind, it is not immediately obvious whether it is less costly to manufacture an automatically deployable spacecraft on the ground and deploy it in orbit, to assemble the whole system in orbit, or to use deployable modules which can be assembled in orbit.

A trade study was performed to evaluate these options using the primary mirror system of the Precision Optical System as the system to be evaluated. The costs associated with the development, transportation and on-orbit assembly for each of the three construction options previously identified in Section 5.1.1 were determined and are compared in bar chart form in figure 5.1-5. The development costs are nearly equal. The cost of the mirrors is not included in the total cost of the system. However, mirror costs do influence system integration costs and are, therefore, included for that calculation. The high packaging efficiency of the assemblable concept results in the lowest transportation charges. Transportation charges for the other two concepts are nearly equal. The largest differences in cost between the three concepts comes from the charges associated with on-orbit construction. The modular concept requires significantly less assembly since the structure is modularized and the mirrors are integrated with the structure on the ground. These results were a major contributor to the decision to use the modular concept for LSS-4.

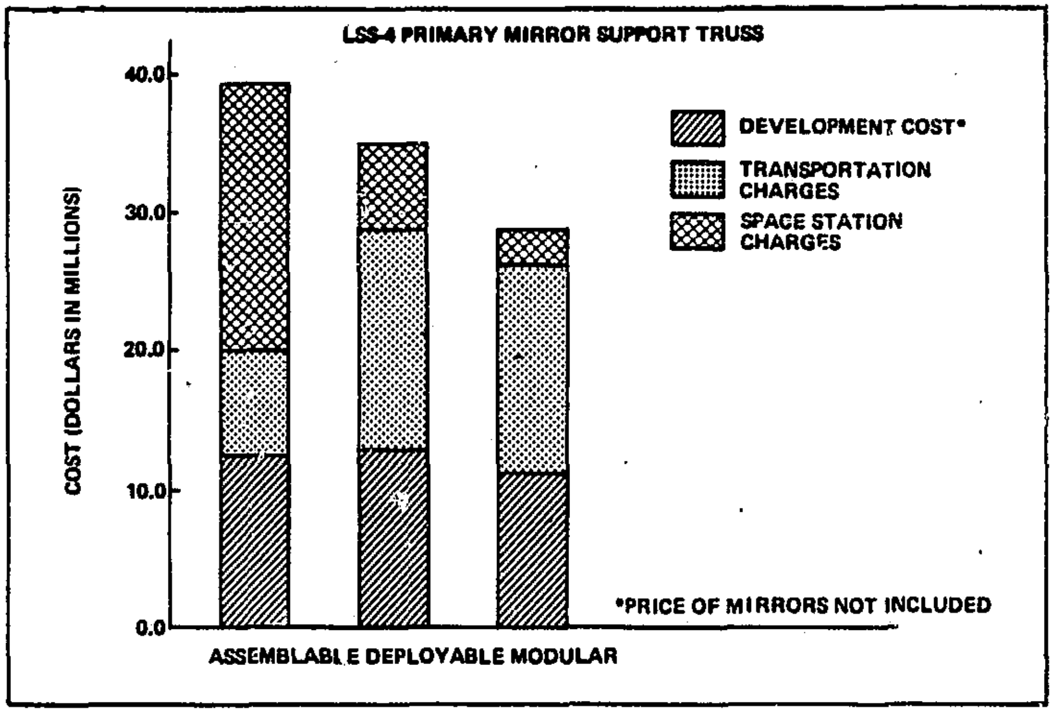

Figure 5.1-5 Cost Trade Study Results

5.2 Operations Trade Studies

This section summarized the trade studies completed during the LSS-4 TDM construction analysis activity.

5.2.1 EVA Crew Schedule

The results of our analysis indicates that the workday should be 6 actual EVA hours.

Three operators per shift (2-EVA and 1-IVA) will be required, full time, during LSS EVA construction activities. The ability to operate more than 1 shift per day will be dependent on the Space Station crew size and other scheduled Space Station activities. Two or three shift operation could result in conflicts in the use of facilities and high noise levels while other crewmembers are trying to sleep. For the LSS TDM EVA construction activities it is recommended that 1 shift per day be utilized.

It is recommended that a 5 day LSS-3 EVA construction week be adopted with 1 IVA day for paperwork and suit maintenance and care.

5.2.2 EVA Personnel Restraints

The restraint methods selected for the LSS-4 TDM construction activities are:

1. The flexible tethers that are currently utilized for the STS missions.
2. The current safety line.
3. A shoe restraint with matching grid work.
4. The hangar that is part of LSS-1 will also serve as an operator restraint.

5.3 Mission Design

This section and Appendix A present a description of some of the design details for the Precision Optical System. The design of this TDM was not carried to the same level as the other two so that more effort could be directed to the Construction/Storage/Hangar Facility and Microwave Radiometer. This section will be limited to a discussion of the primary mirror support structure for the Precision Optical System.

The primary mirror assembly consists of seven structural modules, each with seven hexagonal mirror segments. Each of the structural modules (fig. 5.3-1) is a tetrahedral truss constructed using a combination of deployable and assemblable techniques. The upper surface of each module is a rigid framework manufactured to high precision, with the seven mirror segments attached on the ground. The lower surface is also a rigidly fabricated frame with the deployable diagonal struts attached to it. This allows the upper and lower components of each module, which are sized to fit within the 4.5 meter Orbiter bay diameter, to be packaged efficiently and still be made stiff. The trade study, discussed in the previous section, comparing the costs (including DDT&E, manufacture, transportation and on-orbit construction) of this modular construction method compared with deployable and assemblable concepts showed this to be a more economical construction method.

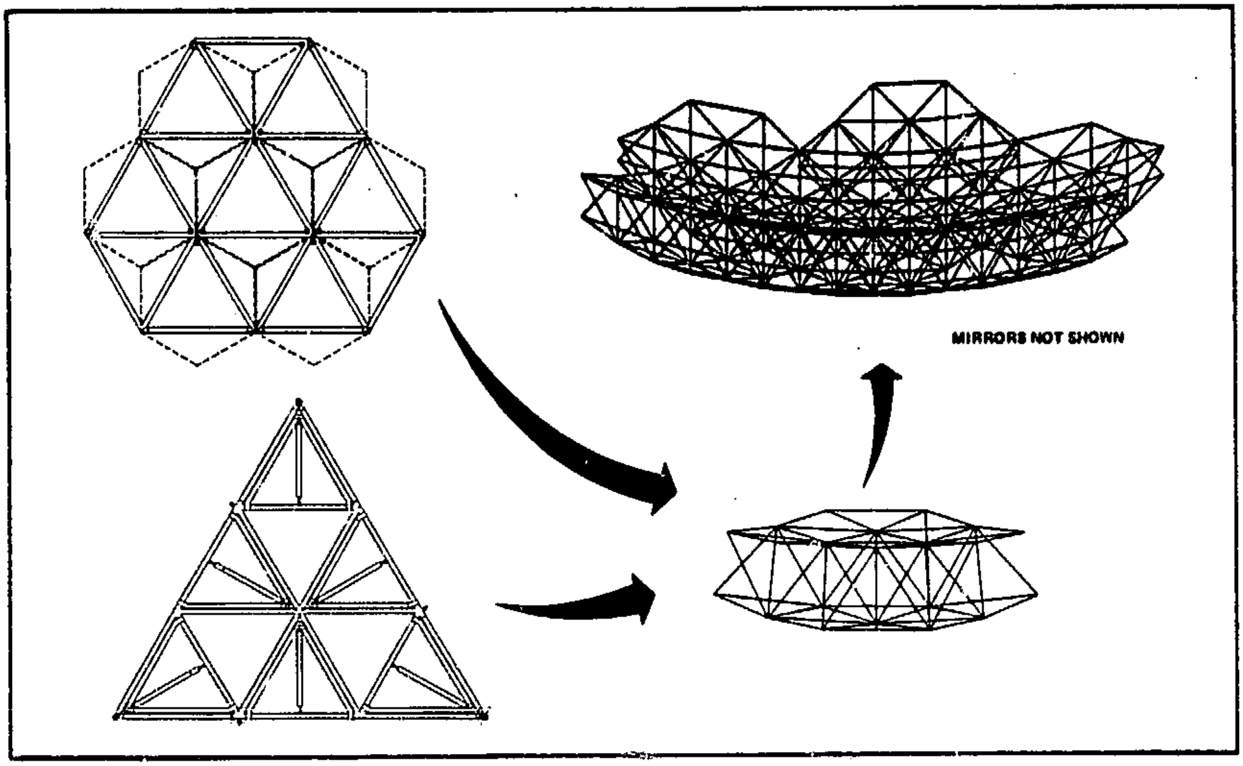

Figure 5.3-1 LSS-4 Primary Mirror Assembly

At the Space Station, each module is assembled by, first, deploying the diagonal members from the lower truss frame and then attaching the upper truss frame (with mirrors) to it. The modules are then attached together, as shown in figure 5.3-2, to form the primary mirror assembly. The secondary mirror and supports are then attached followed by the light shield.

5.4 Operations Analysis

This section summarizes the analysis of the requirements for constructing the LSS-4 TDM on the Space Station.

5.4.1 Construction Method

In order to demonstrate various construction methods during the Space Station LSS TDM activity, different methods were considered for each mission.

A combination of prefabrication and assembly was chosen for construction of the LSS-4 TDM. Prefabrication and EVA assembly of modules can minimize on-orbit assembly time and, therefore, costs. Transportation size, weight, and packaging becomes a major consideration with this type construction.

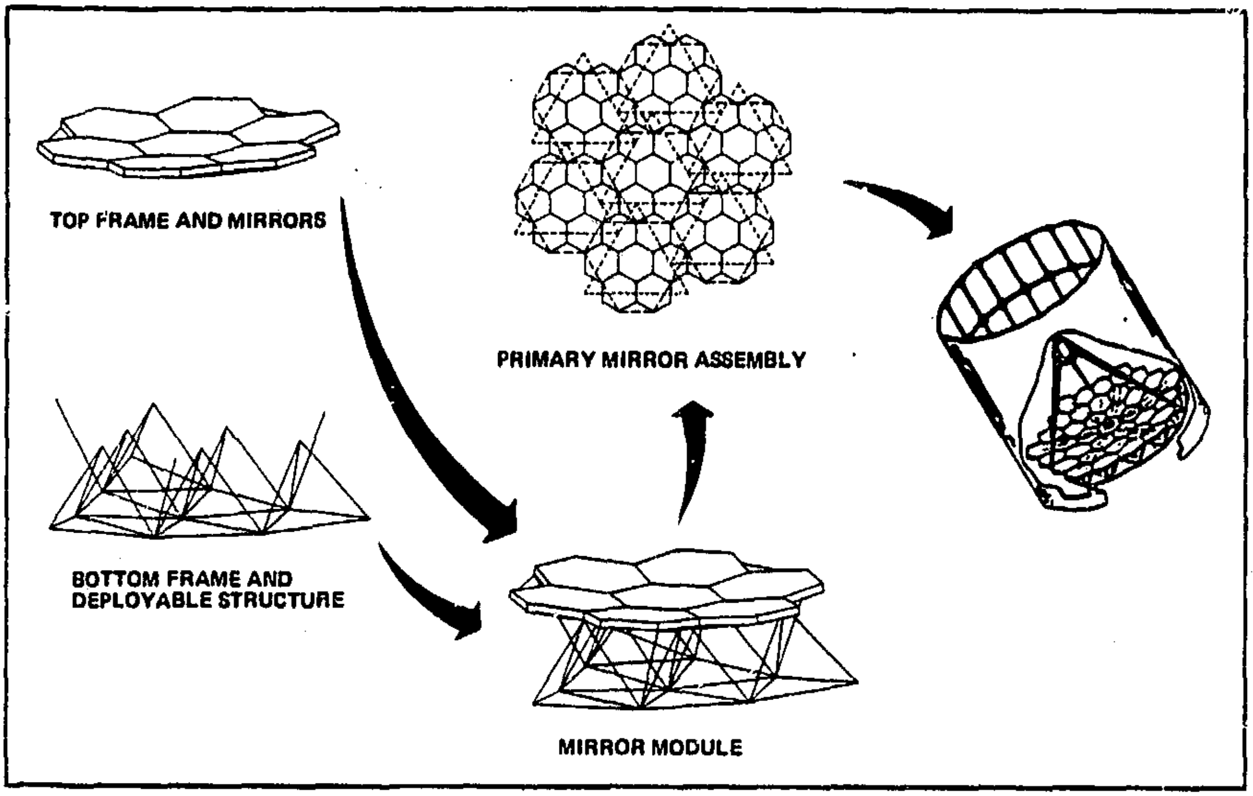

Figure 5.3-2 LSS-4 Construction Scenario

5.4.2 Functional Flow Analysis

Functional flow diagrams were prepared to identify the LSS TDM system organization and function. Utilizing preliminary design information, drawings, and mission data forms, a scenario of construction tasks was prepared for the precision optical system LSS-4. The first scenario was prepared to provide a picture of the manual assembly functions required to accomplish the LSS-4 TDM objectives. As shown in figure 5.4-1, LSS-4 begins with the attachment of the instrument housing to the platform. The primary mirror truss is then manually assembled. The extendable masts, secondary mirror truss ring, secondary mirror, light shield, etc. are then installed. Tests are conducted throughout this construction sequence to determine the dynamic characteristics, structural accuracy and thermal deformations of the structure. This construction scenario was then upgraded to a functional flow diagram in order to define the end to end manual assembly and test operations for the LSS-4 mission. It was necessary to examine each of the proposed functions in terms of specifics regarding sublevel requirements for each function and in terms of the possible constraints that would affect the way in which each function was accomplished.

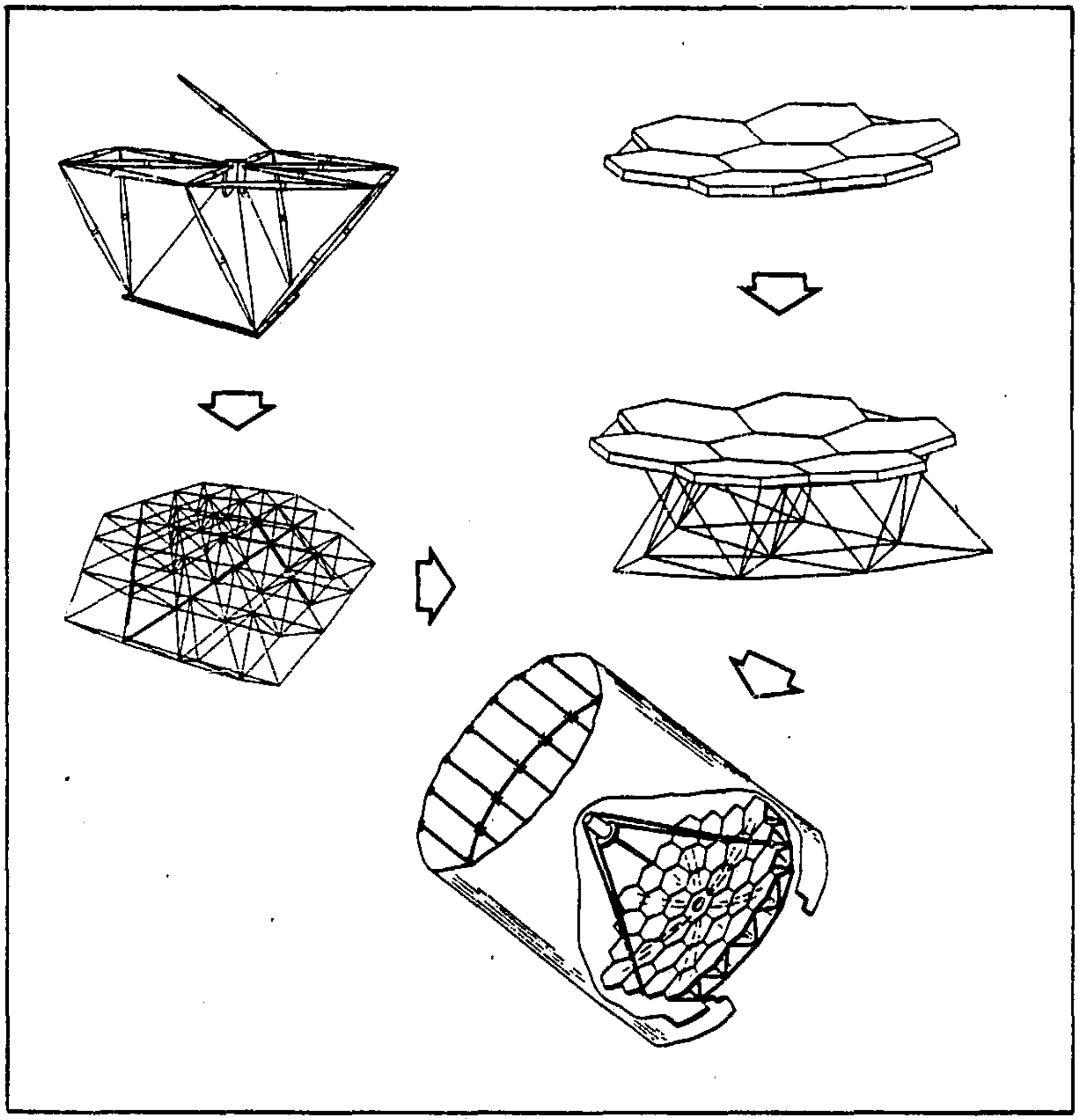

Figure 5.4-1 LSS-4 Manual Truss Assembly Construction Sequence

Then utilizing the preliminary design information, drawings, and mission data forms, a second construction scenario was prepared. This scenario was prepared to provide a picture of the modular assembly functions required to accomplish the LSS-4 TDM objectives. As shown in figure 5.4-2 the sequence begins by first deploying the diagonal members from the lower truss frame and then attaching the upper truss frame (with mirrors) to it. The modules are then attached together to form the primary mirror assembly. The secondary mirror and supports are then attached followed by the light shield. Dynamic tests and accuracy measurements were included during the construction activities to verify the characteristics of the structure and construction methods.

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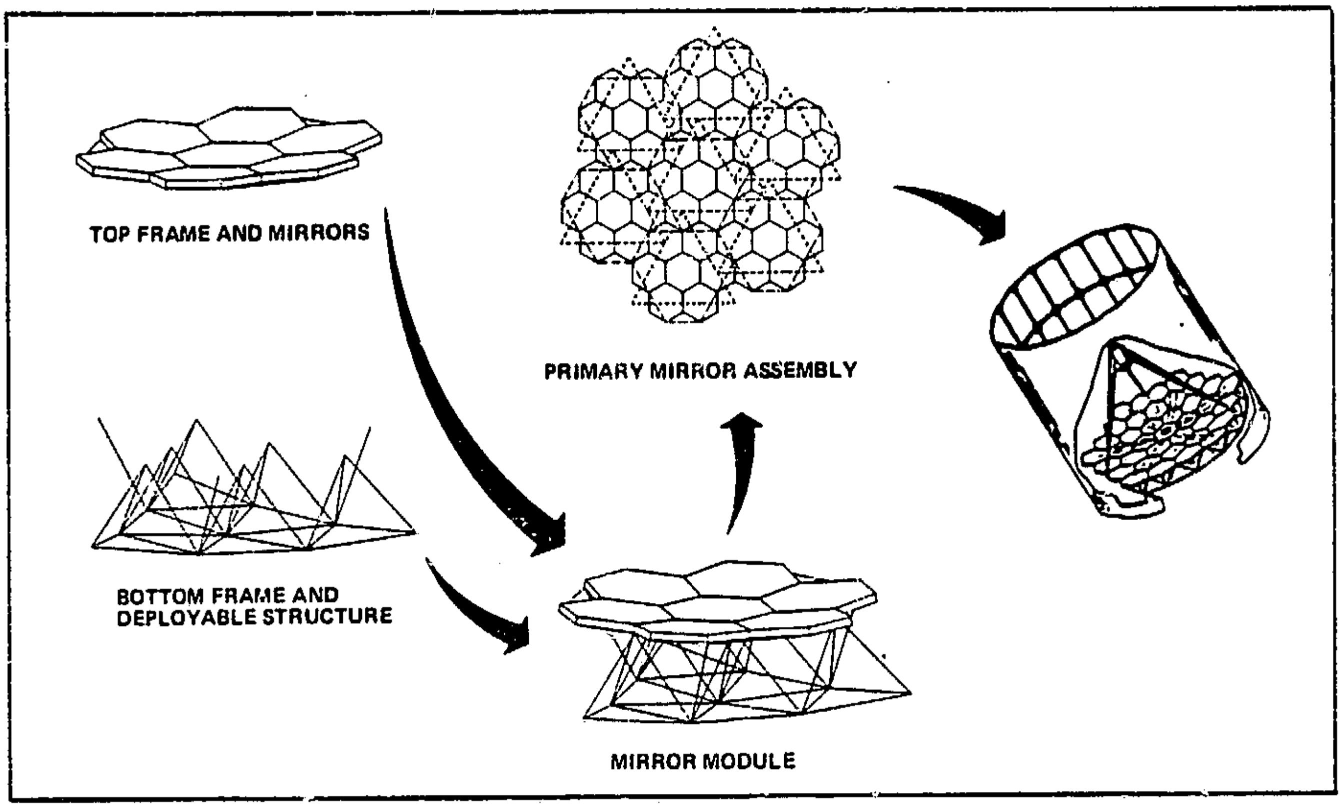


Figure 5.4-2 LSS-4 Modular Construction Sequence

The LSS-4 functional flow diagrams were then prepared and documented as seen in figure 5.4-3.

5.4.3 Task Analysis

As the functional flow diagrams were being prepared, preliminary task analysis was begun to further define the LSS-4 TDM construction tasks. These were refined and updated as more detailed design data was generated. As the detailed time lines were evolved, task duration was considered. This combination generated a detailed timeline analysis.

5.4.4 Timeline Analysis

These Timeline analyses were used to derive human performance requirements by showing the functional relationships between tasks as well as task loadings for the combinations of tasks. Design details and operator requirements were coordinated with Boeing designers and were used as a basis for updating the detailed task analyses and timelines.

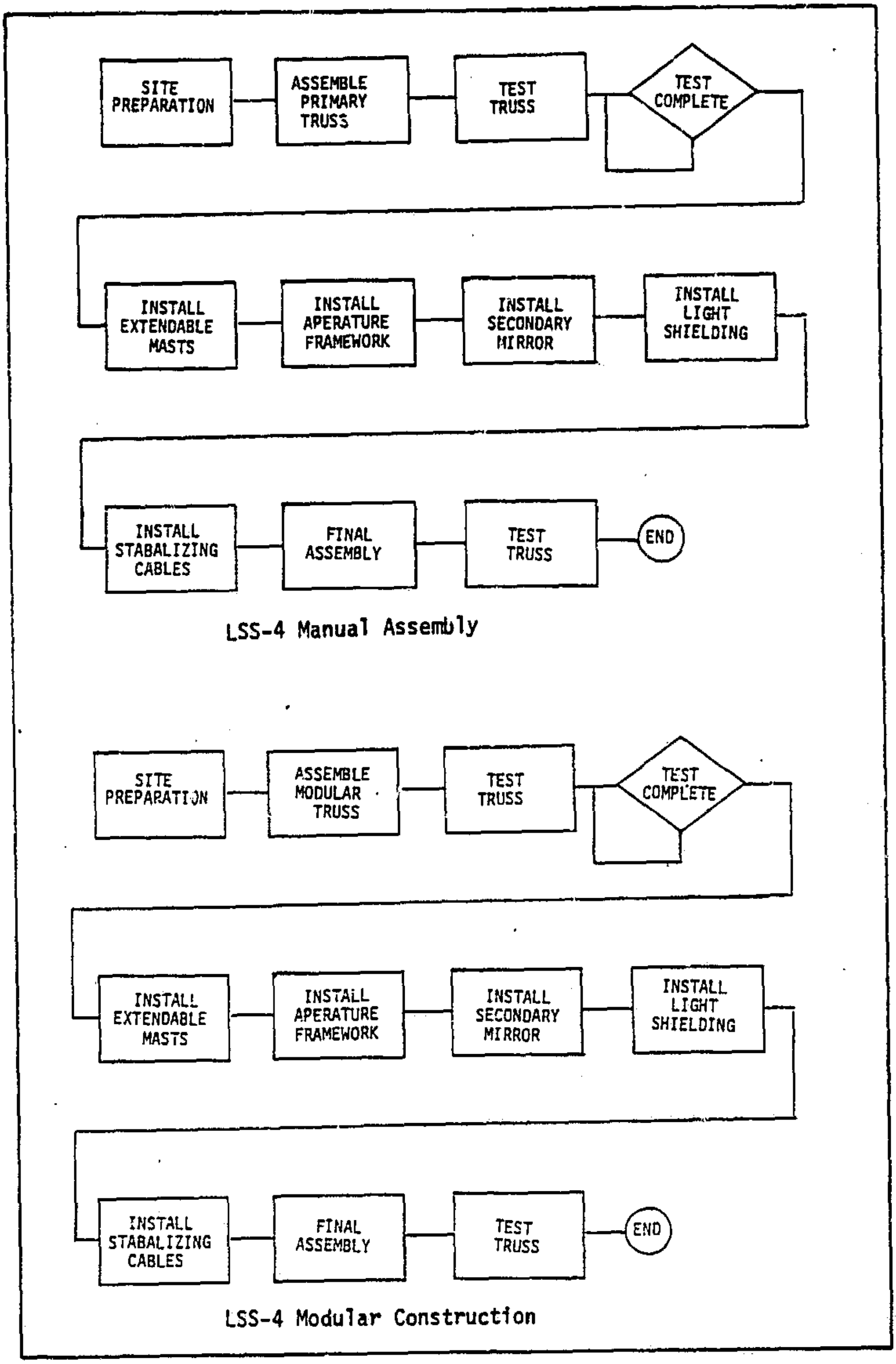


Figure 5.4-3 LSS-4 Functional Flows

The analysis indicates the estimated amount of operator's time, for each type of construction, which is occupied throughout the LSS construction tasks. These operator task load estimates were derived from neutral buoyancy simulation, times from previous missions, and analysis of NASA video tape of STS-6, STS-11, and STS-13 missions. In addition, interviews with previous and current astronauts were reviewed for pertinent EVA data. A summary of the LSS-4 manual assembly and modular assembly timelines is presented in figure 5.4-4.

LSS-4 Concept	Elapsed Hours	25% Contingency	Total Hours
Assemblable	229.3	57.3	286.6
Modular	169.63	42.4	212.0

Figure 5.4-4 LSS-4 Timeline Summary

5.5 Development Activities

The technology development missions defined in this report will demonstrate the ability to construct large space structures on an early Space Station. However, precursor developments are required to advance the necessary technology and operational procedures required for on-orbit assembly or construction. These precursor activities involve the design, manufacture and test of structural components for the TDMs and the development of detailed procedures for their construction in space. Several testing arenas and types of tests can be used for these developments: ground tests in the laboratory, neutral buoyancy tests in a water tank and tests in space using the Space Shuttle.

Figure 5.5-1 summarizes the general areas where development activities for large space structures need to be conducted and the locations for each. In all cases, ground testing is the primary development testing arena, but all developments need to be demonstrated in space to verify the ground tests. Zero-g simulations which involve human interaction are most economically conducted in a neutral buoyance simulator, subject to the limitations of the physical dimensions of the facility.

For the Precision Optical System in particular, a list of development tests was established for each type of test facility and is shown in figure 5.5-2. The development program outlined uses full size structural components, including at least two primary mirror support structure modules with dummy mirrors, to determine the behavior of the structure and to develop techniques for its construction. Because of the high stiffness of

DEVELOPMENTS NECESSARY FOR LSS TDM	TESTS		
	GROUND	NEUTRAL BUOYANCY	SHUTTLE
ASSEMBLABLE JOINT	X	X	X
FOLDING DEPLOYABLE JOINT	X	X	X
MRS REFLECTIVE MEMBRANE SURFACE	X		X
MRS MEMBRANE SURFACE CONTOUR MEASURING SYSTEM	X		X
MRS MEMBRANE TENSIONING SYSTEM	X		X
MIRROR POSITIONING CONTROLS	X		X
DEPLOYABLE TRUSS BEAMS	X	X	X
TENSION STABILIZED BEAMS	X		X
CHERRYPICKER RMS	X		X
EVA ASSEMBLY OPERATIONS CAPABILITY	X	X	X
DYNAMIC TESTING	X		X
SURFACE ACCURACY MEASUREMENT	X		X
MODAL IDENTIFICATION TECHNIQUE	X		X

Figure 5.5-1 Precursor Technology Development

Ground Tests:
- Deploy and assemble primary mirror assembly
- Structural tests
  - accuracy measurement
  - dynamic
  - thermal
  - static
- Mirror tests
  - alignment measurement system
  - adjustment mechanisms (coarse and fine)
  - dynamic
  - static
  - remove and replace mirror segment

Neutral Buoyancy Simulator (NBS) Tests:
- Deploy and assemble primary mirror assembly
- Remove and replace mirror segment

Shuttle Flight Tests:
- Deploy and assemble primary mirror assembly
- Assemble secondary mirror system
- Measure accuracy
- Dynamic tests
- Measure thermal deformations
- Replace a mirror segment
- Perform mirror alignment tests (coarse and fine)

Figure 5.5-2 LSS-4 Development Tests

the structure, most of the tests can be accomplished on the ground in a 1-g environment. Neutral buoyancy simulations will help to determine operational procedures and techniques, and final verification will be done in space.

5.5.1 Ground Tests

The determination of the structural characteristics of the precision optical system design can be accomplished using ground tests. Structural deformations due to the effect of gravity will be small because the structural stiffness must be high. Therefore, conventional ground test methods for spacecraft will apply to this TDM. The determination of the effect of joint slop on the structural dynamics and damping of the structure, however, may require special suspension systems to negate the effects of gravity.

In addition to the thermal and structural ground tests, development of the precision measurement and control system for the primary mirror segments will be accomplished on the ground. The precision alignment of the mirror segments requires the accurate knowledge of the behavior of the structure to control system forces as well as to external disturbances.

Ground tests can also be used to develop the procedures and techniques required for the construction and checkout of the structural components of the precision optical system and to verify the mechanical systems which are required to attach the various assemblies together.

5.5.2 Neutral Buoyancy Simulator (NBS) Tests

Zero-g activities which require human involvement are best simulated in a neutral buoyancy simulator which uses the buoyant forces on objects submerged in water to simulate the weightless conditions of space. This test facility can be used in the development of the precision optical system to demonstrate the procedures and techniques for the assembly of the primary mirror modules, the attachment of several modules together, the assembly of the secondary mirror and its support, the routing of utilities, and the attachment of the light shield panels.

5.5.3 Shuttle Flight Tests

After the structural components and assemblies for the precision optical system have been tested on Earth and the construction procedures and techniques have been developed and simulated, they must be also be demonstrated in space. Orbiter flight tests of the construction of the precision optical system can be used to verify the measurement and control systems for the alignment of the optical reflector segments as well as the mechanical systems. Dynamic measurements taken during these tests can also be used to verify ground tests results, analytical models and predictions. Assembly procedures and techniques developed in the neutral buoyancy simulator can be duplicated in space to determine the accuracy of NBS testing.

5.6 Programatics

The study of LSS-4 included preliminary considerations of program structure, cost, schedules and phasing. This programmatic analysis was performed on two subtasks: (1) plans and schedules and (2) cost analysis.

5.6.1 Plans and Schedules

The preliminary program master schedule for LSS-4 was not updated due to the change in the statement of work by NASA direction. Figure 5.6-1 shows the preliminary master schedule.

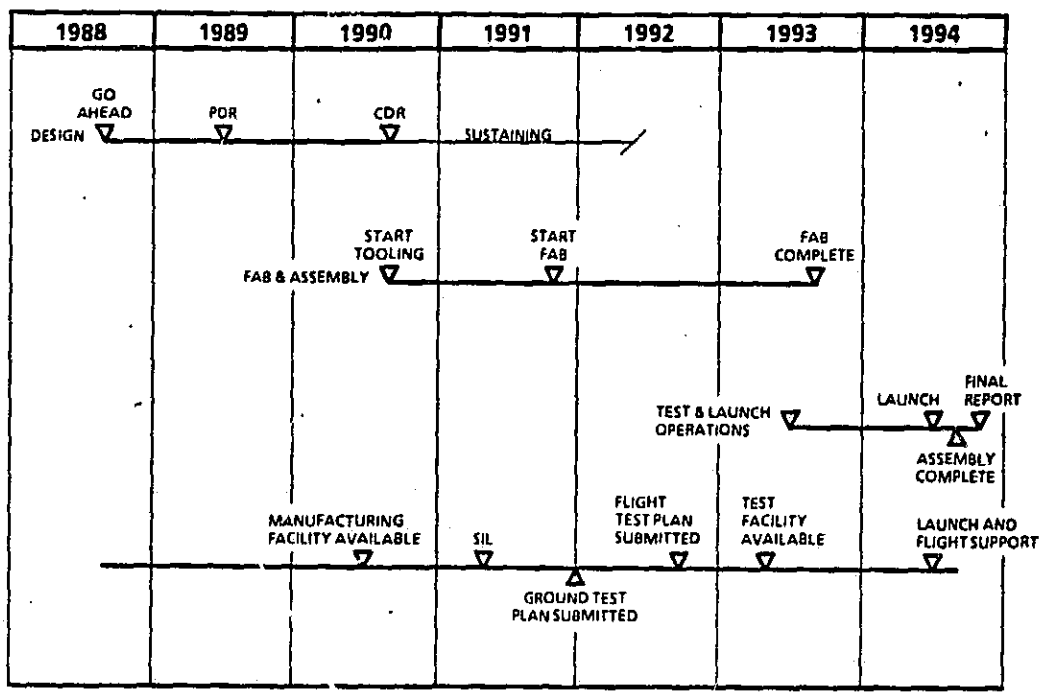


Figure 5.6-1 LSS-4 Master Schedule

5.6.2 Cost Analysis

An analysis of the Precision Optical System was conducted during Phase I of this study (Reference 1) to determine the costs associated with its design, development, and manufacture. These costs were updated in Phase II to reflect maturity in the details of the design.

TDM costs were determined using the cost data base we have developed from experience with previous spacecraft. New equipment, hardware and development costs were defined using the Boeing Parametric Cost Model (PCM) cost analysis computer model and the RCA PRICE hardware acquisition model.

The Ground Rules Provided by MSFC are:

- o Cost estimates are in FY-84 dollars, including fiscal year funding requirements.
- o Space Station ATP are FY-86 with initial launch in FY-90 and IOC in FY-91.
- o Cost estimates include all requirements unique to demonstrating the technology feasibility.

The Additional Ground Rules and Assumptions used are:

- o The Boeing PCM hardware cost model was used to estimate all structural/mechanical items and all support costs, i.e. SE&I, system ground test, tool & test equipment, program management, etc.

- o PCM was used to estimate all integration costs.

- o The RCA PRICE hardware cost model was used to estimate the cost of one set of primary mirrors and secondary mirror assembly.

- o Design costs reflect the repetitive nature of the hardware.

- o The electronics package for the Precision Optical System was not priced.

- o Learning was assumed (88% of structural items).

- o Development quantity = 2

The development costs for the Precision Optical System are summarized in figure 5.6-2.

Engineering ($M)	**154.6**
Total Hardware (2 Units)	**118.8**
Total Development ($M)	**273.4**
Flight Unit Cost ($M)	**59.4**
Does not include focal plane electronics and mirror control electronics	
1984 dollars	

Figure 5.6-2 LSS-4 Development Costs

5.7 Space Station Resources Required

5.7.1 Accommodations

LSS TDM EVA activities require special equipment and/or procedures. These in turn will require provisions for accommodations in the basic Space Station design. The accommodation needs of the LSS-3 TDM were defined by analysis of both mission and Space Station requirements/capabilities. A detailed list os the Space Station architectural features, required for LSS-4 EVA construction and test activities is provided in figure 3.7-1 previously shown in section 3.7.

5.7.2 Operations

Scheduling of the Space Station facilities, activities, and personnel is of prime importance to minimize conflicts during LSS EVA construction activities. Communications, data equipment, and links required for EVA will need to be available and operational. All other missions and Space Station facility usage will require close coordination. Figure 5.7-1 shows the Space Station operations that need to be scheduled to avoid conflicts with LSS-4 construction activities.

5.7.3 Crew Support

The LSS-4 crew skills were identified as explained in section 3.7.3. The numbers shown in the crew skill support (figure 5.7-2) represent the percent of operation duration

Scheduling
- **Communications**
  - **CCTV**
  - **Intercomm**
  - **Links**
- **Data**
  - **Processing**
  - **Handling**
- **Missions**
  - **RMS usage**
  - **Facilities (briefing room)**
- **Crew members**
  - **2 EVA**
  - **1 IVA**

Figure 5.7-1 LSS-4 Space Station Operations

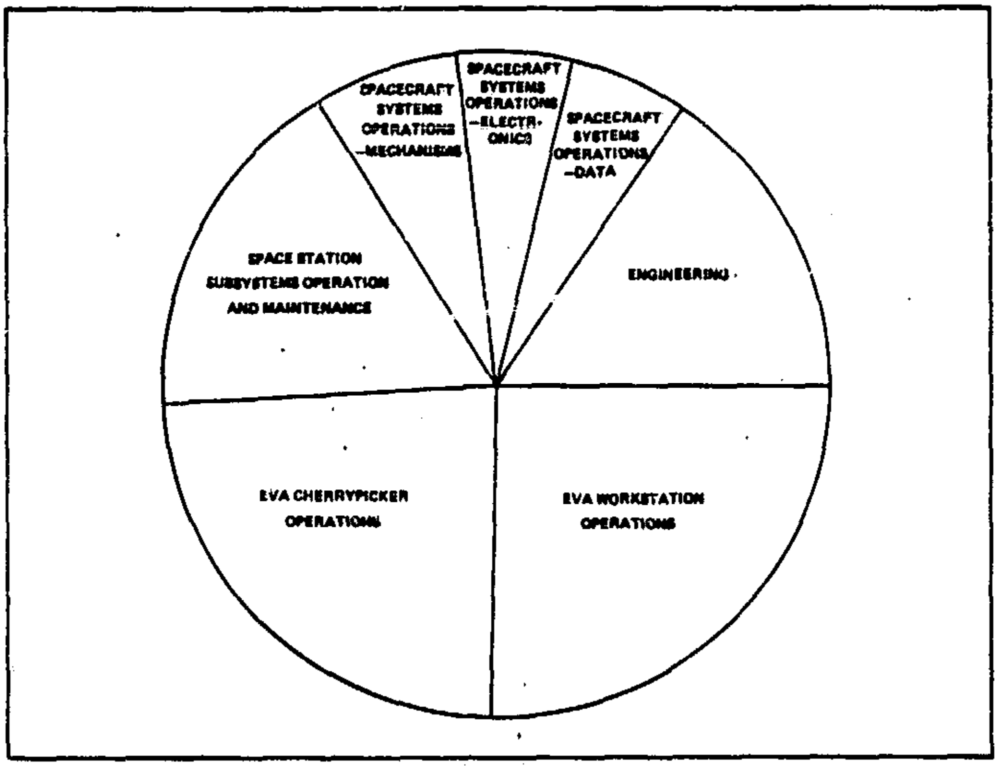


Figure 5.7-2 Crew Skill Support

time each skill is required. These percentages were estimated from the data used to calculate the operation time. Particular attention was paid to the crew skill descriptions in figure 3.7-5 in making sure that the proper crew skills were utilized for each operation.

5.7.4 Special Equipment

During the definition and analysis of the LSS-5 TDM, special equipment requirements were considered. The required support equipment, instrumentation, data systems, and small tools identified during this study are listed in figure 5.7-3. The articulated holding fixture is an example of the special equipment that will need to be supplied with the LSS-4 mission hardware. Some common equipment is envisioned to remain on the Space Station for use with other missions.

5.8 Potential Problems and Concerns

Several areas of concern must be considered when constructing the Precision Optical System at the Space Station. The additional mass and inertias of the structure as well as its structural dynamic characteristics must be accommodated by the Space Station control system. The dynamic loads resulting from events such as Orbiter docking and thruster firings must also be accounted for. Large Space Structures attached to the Space Station will also increase the drag due to their size. The large size of the structures may also influence the thermal balance of the Space Station and interfere with communication paths. For the Precision Optical System there is the added concern of handling and protecting the fragile mirror segments.

These and other concerns raised by the construction of large space structures affect a wide range of technologies and subsystems and need to be carefully considered in the design of the Space Station as well as in the design of the construction project. The results of initial investigations of some of these concerns are presented in the following sections.

5.8.1 Mass and Inertia

The mass and inertia of LSS construction projects must be accommodated by the Space Station attitude control system. Therefore the inertia properties of the Precision Optical System structure including the mirrors were estimated and are shown in figure 5.8-1. The instrument module which contains the focal plane instruments and other equipment is not included in these estimates. The center of mass location and the inertia properties are given in relation to its interface with the Space Station which is at the center of the bottom surface of the primary mirror support truss. Primary and secondary mirror weights are based on an areal density of 25 kg/m^2.

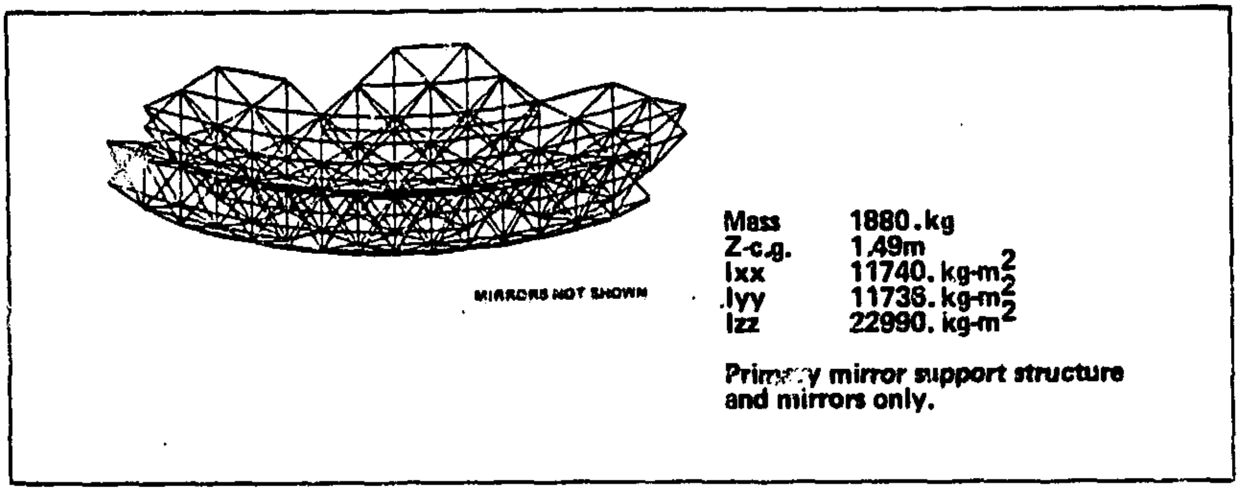


Figure 5.8-1 LSS-4 Mass Properties

5.8.2 Structural Dynamic Characteristics

The calculation of the structural dynamic characteristics for LSS-4 was accomplished during the design trade studies conducted to determine which primary mirror support structure concept would be used. A NASTRAN finite element model was used to determine the free-free mode shapes and frequencies of the primary mirror support structure with the mass of the segmented mirrors included. As shown in figure 5.8-2, the first free-free frequency is 9.5 Hz. Even with the structure attached to the Space Station and the secondary mirror system attached, the frequencies will probably be higher than the primary frequencies of the Space Station itself, and, therefore will not be of significant concern for the control system.

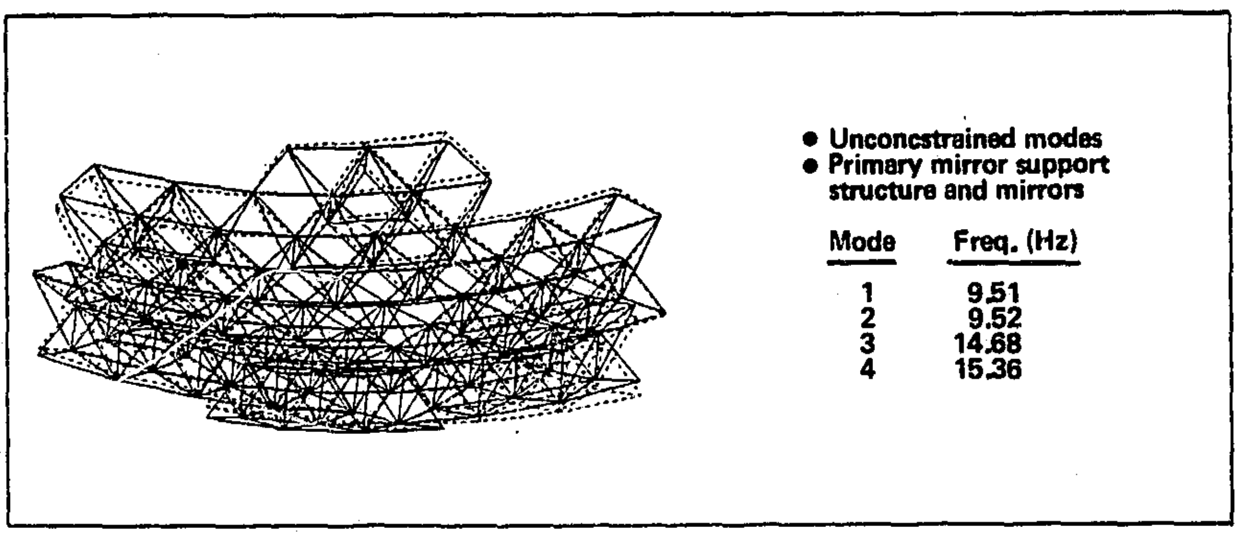


Figure 5.8-2 LSS-4 Dynamic Characteristics

5.8.3 Drag

Another concern created by LSS construction is the increased frontal area which increases the rate of orbital decay due to drag. The orientation of the structure can have a pronounced effect on the drag.

The drag on a body in low Earth orbit depends on its ballistic coefficient (area per unit mass). The drag areas for LSS-4 were calculated and are shown in figure 5.8-3 along with the area/mass ratio. The effect that the optical system has on the total Space Station drag properties is shown in the last line of the table, expressed in terms of the percent increase in area/mass ratio of the Space Station. These calculations are based on the assumption that the areas as well as the mass are additive. In actuality, some shadowing may occur which will help to reduce the area/mass ratio.

	X-Dir	Y-Dir	Z-Dir
LSS-4 area (m^2)	156	156	123
Area/mass ratio (m^2/kg)	.031	.031	.024
% increase for Space Station	2.6	2.6	1.0

Assumption: TDM area adds to Space Station area

Figure 5.8-3 LSS-4 Drag Effects

6.0 INITIAL SPACE STATION CAPABILITY

The current Space Station concepts (IOC 1992), as defined by the Space Station Needs, Attributes, and Architectural Options studies and the NASA CDG meetings were analyzed to determine the extent to which the early Space Station can support the LSS technology development missions.

6.1 Review of Current Concepts

The first step in the review process was to collect the documented results of the eight Space Station Needs, Attributes, and Architectural Options Studies and the NASA CDG Space Station concept. The next step was to review the results of these studies and select a set of representative Space Station concepts for further evaluation. A complete set of the Space Station study concepts with a list of pertinent resources as identified are listed in Appendix C.

In analyzing the early Space Station configurations, it was determined that all the configuration designs fell into one of four configuration philosophies. These four configurations: Radial Hub, Tunnel Hub, SOC (Space Operations Center) type, and Raft are shown in figure 6.1-1

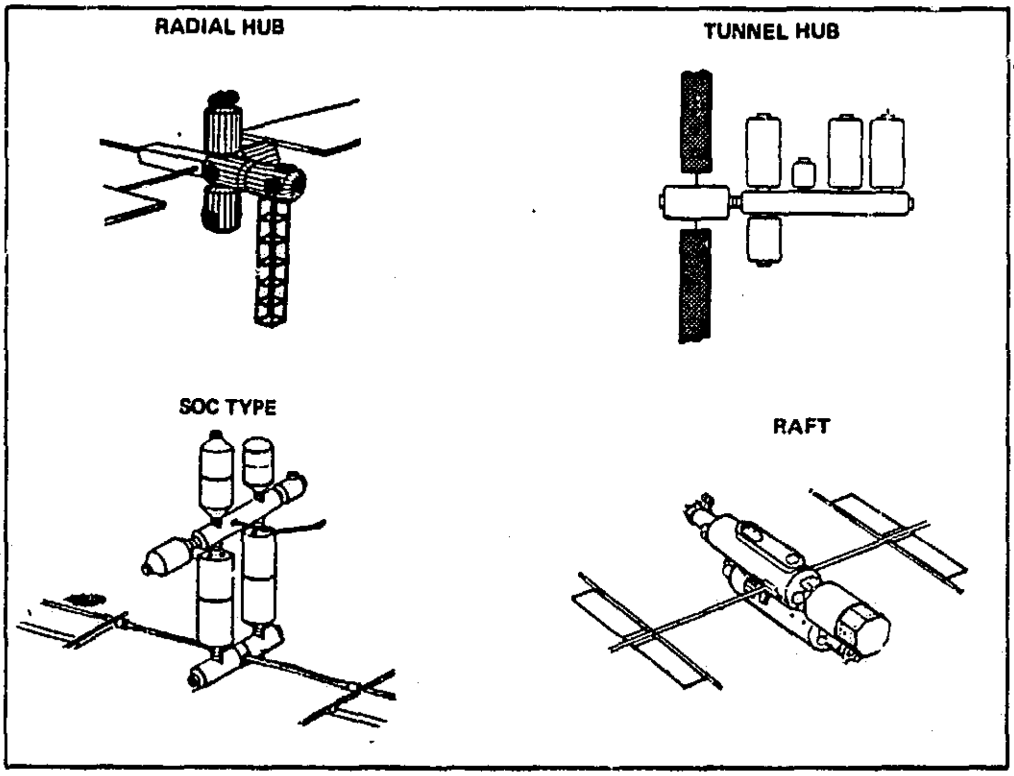


Figure 6.1-1 Space Station Configurations

6.2 LSS TDM Accommodation Assessment

In selecting a representative set of Space Station concepts for further evaluation, we decided to evaluate these four configuration types. Each type is unique enough to make it important to understand each concepts ability to support the construction of LSS technology development missions.

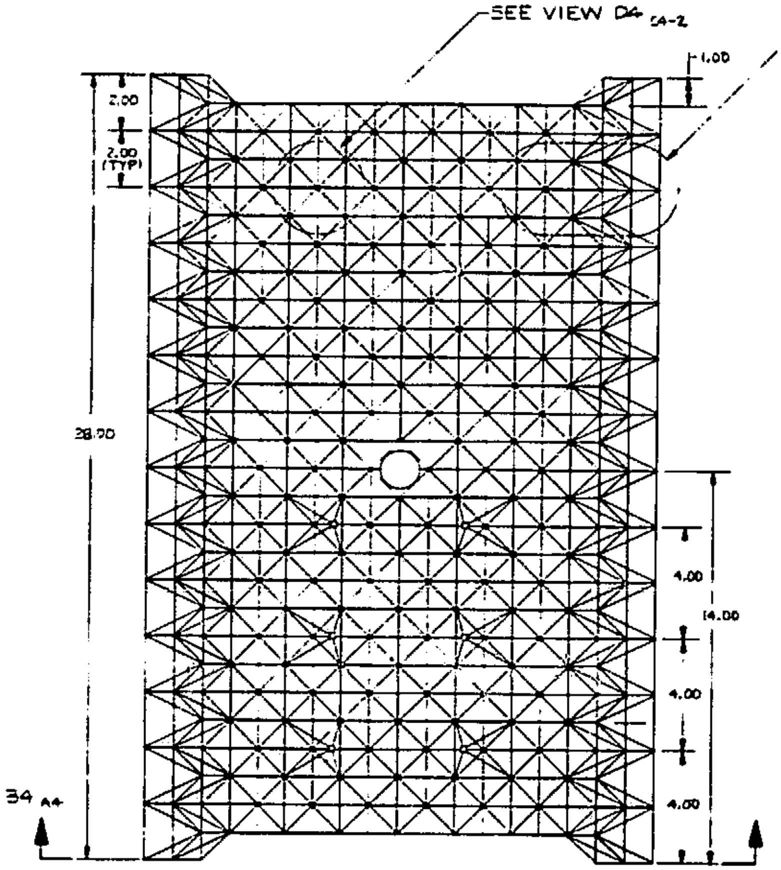
It was determined that all four configurations would adequately support construction of the LSS technology development missions. The LSS-I TDM design was changed to insure adequate Space Station mounting. In order to accomplish this a docking tunnel attachment method was incorporated.

7.0 CONCLUSIONS

Future space systems will require the development of the facilities and techniques needed for the on-orbit construction of large space structures. The logical place for this task is the Space Station which can supply the needed human and physical resources. We need to start now to design into the Space Station the facilities and accommodations required for these projects. Space system designs must also reflect the availability of a construction site in low Earth orbit and the valuable human resource which can reduce the complexity and expense of future systems.

The large space structures technology development missions described can serve to advance the design and operational techniques for LSS construction at the Space Station. These missions provide a logical progression from ground tests and Orbiter flight tests. They can also be used as testbeds to support the technology advancement of other disciplines.

APPENDIX A



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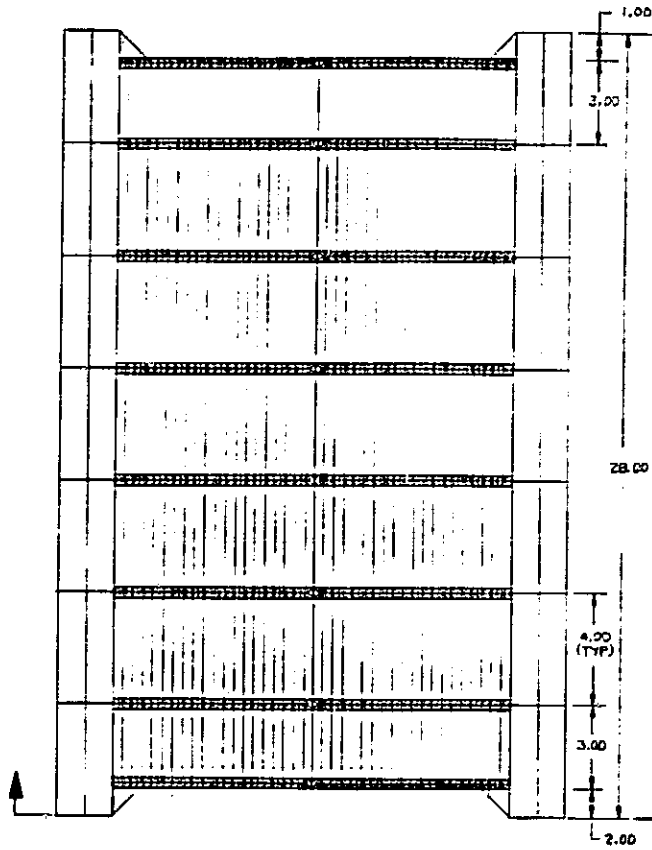
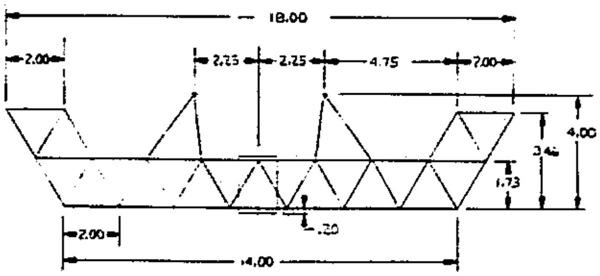
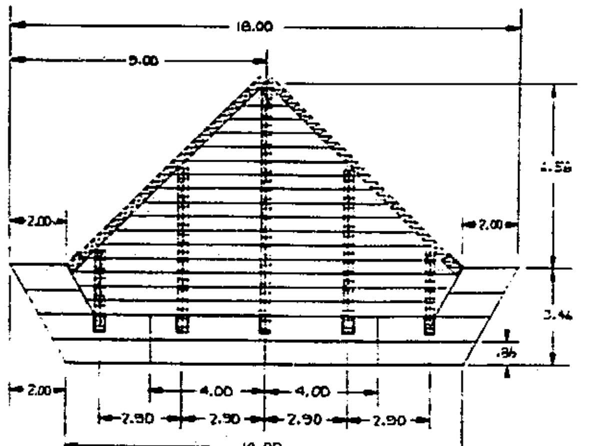
1 INCH = 2 METERS



-1 PLATFORM ASSY
1 INCH = 2 METERS



VIEW B4
1 INCH = 2 METERS



VIEW B2
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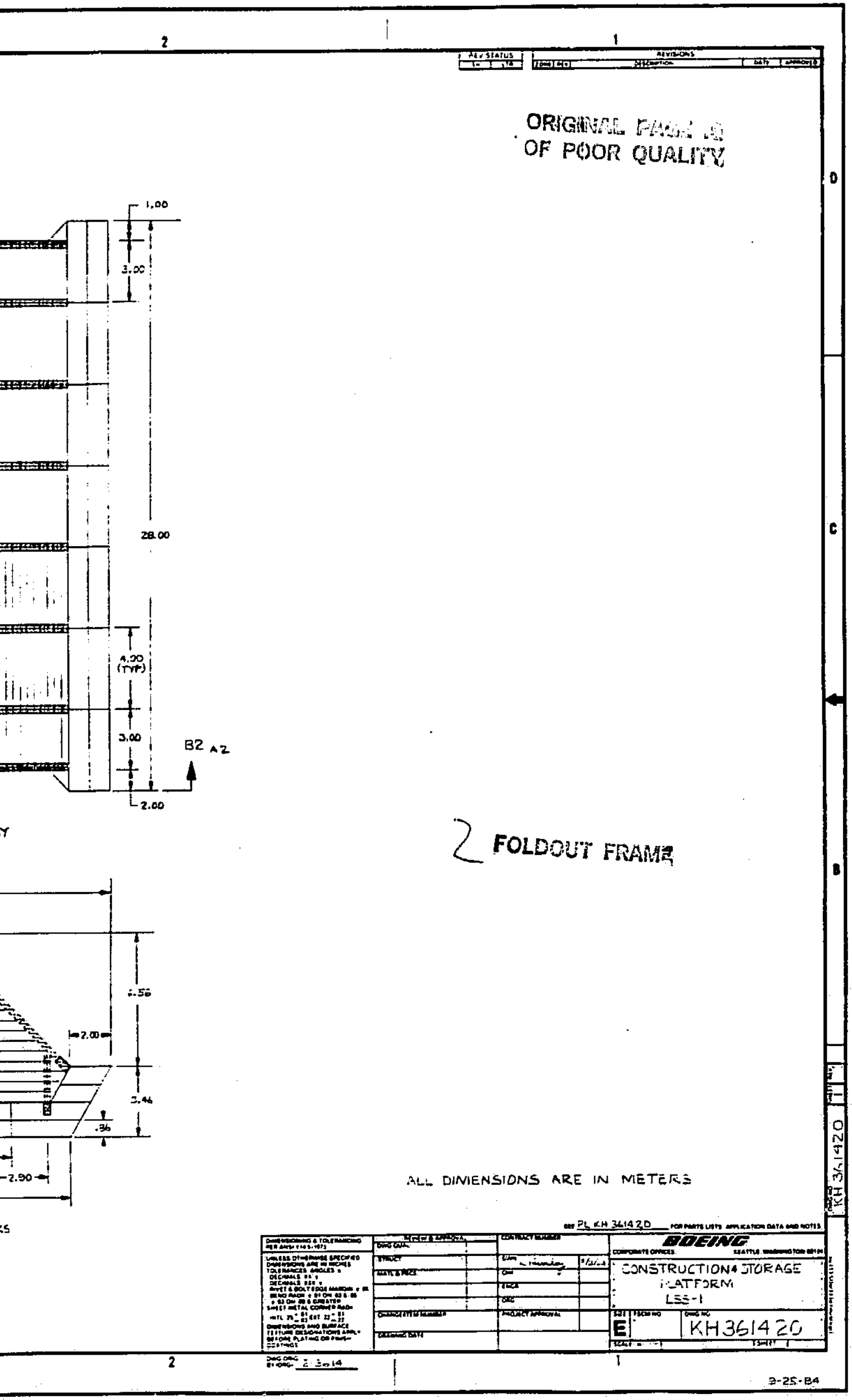
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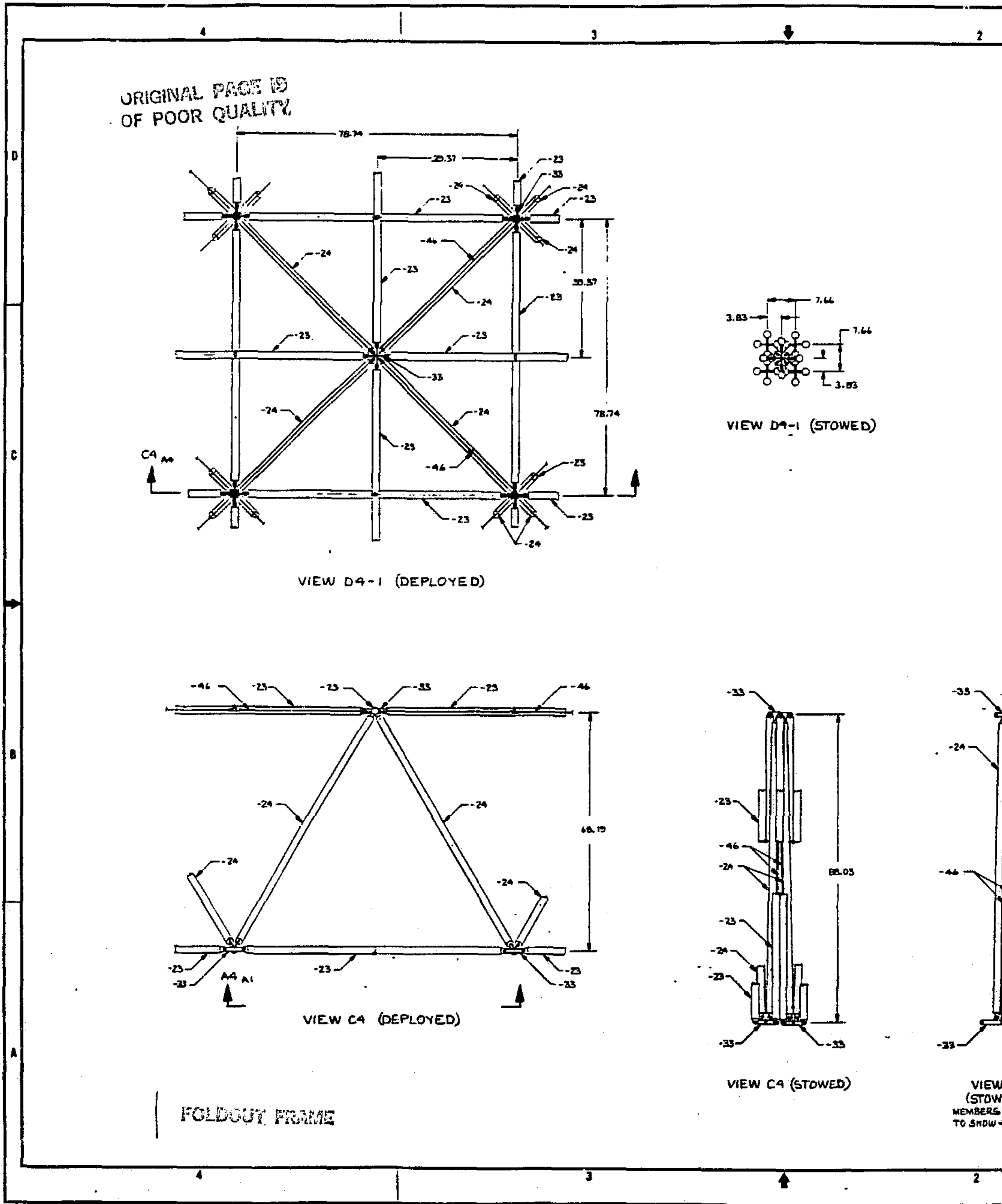
3.46
.36
2.90
ALL DIMENSIONS ARE IN METERS
PL KH 361420
BOEING
CONSTRUCTION & STORAGE PLATFORM
LSS-1
E
KH 361420
KH 361420
3-25-84



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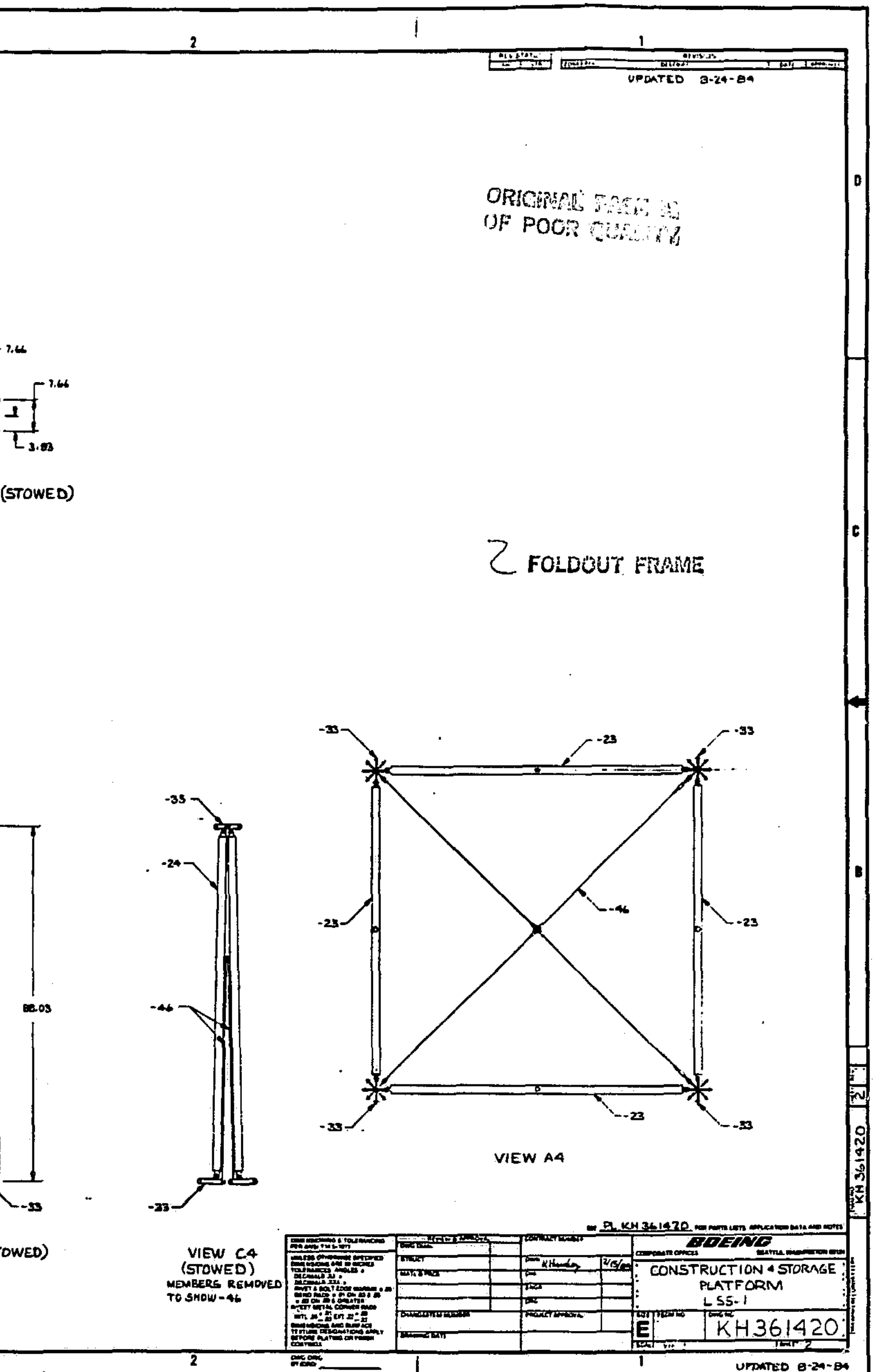
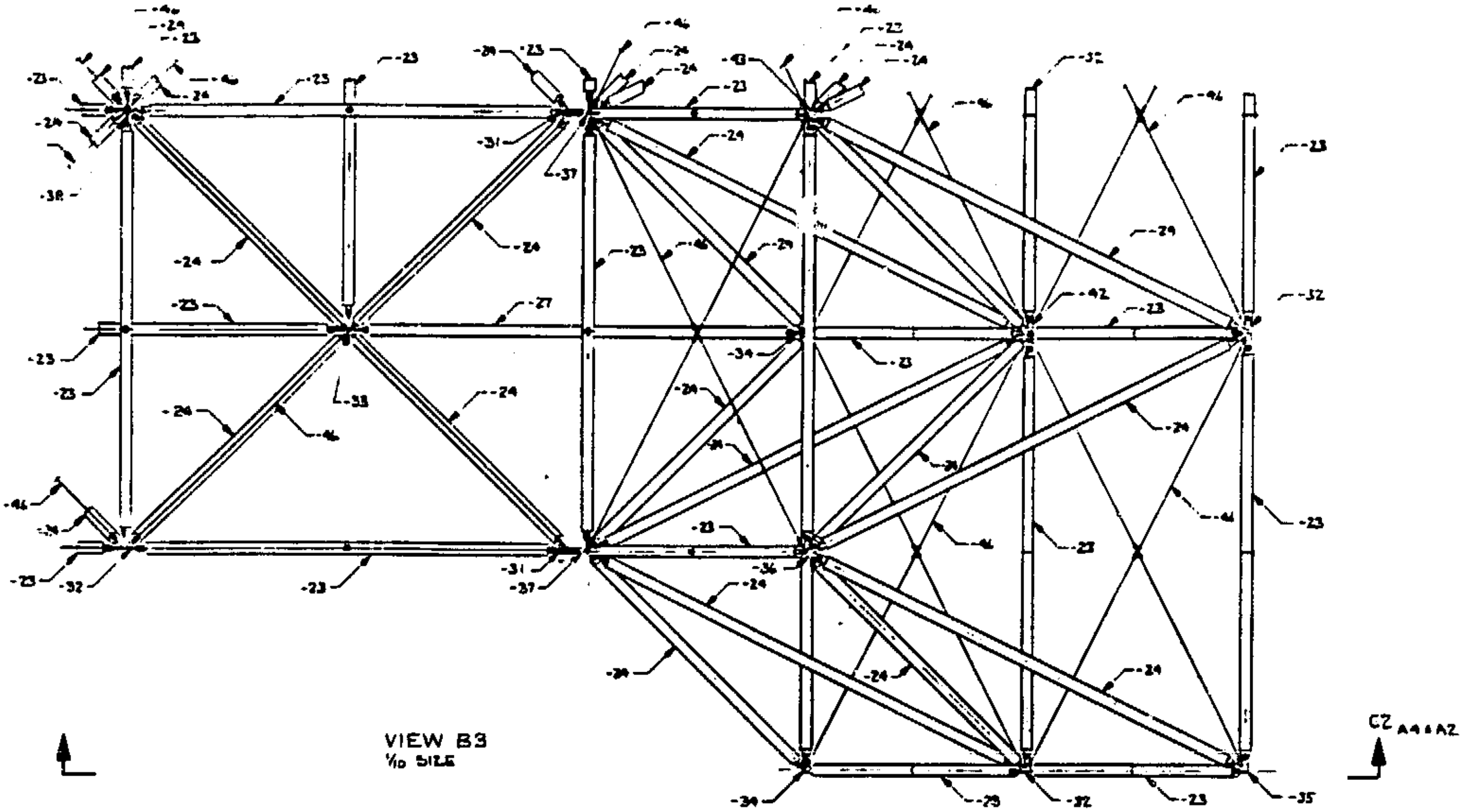


KH 361450 5



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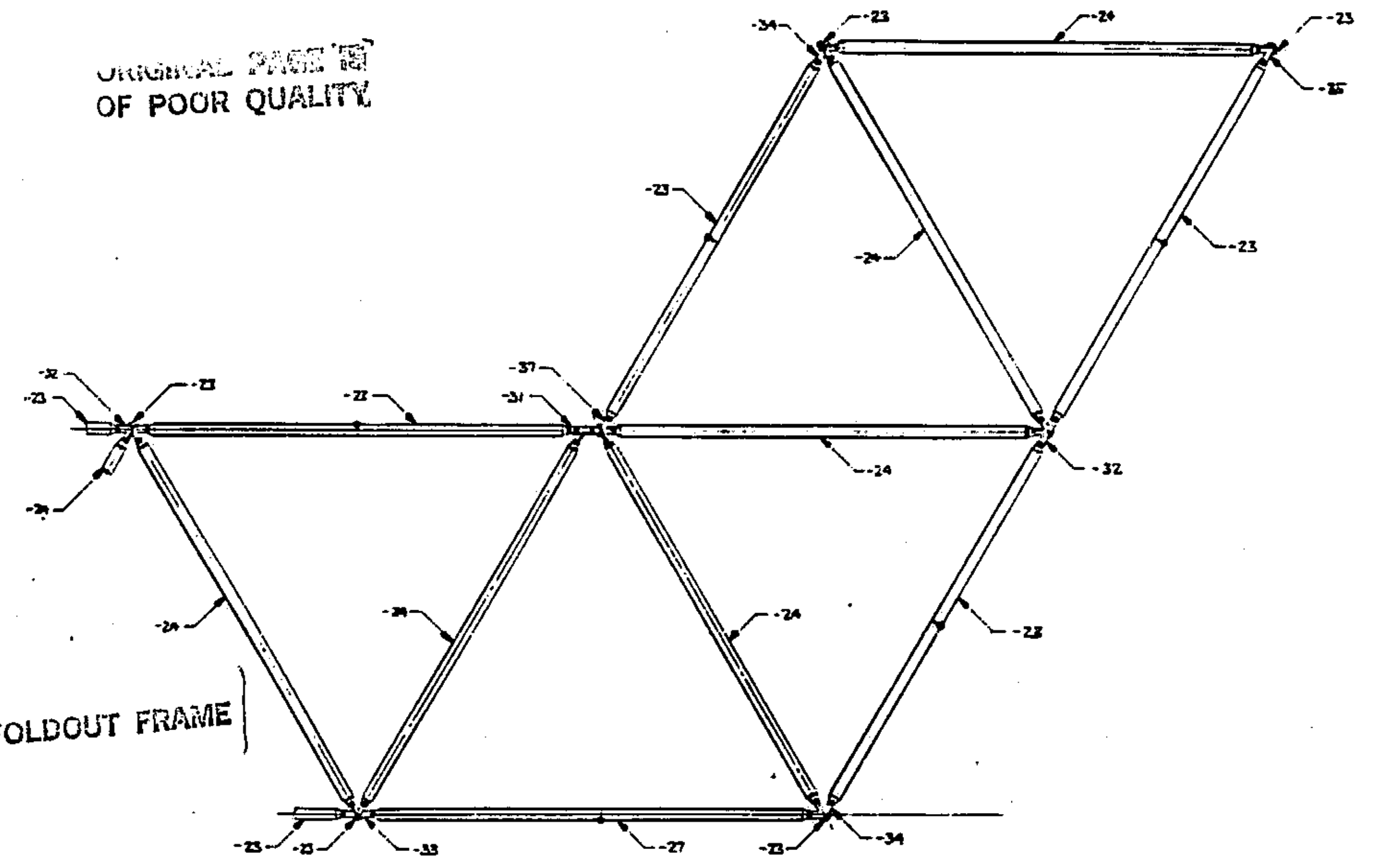

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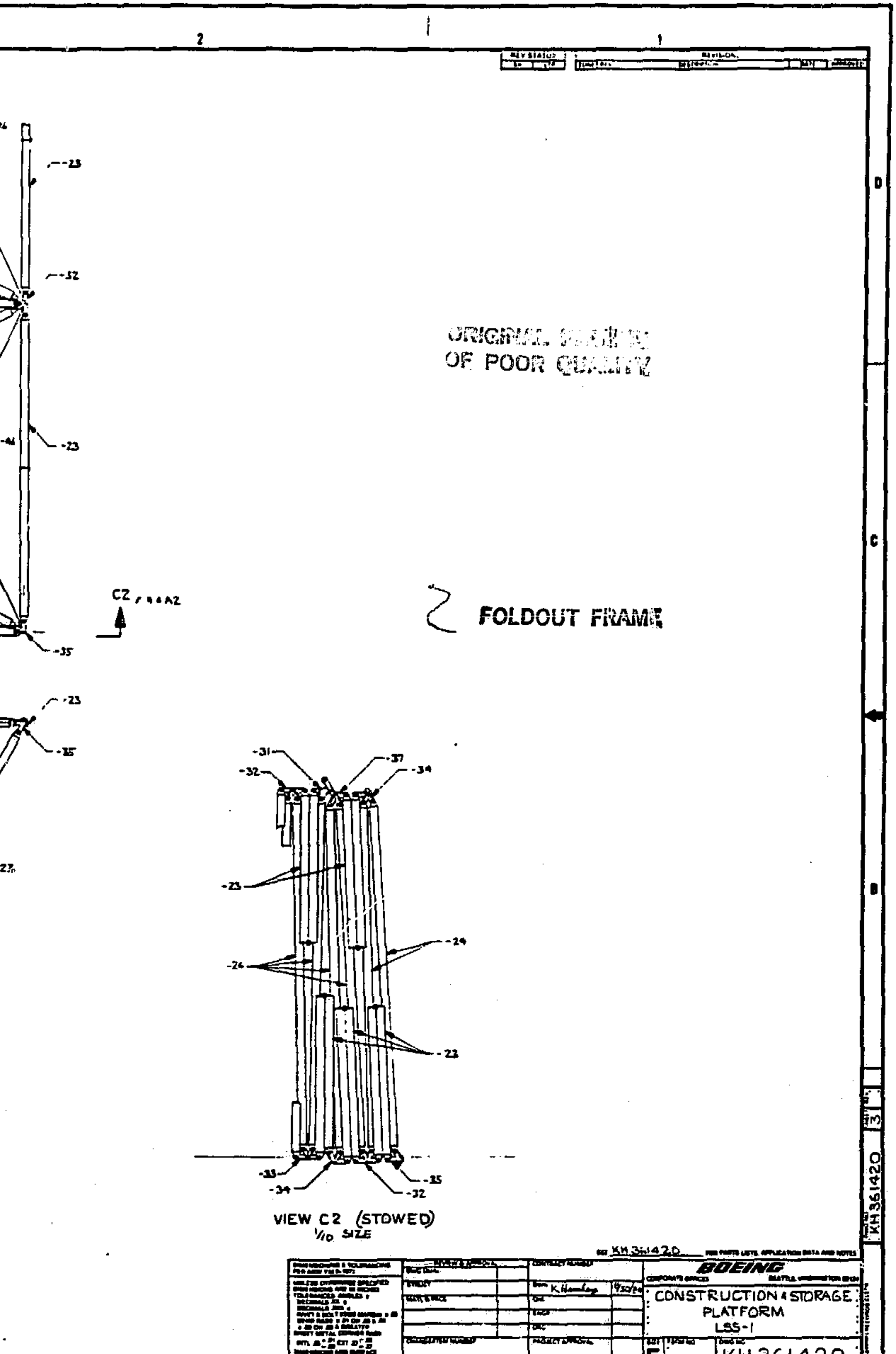
VIEW C2 (DEPLOYED)
1/10 SIZE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BOEING
CONSTRUCTION & STORAGE
PLATFORM
LSS-1
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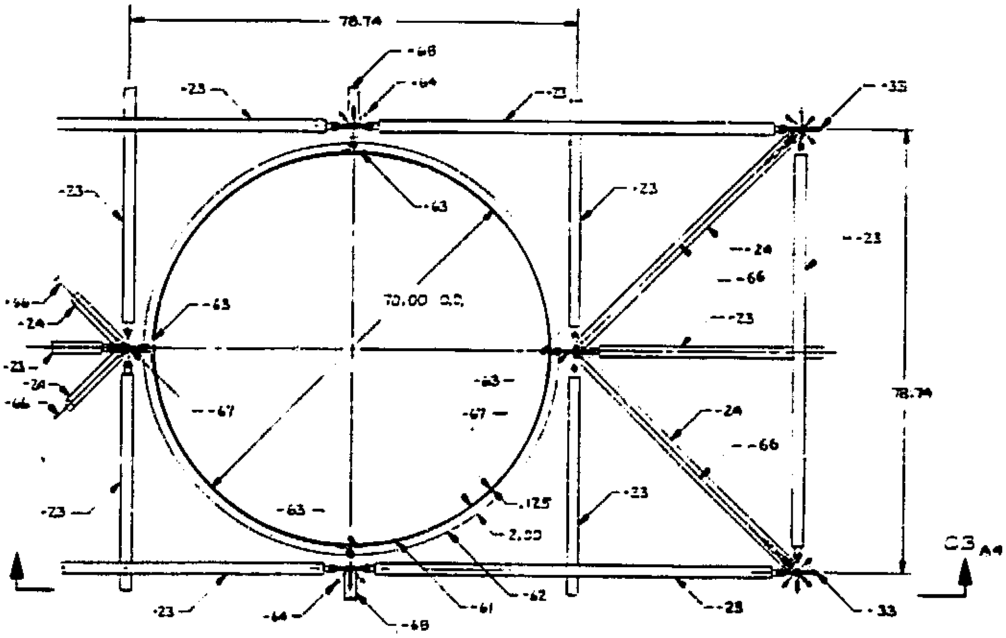
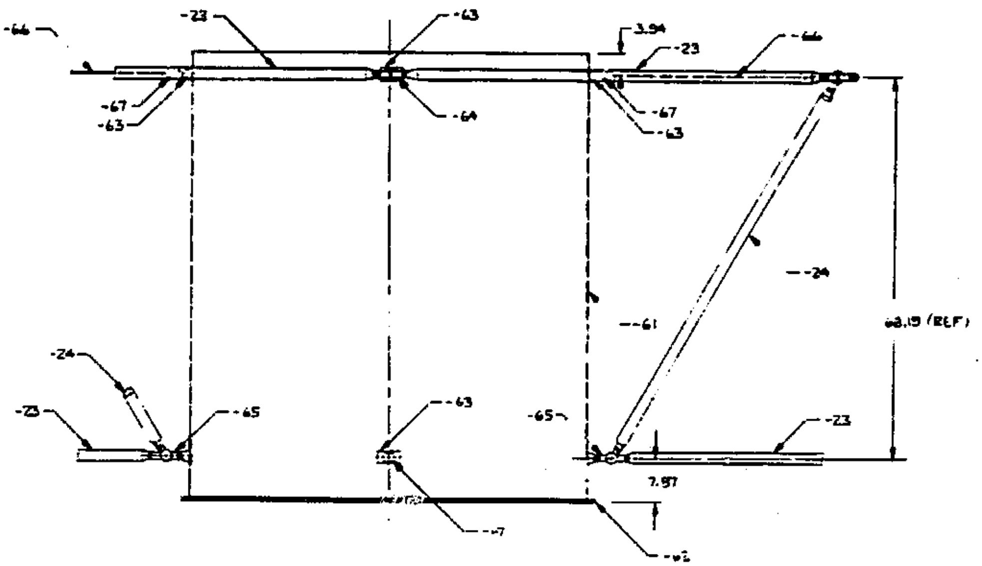


VIEW C4
INSTALLATION OF -60 ACCESS TUNNEL



VIEW C3

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SEE PL KH361420 FOR PARTS LISTS APPLICATION DATA AND NOTES

BOEING

CONSTRUCTION & STORAGE PLATFORM

LSS-1

E

KH361420

SHEET 4

PARTS LIST

THE BOEING COMPANY — SEATTLE, WASHINGTON 98124

DRN K Hemley	8/30/84	MATL & PRCS		DWG QUAL	
CHK		STRUCT		ORG APPVL	
ENGR				PROJ APPVL	

CODE IDENT NUMBER 81205 PL KH361420

TITLE CONSTRUCTION & STORAGE PLATFORM LSS-1

CONTRACT NUMBER NAS 8-35043

DWG ORIG BY ORG

DEPENDENT DRAWING

RELEASE CONTROL NUMBER	RELEASE
1.	
2.	
3	

APPLICATION AND PARTS RELEASE

PART NUMBER	QTY PER NEXT ASSY	QTY PER END ITEM	NEXT HIGHER ASSEMBLY DWG	END ITEM NUMBER CI	END ITEM NUMBER PEI	PROGRAM DESIGNATOR	USED ON MODEL	END ITEM EFFECTIVITIES	DWG SHEET NUMBERS	RCN	RFC
1	—	1	NONE			—	—	NONE	1 THRU 3		

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PARTS LIST

THE BOEING COMPANY
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CONTRACT NUMBER: NAS 8-35043 | FSCM NUMBER: 81205 | PL KH361420 | SHEET 2 | REV LTR

NOTE NUMBER	NOTE CODE	NOTE
1		3K TOW OF P75S GRAPHITE FIBER IMPREGNATED WITH 35% - 38% BY VOLUME E773 EPOXY RESIN. US POLYMERIC CO. 706 EAST DYER ROAD, SANTA ANA, CALIF
2		LONGO WIND 260 TOWS EQUALLY SPACED ABOUT CIRCUMFERENCE AT 0° TO 2° ORIENTATION RELATIVE TO AXIS OF TUBE
3		CIRC WIND WITH .594 ± .03 INCH PITCH PER REVOLUTION, RIGHT OR LEFT THREAD ADVANCE OPTIONAL
4		CURE CYCLE: PLACE THERMOCOUPLES TO READ MANDREL & TUBE TEMPERATURES. ROTATE DURING CURE CYCLE. RAISE TEMP FROM 120°F TO 275°F AT 3-4° PER MINUTE. START CURE TIME WHEN LAGGING THERMOCOUPLE REACHES 265°F. CURE AT 275°F ± 10°F FOR ONE HOUR. COOL TO 125°F AT 3-4°F PER MINUTE.
5		SOLVENT CLEAN FAYING SURFACE ON FITTINGS AND TUBE BORES. APPLY A UNIFORM COATING OF BMS 5-109 TYPE I, CLASS I, GRADE B EPOXY ADHESIVE TO ALL FAYING SURFACES. INSERT FITTINGS INTO TUBES, WIPE OFF EXCESS ADHESIVE AND PUT ASSY IN A FIXTURE TO CONTROL PIN TO PIN LENGTH. CURE PER ADHESIVE VENDORS DIRECTIONS. MAXIMUM CURE TEMPERATURE 150°F.
6		INJECTION MOLD WITH POLYETHERETHERKETONE RESIN FILLED 30% TO 35% BY WEIGHT WITH PAN GRAPHITE FIBER
7		PULTRUDE 170 ± 5 TOWS OF 1 MATERIAL TO FORM A NOMINAL .25 DIA ROD.
8		SOLVENT CLEAN ROD ENDS AND FITTING BORES. ADHESIVE BOND THE SAME AS 5
9		INJECTION MOLD BOLT TO THE DIMENSIONS OF AN6 AND NOT TO DIMENSIONS OF AN 315-6. GRIP LENGTH IS CALLED OUT IN PL. IT SHALL BE OPTIONAL TO MACHINE FASTENER FROM MOLDED BAR STOCK
10		INJECTION MOLD BOLT TO THE DIMENSIONS OF AN5 AND NOT TO DIMENSIONS OF AN 315-5. SEE NOTE 9
11		PAN HEAD PHILLIPS MACHINE SCREW 18-8 STAINLESS STEEL. #10-32-2A × 1/2 ANY SOURCE.

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						1		-2	STRUCTURE ASSY	B4-1											
						10		-3	COVER PANEL ASSY	D3-1											
						4		-4	COVER PANEL ASSY	B3-1											
								-5													
						2		-6	END PANEL ASSY	B2-1											
						2		-7	OPP-6	B3-1											
						2		-8	END PANEL ASSY	B2-1											
						2		-9	OPP-8	B3-1											
						14		-10	BEAM ASSY	C3-1											
						2		-11	BEAM ASSY	B3-1											
						4		-12	BEAM ASSY	B2-1											
						14		-13	ERECTOR ASSY	C2-1											
						2		-14	ERECTOR ASSY	A3-1											
						4		-15	ERECTOR ASSY	A2-1											
						1		-16	TRANSFER TUNNEL ASSY												
						8		-17	SKIN PANEL												
						4		-18	SKIN PANEL												
						4		-19	SKIN PANEL												
						8		-20	SKIN PANEL												

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						70		-22	SKIN PANEL												
					514			-23	TUBE ASSY							5					
					536			-24	TUBE ASSY							5					
					12			-25	TUBE ASSY							5					
					12			-26	TUBE ASSY							5					
					26			-27	TUBE ASSY							5					
								-28	TUBE							1,2,3,4					
								-29	TUBE							1,2,3,4					
								-30	TUBE							1,2,3,4,					
					28			-31	FITTING							6					
					14			-32	FITTING							6					
					74			-33	FITTING							6					
					2			-34	FITTING							6					
					2			-35	OPP -34							6					
					2			-36	FITTING							6					
					2			-37	OPP -36							6					
					6			-38	FITTING							6					
					6			-39	FITTING							6					
					6			-40	FITTING							6					

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					6			-42								6					
					34			-43								6					
					2			-44								6					
					2			-45	FITTING							6					
				—	162			-46	X BRACE ASSY												
				2				-47	ROD							7					
				2				-48	ROD							7					
				6				-49	CLEVIS							6					
				2				-50	TURNBUCKLE							6					
				2				-51	STUD FITTING							6					
				2				-52	CLEVIS FITTING							6					
				1				-53	X FITTING							6					
				8				-54	BOLT							6,10					
				12				-55	NUT							6,10					
				8				-56	WASHER							6					
				1100				-57	BOLT							6,9					
				1100				-58	NUT							6,9					
				1100				-59	WASHER							6					
					1			-60	TUNNEL ASSY												

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				2				-67	CABLE FITTING												
				2				-68	TUBE ASSY												
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		1			2			-70	OPP -69	SH5											
		1	1					-71	RAIL	SH5											
		1						-72	CARRIAGE ASSY	SH8											
		2	2					-73	TUBE ASSY	SH5											
		2	2					-74													
		2	2					-75													
		1	1					-76													
		1	1					-77													
		1	1					-78													
		1	1					-79													
		1	1					-80	TUBE ASSY	SH5											

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			1	1				-82													
			1	1				-83													
			1	1				-84													
			1	1				-85													
			1	1				-86													
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			1	1				-93													
			1	1				-94													
			1	1				-95													
			1	1				-96													
			1	1				-97													
			1	1				-98													
			1	1				-99		SH5											
			1	1				-100	TUBE ASSY	SH6											

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CONTRACT NUMBER

FSCM NUMBER 81205 PL KH361420 SHEET 9 REV LTR

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			1	1				-102													
			1	1				-103													
			1	1				-104													
			1	1				-105	TUBE ASSY	SH6											
				1				-106	FITTING	SH5											
				1				-107		SH6											
				1				-108		SH6											
				1				-109		SH5											
				1				-110													
				1				-111													
				1				-112													
				1				-113		SH5											
				1				-114		SH6											
				1				-115													
				1				-116													
				1				-117													
				1				-118													
				1				-119													
				1				-120	FITTING	SH6											

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				1				-121	FITTING												
				1				-122													
				1				-123													
				1				-124	FITTING												

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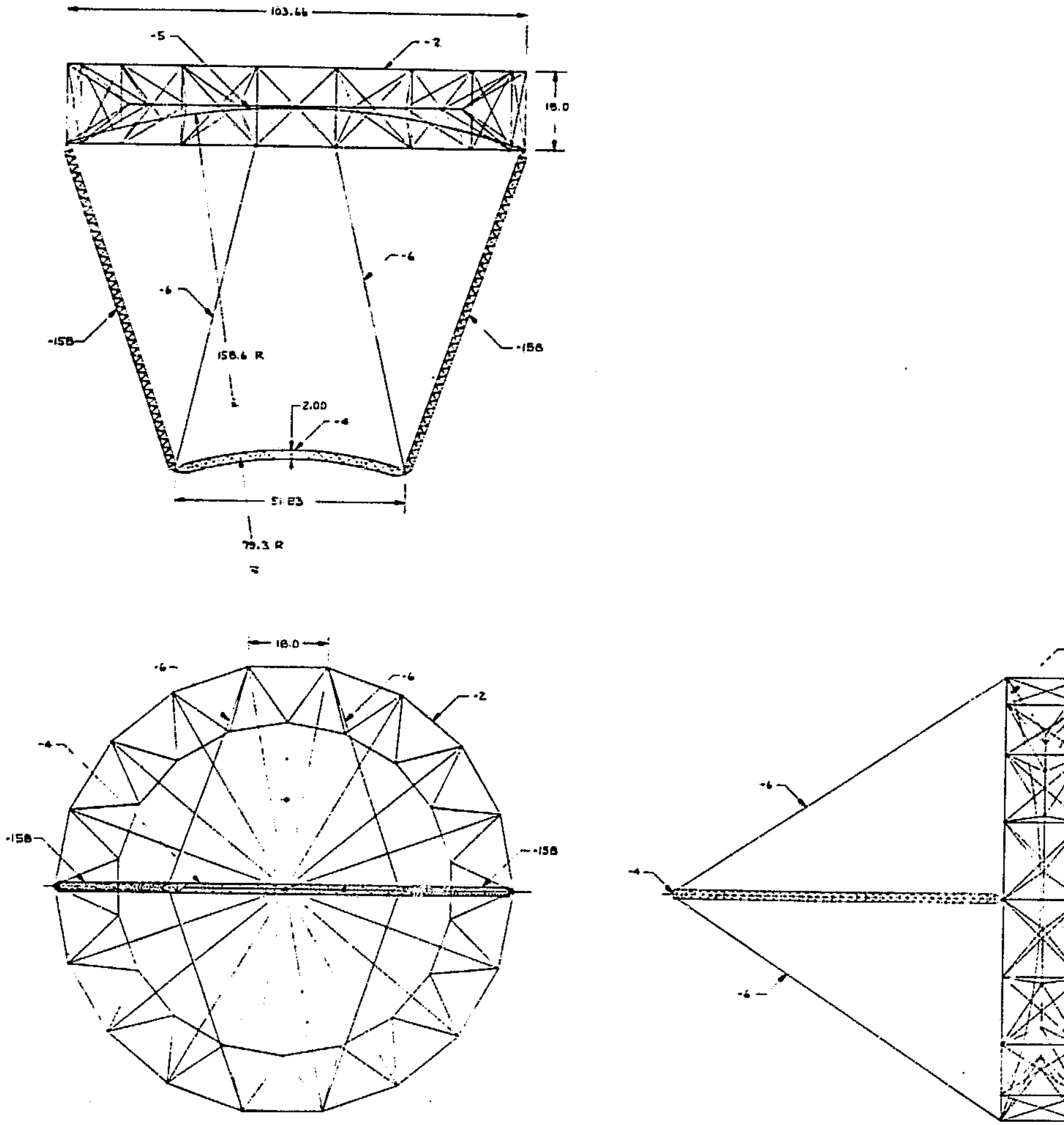

-1 ANTENNA ASSY
1 INCH = 10 METERS
DIMENSIONS IN METERS

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UPDATED 8-2-84

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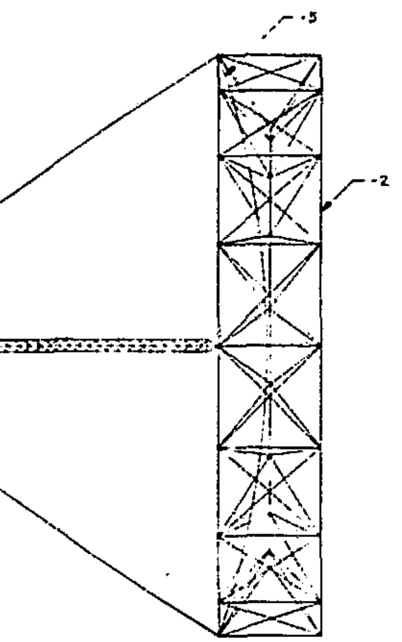

DRAWING SHEET INDEX

SHEET	DESCRIPTION
1	-1 ANTENNA ASSY - 3 VIEW & DWG
2	-2 RING ASSY & DWG & STRUTS
3	-2 RING ASSY CABLES & JOINTS
4	-3 MAST ASSY & TUBES (REPLACED BY -15B)
5	-3 MAST ASSY DETAILS & SPREADERS (REPLACED BY -15B)
6	-3 MAST ASSY TUBES & FITTINGS (REPLACED BY -15B)
7	-4 ARRAY ASSY
8	-4 ARRAY ASSY PANEL VIEWS
9	-4 ARRAY ASSY CORNER PLATES
10	-4 ARRAY ASSY LATCH & TUBE FITTINGS
11	-4 ARRAY ASSY TUBE ASSYS & FITTINGS
12	-4 ARRAY ASSY TUBES & FITTINGS
13	-5 MEMBRANE ASSY RADIAL CABLES
14	-5 MEMBRANE ASSY TRANSVERSE CABLES
15	-5 MEMBRANE ASSY CABLE FITTINGS
16	-5 MEMBRANE ASSY CABLE FITTINGS
17	-15B MAST ASSY & PANEL DETAILS
18	-15B MAST ASSY PANEL DETAILS & FITTINGS
19	-15B MAST ASSY FITTINGS
20	-15B MAST ASSY TUBE ASSYS & TUBES
21	-15B MAST ASSY JOINT DETAILS
22	-15B MAST ASSY END PANELS

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SEE PL KH361418 FOR PARTS LISTS, APPLICATION DATA AND NOTES

BOEING

SEATTLE, WASHINGTON

DWN K. HERNLEY 10-2-83

ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3

SIZE E

KH361418

KH361418

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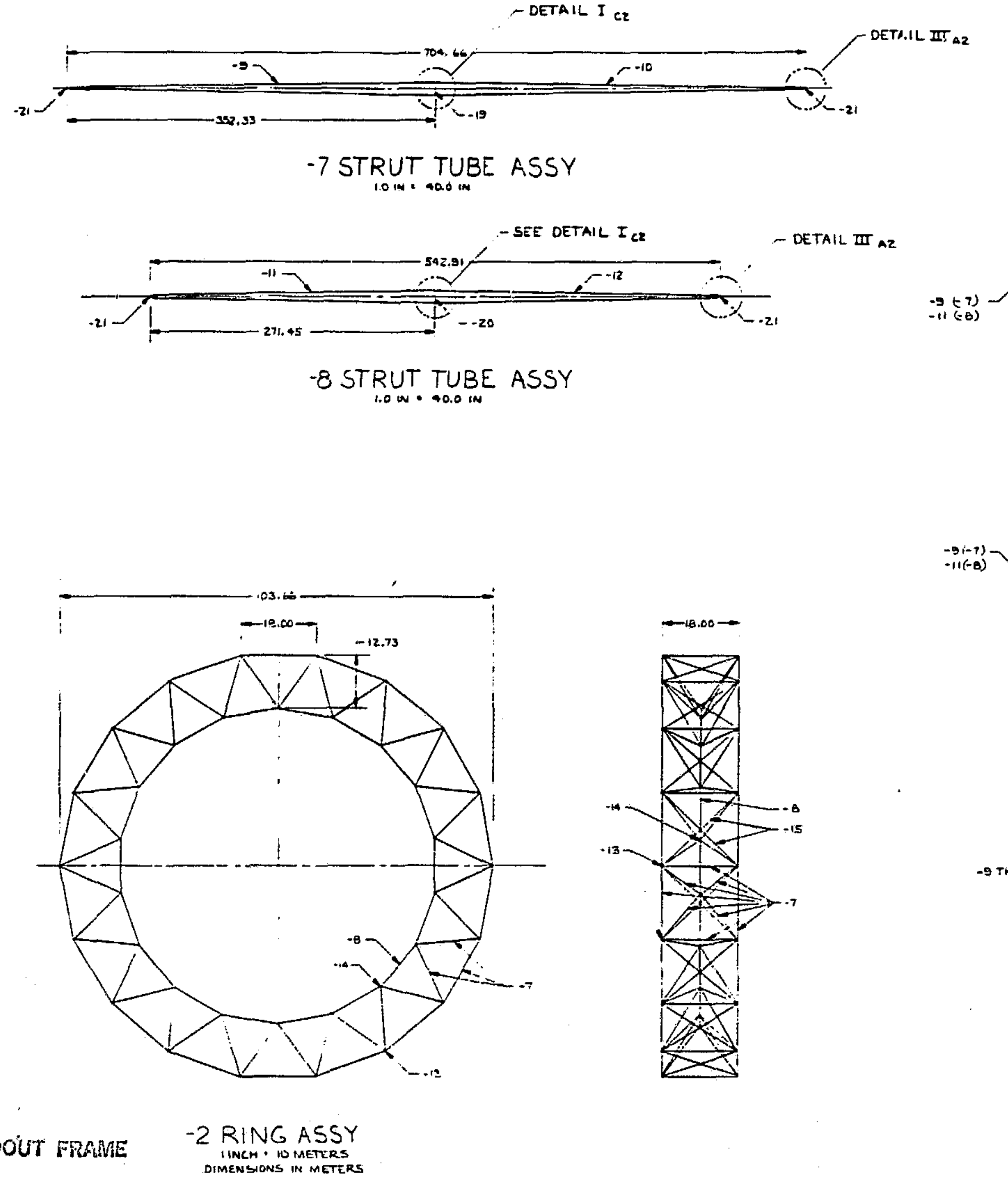
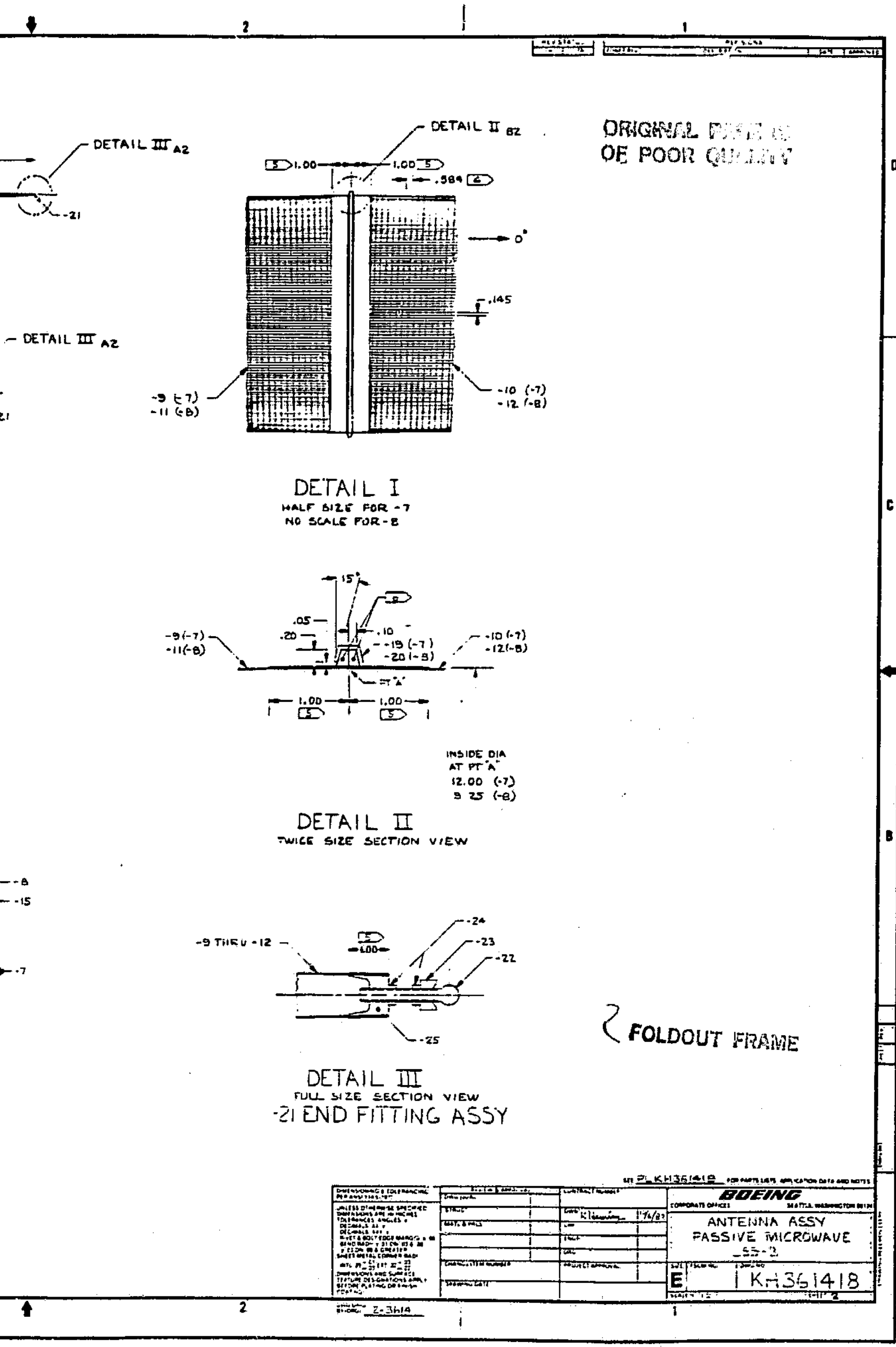
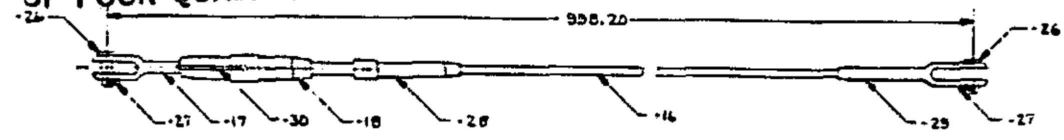


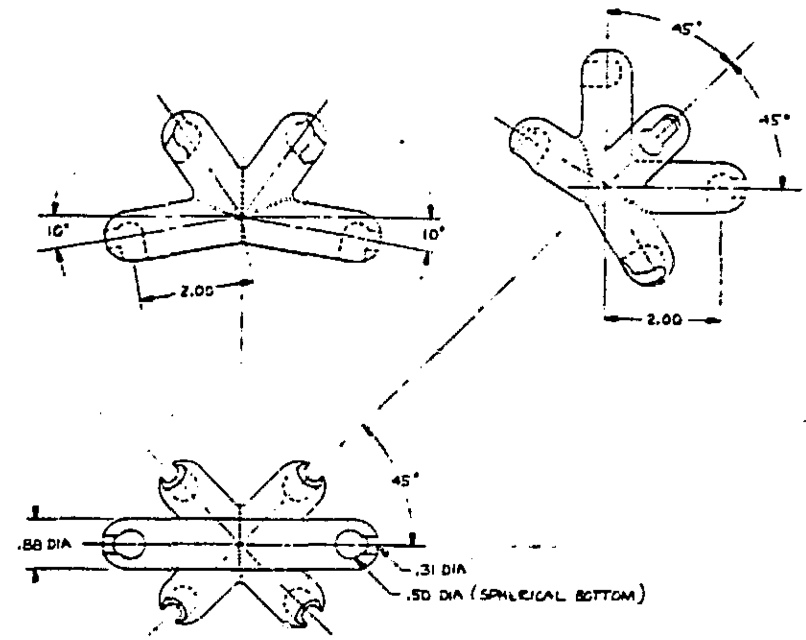
FOLDOUT FRAME


DETAIL III A2
DETAIL II B2
DETAIL III A2
-21
1.00
1.00
.589
0°
.145
-9 (-7)
-11 (-8)
-10 (-7)
-12 (-8)
DETAIL I
HALF SIZE FOR -7
NO SCALE FOR -8
15°
.05
.20
.10
-9(-7)
-11(-8)
-19 (-7)
-20 (-8)
-10 (-7)
-12(-8)
PT "A"
1.00
1.00
INSIDE DIA
AT PT "A"
12.00 (-7)
9.25 (-8)
DETAIL II
TWICE SIZE SECTION VIEW
-8
-15
-7
-9 THRU -12
1.00
-24
-23
-22
-25
DETAIL III
FULL SIZE SECTION VIEW
-21 END FITTING ASSY
FOLDOUT FRAME
PL KH361418
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
E
KH361418
Z-3614

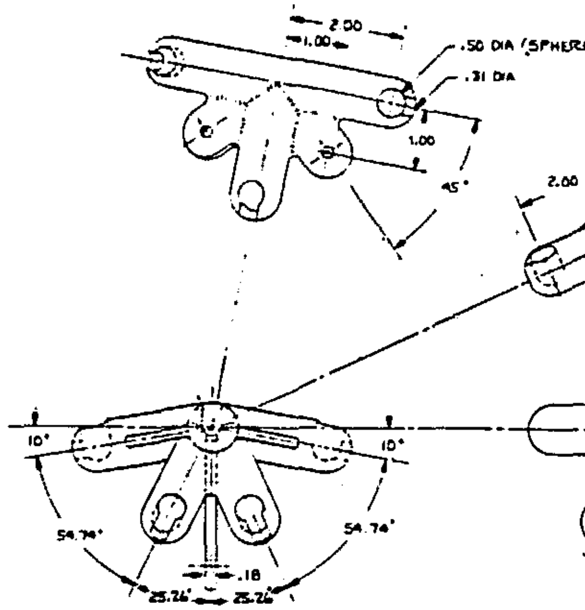
KH 361418 S



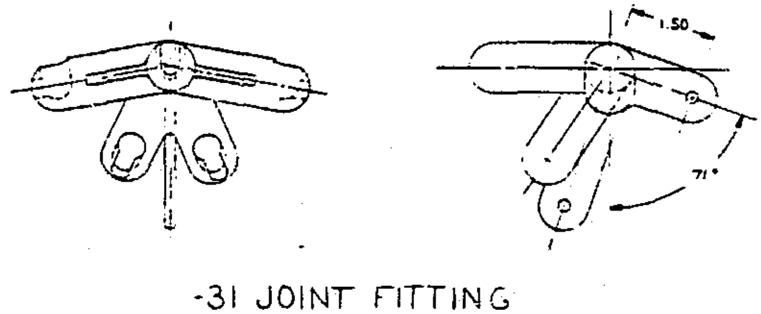
-15 CABLE ASSY
FULL SIZE



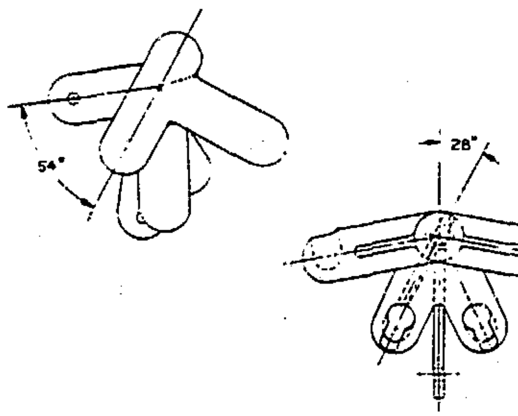
-14 JOINT FITTING
FULL SIZE



-13 JOINT FITTING
FULL SIZE

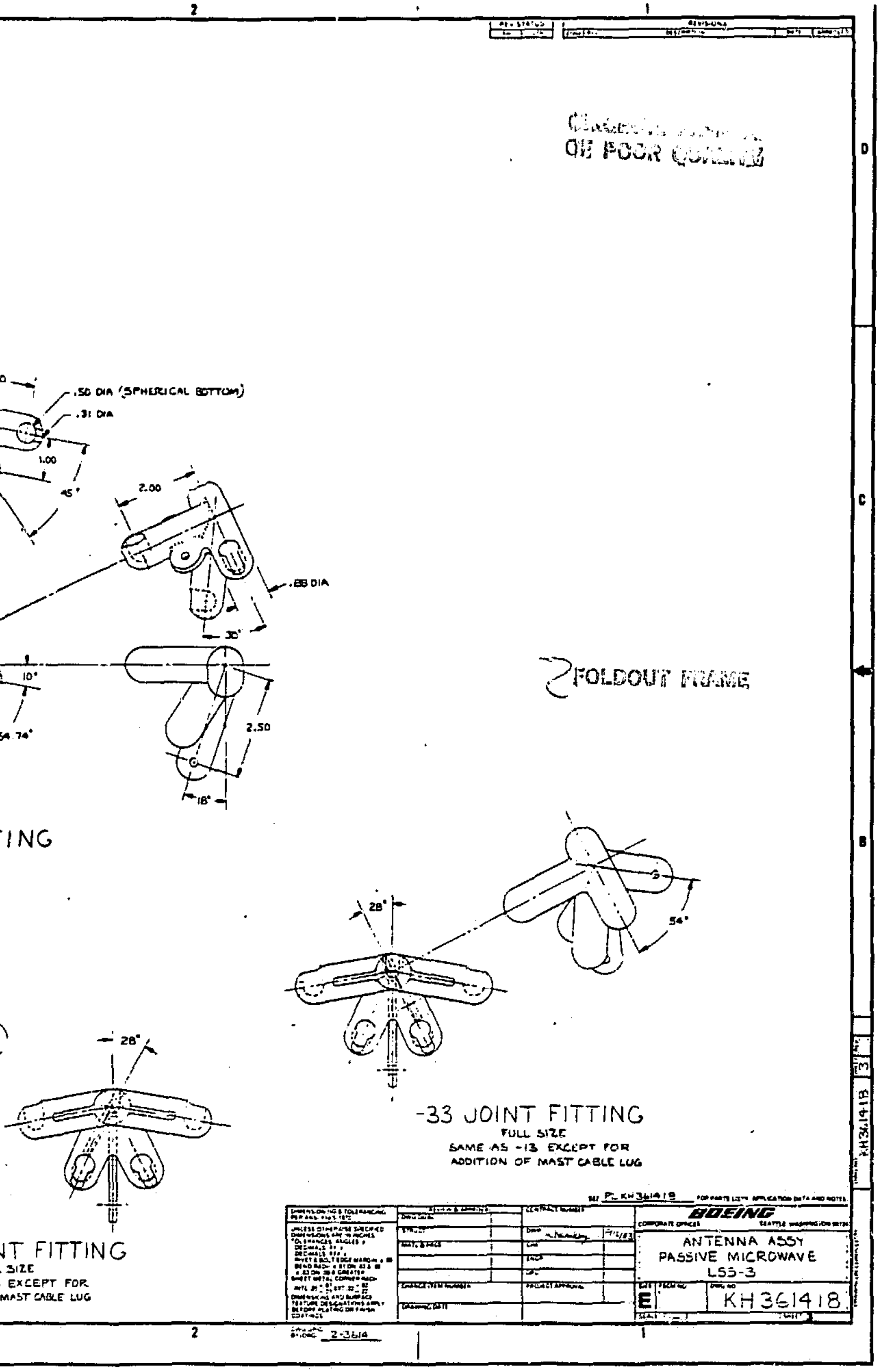


-31 JOINT FITTING
FULL SIZE
SAME AS -13 EXCEPT FOR
ADDITION OF MAST LUG



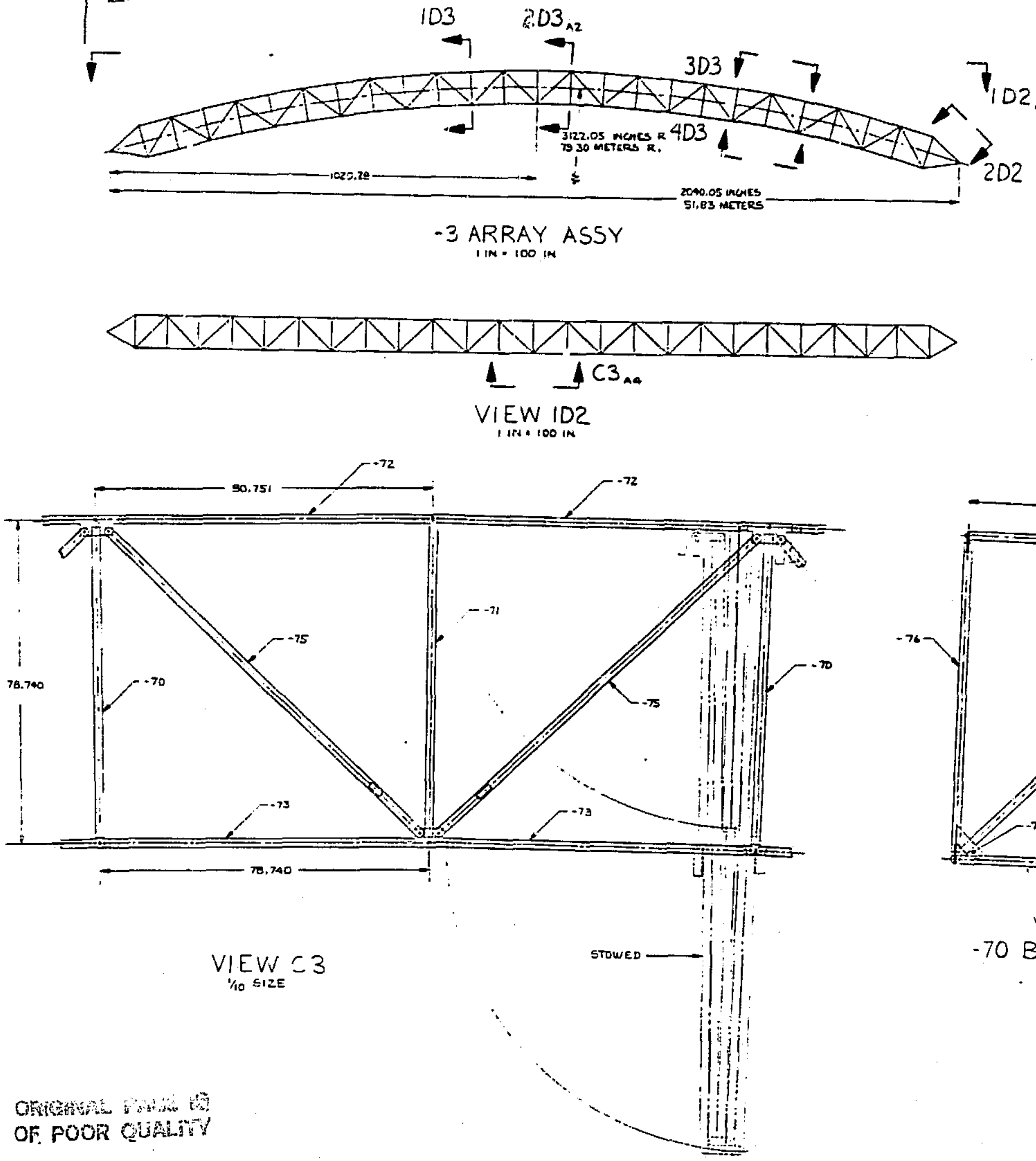
-32 JOINT FITTING
FULL SIZE
SAME AS -13 EXCEPT FOR
ADDITION OF MAST CABLE LUG

FOLDOUT FRAME

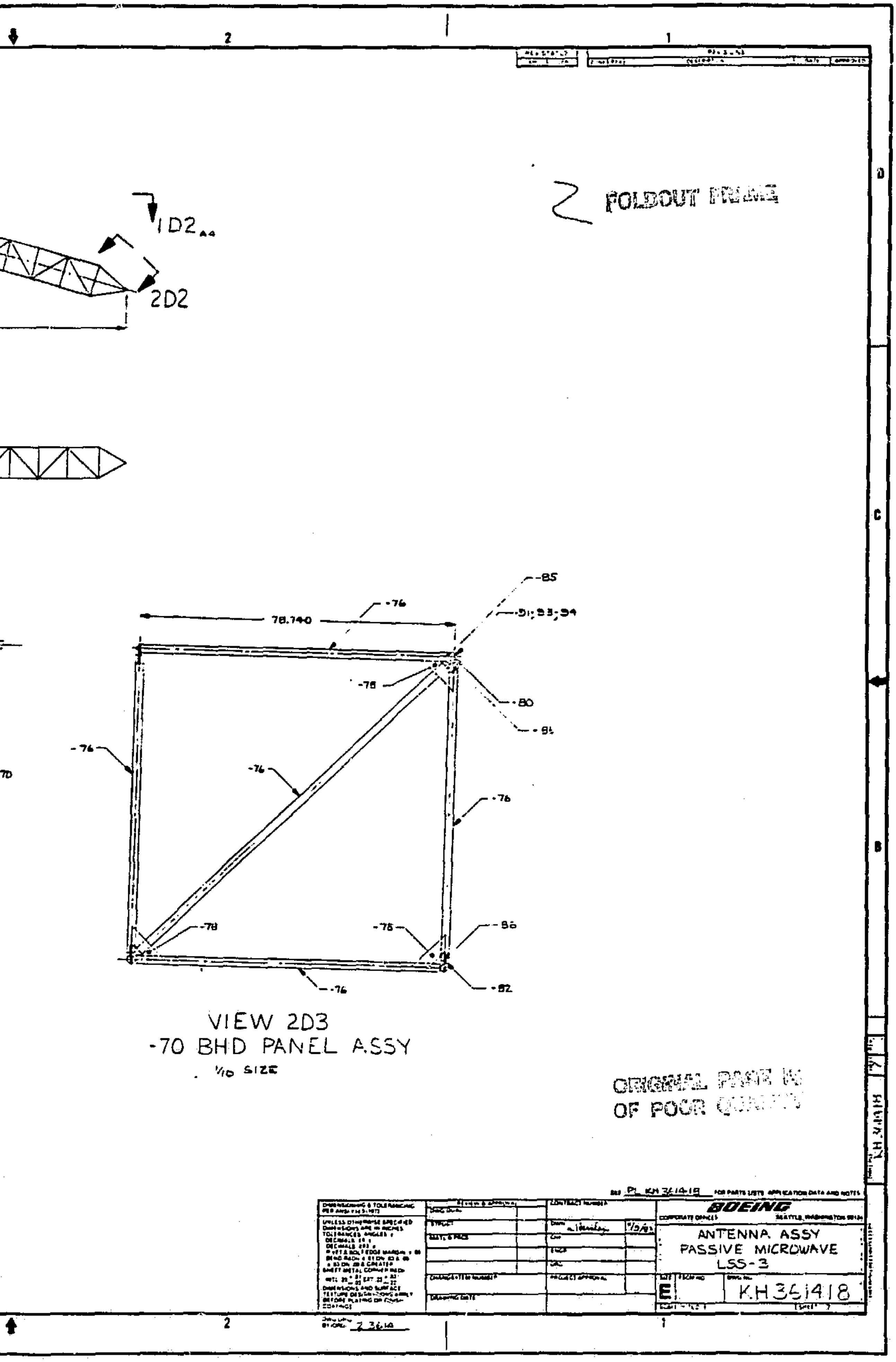

OF POOR QUALITY
FOLDOUT FRAME
.50 DIA (SPHERICAL BOTTOM)
.31 DIA
1.00
45°
2.00
.88 DIA
30°
10°
54.74°
2.50
18°
TING
28°
54°
28°
-33 JOINT FITTING
FULL SIZE
SAME AS -13 EXCEPT FOR
ADDITION OF MAST CABLE LUG
NT FITTING
SIZE
EXCEPT FOR
MAST CABLE LUG
PL KH361418
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH361418
KH361418
3
2-3614

KH 361418 3

FOLDOUT FRAME

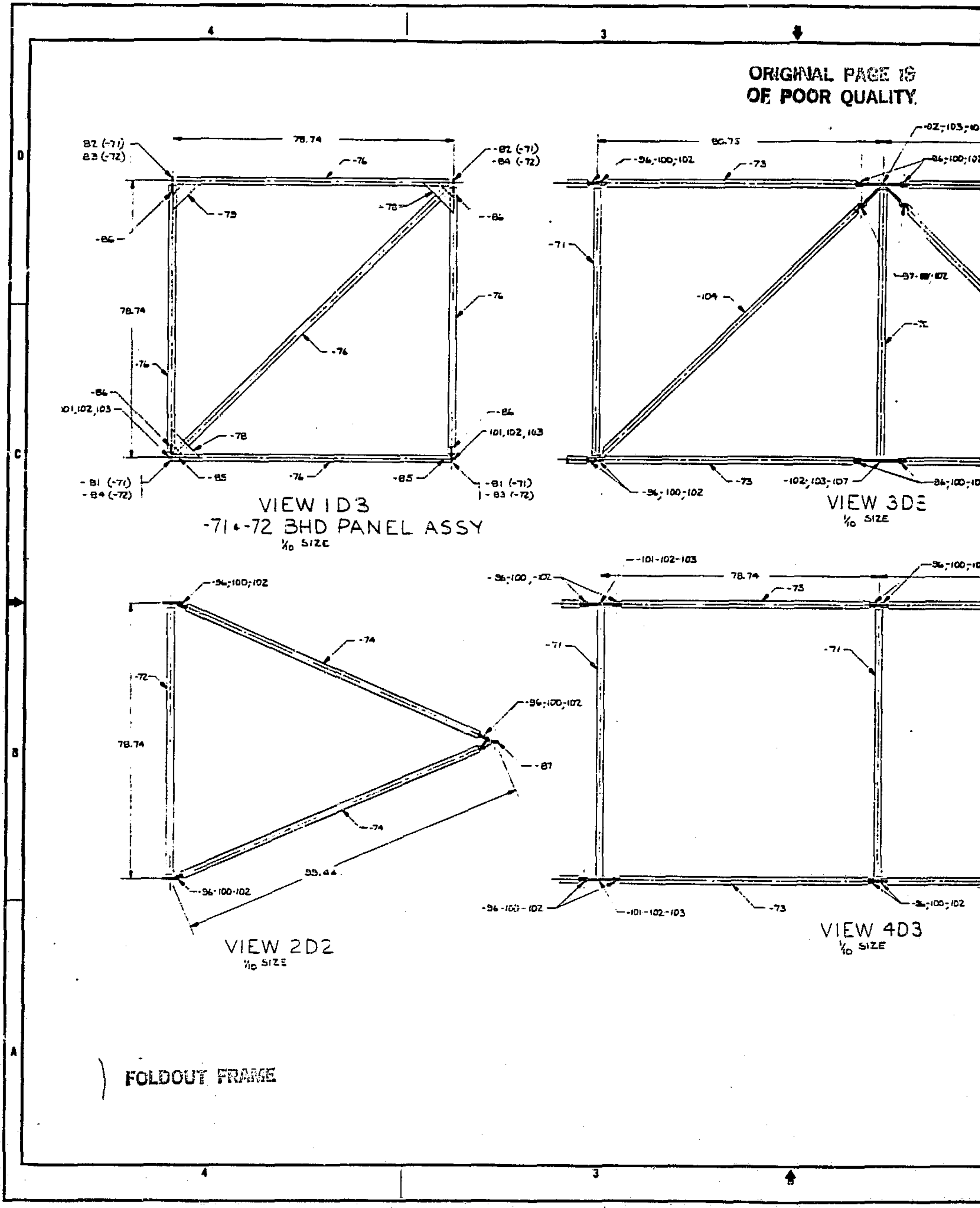


FOLDOUT FRAME 2



ORIGINAL PAGE IS
OF POOR QUALITY

KH 361418



VIEW 1D3
-71 + -72 BHD PANEL ASSY
1/10 SIZE

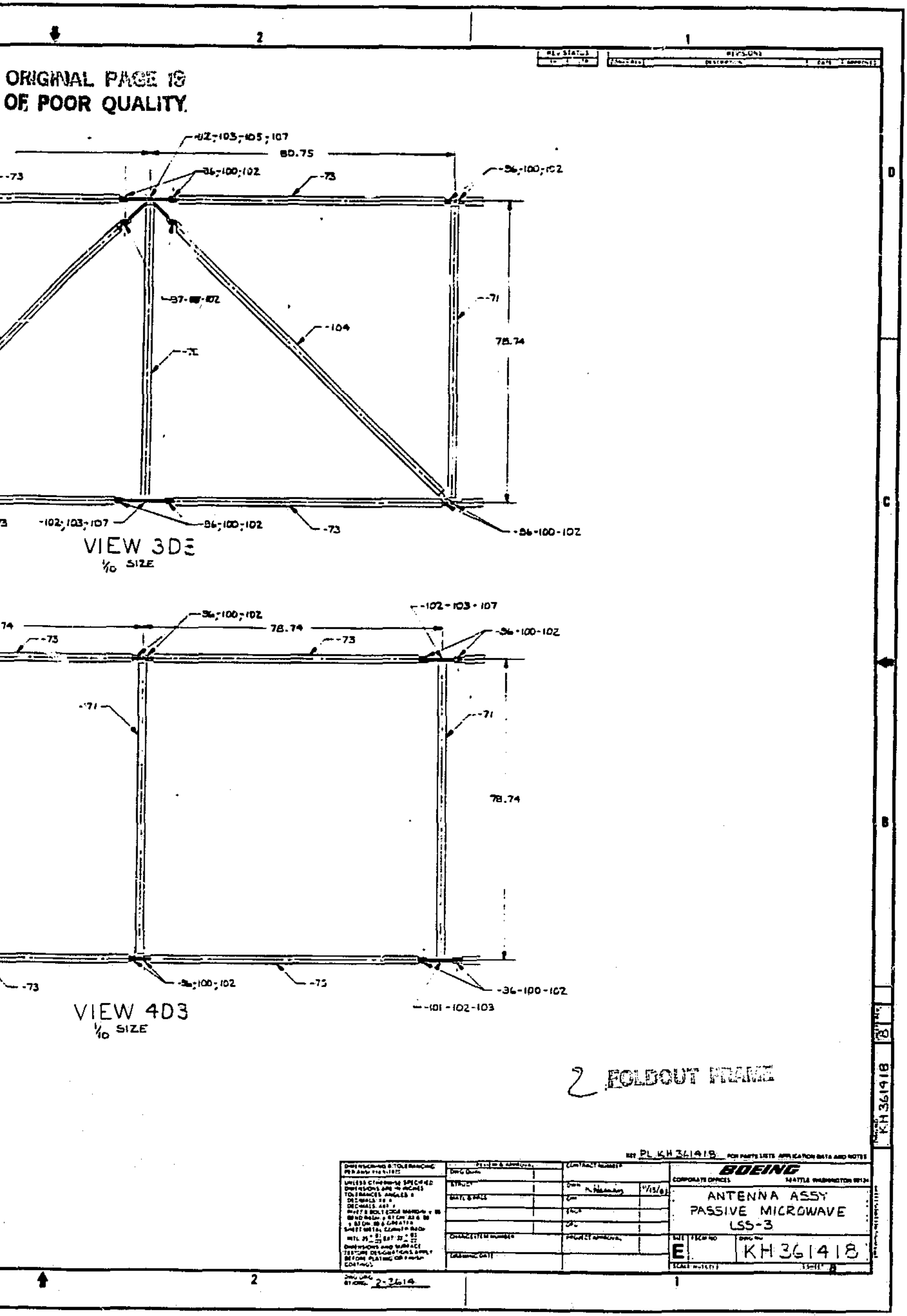
VIEW 3D3
1/10 SIZE

VIEW 2D2
1/10 SIZE

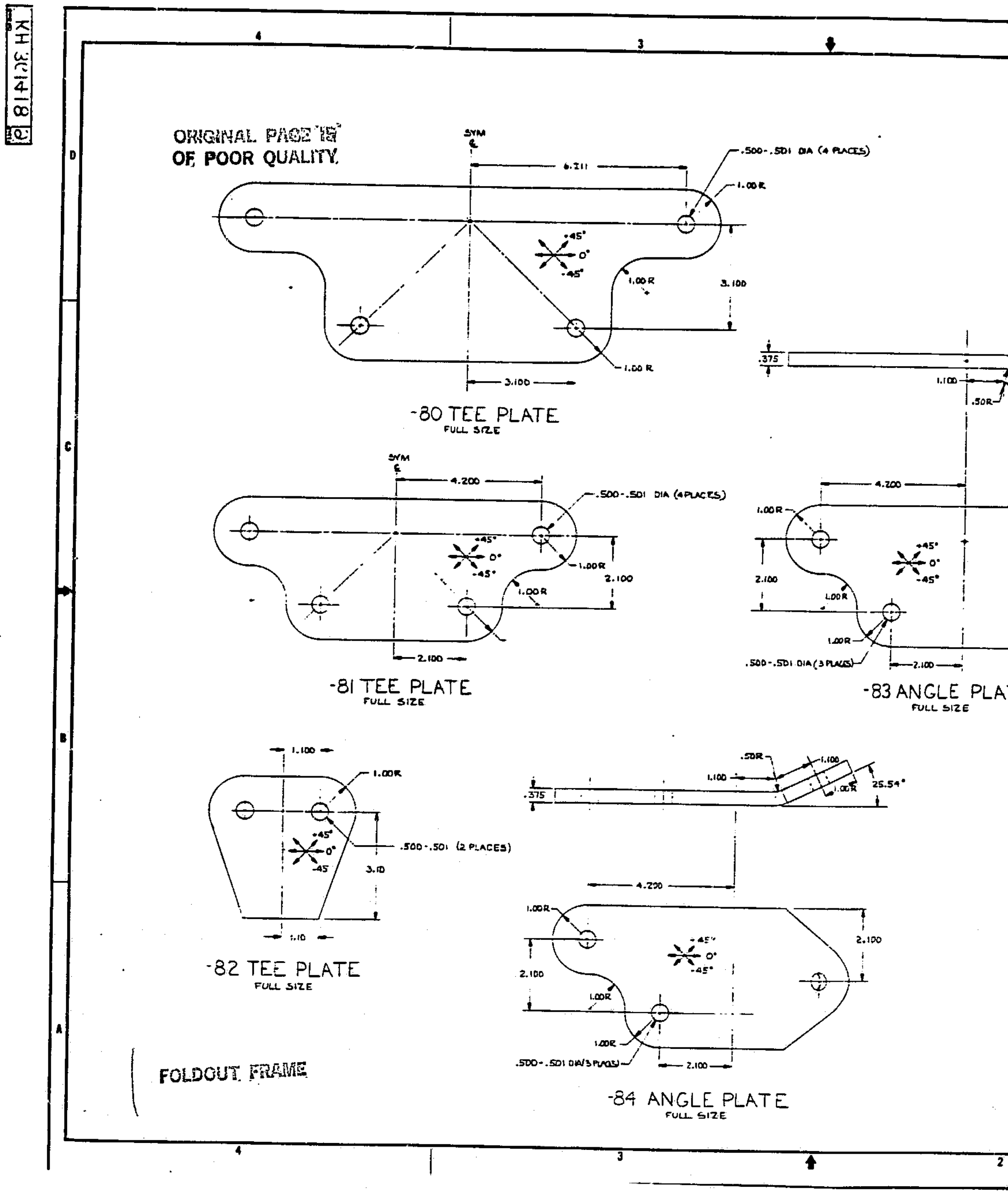
VIEW 4D3
1/10 SIZE

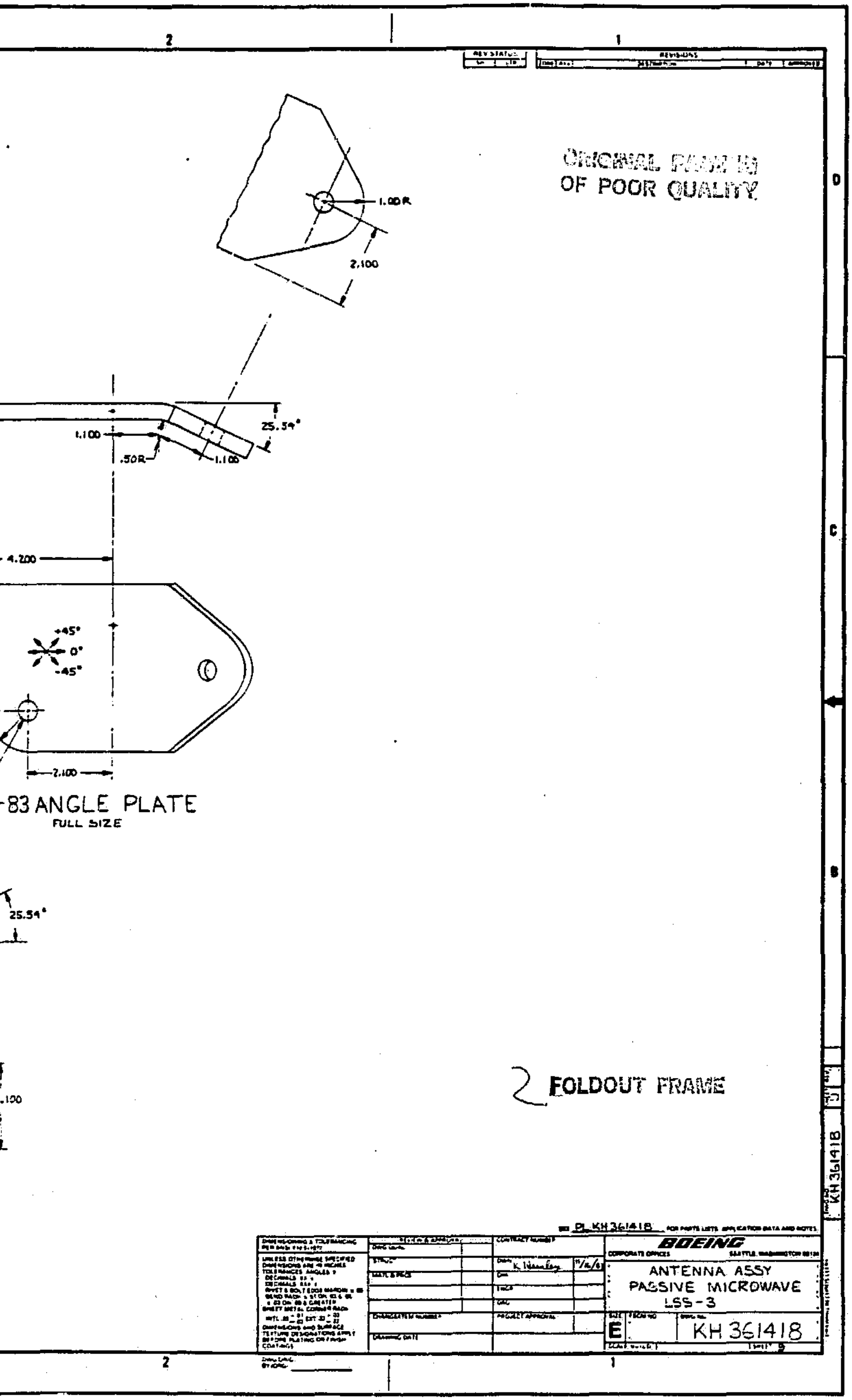
FOLDOUT FRAME

ORIGINAL PAGE IS
OF POOR QUALITY



KH 361418


KH 3C1418
ORIGINAL PAGE IS OF POOR QUALITY
SYM ℄
6.211
.500-.501 DIA (4 PLACES)
1.00 R
+45°
0°
-45°
3.100
3.100
-80 TEE PLATE
FULL SIZE
4.200
.500-.501 DIA (4 PLACES)
1.00 R
2.100
2.100
-81 TEE PLATE
FULL SIZE
.375
1.100
.50R
-83 ANGLE PLA
FULL SIZE
1.100
1.00R
.500-.501 (2 PLACES)
3.10
1.10
-82 TEE PLATE
FULL SIZE
.50R
1.100
25.54°
.500-.501 DIA (3 PLACES)
-84 ANGLE PLATE
FULL SIZE
FOLDOUT FRAME



ORIGINAL PAGE IS OF POOR QUALITY
1.00 R
2.100
25.54°
1.100
.50R
1.100
4.200
+45°
0°
-45°
2.100
-83 ANGLE PLATE
FULL SIZE
25.54°
.100
2 FOLDOUT FRAME
PL KH361418
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH 361418

KH 361418

KH 3C1418 10

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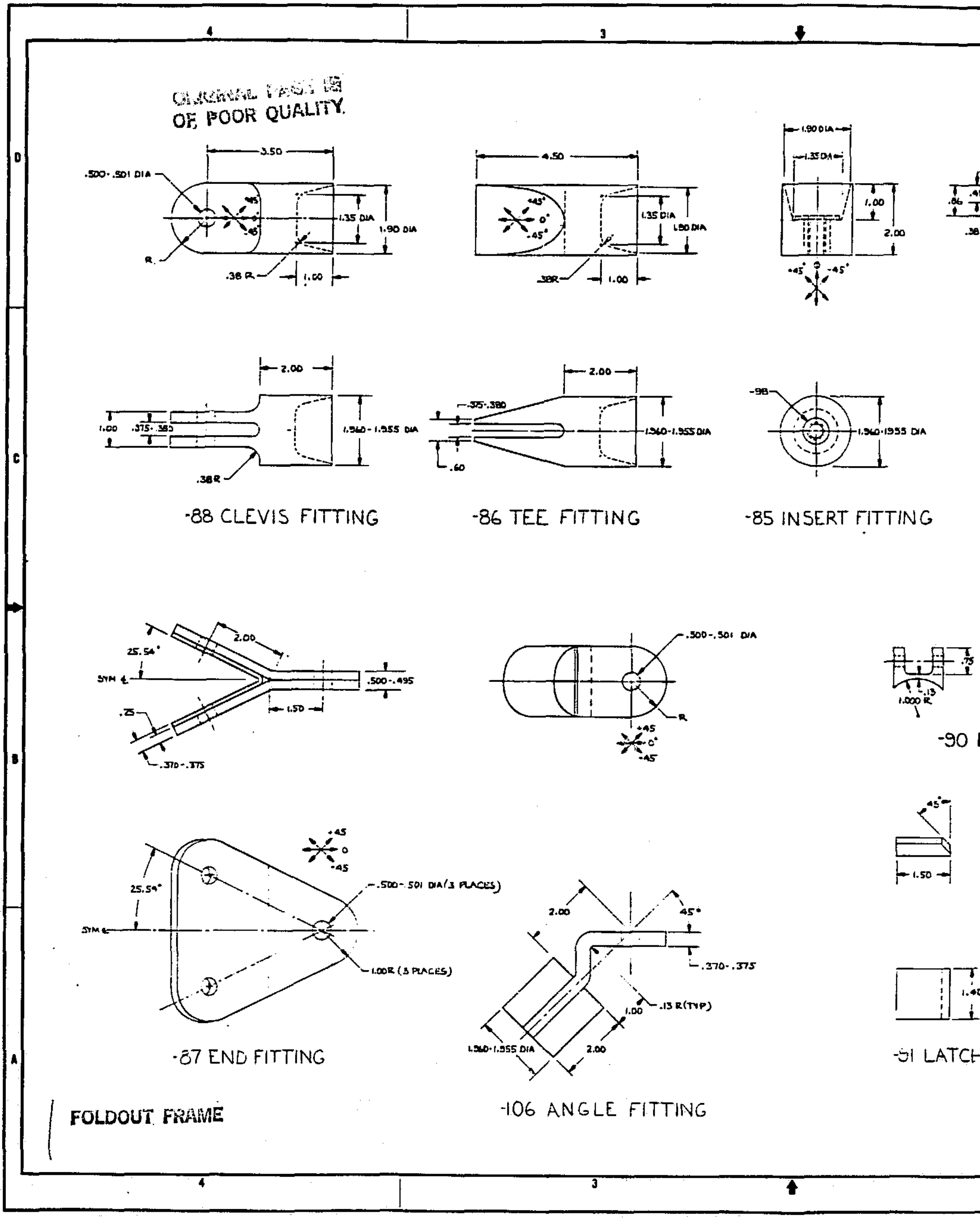
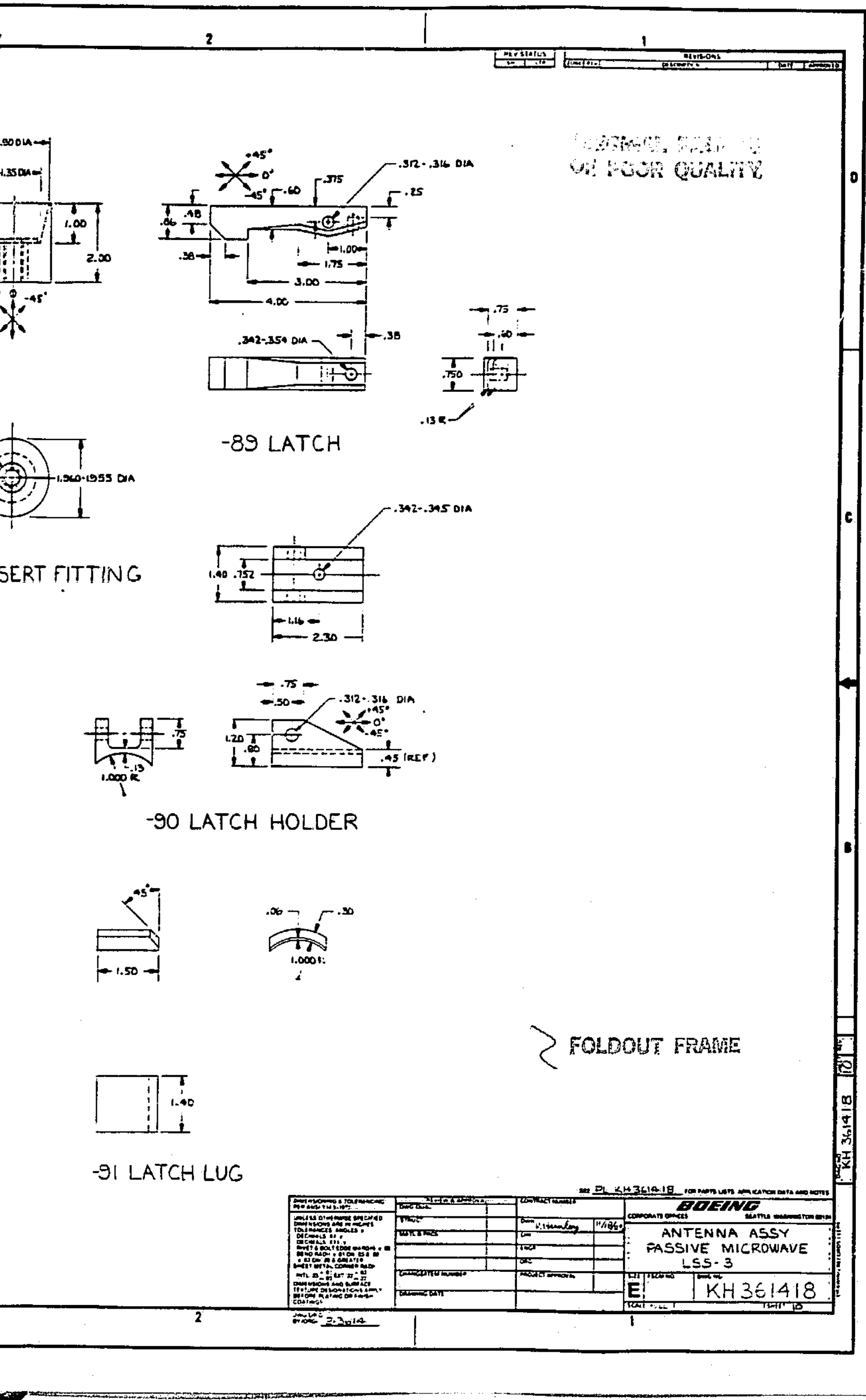
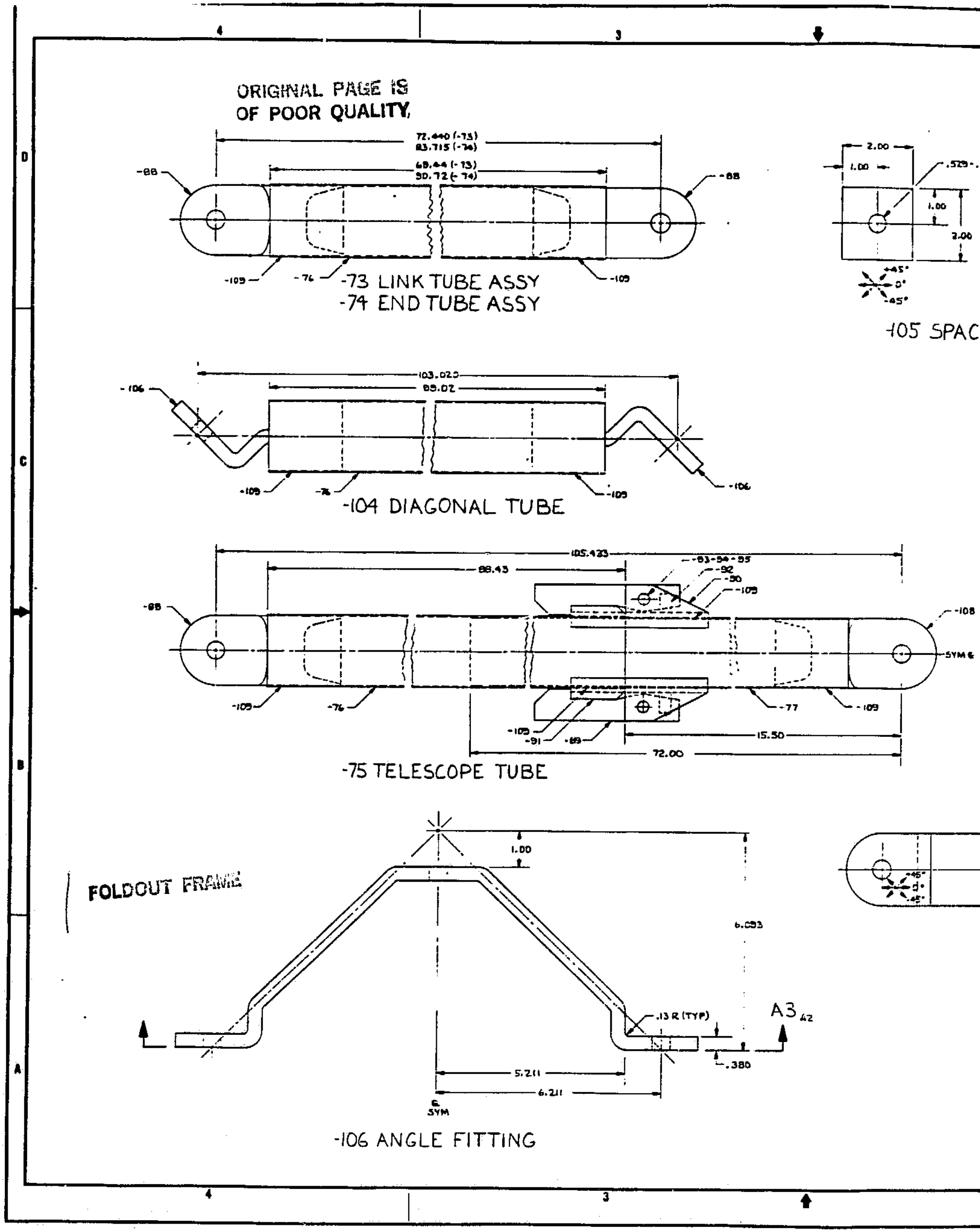


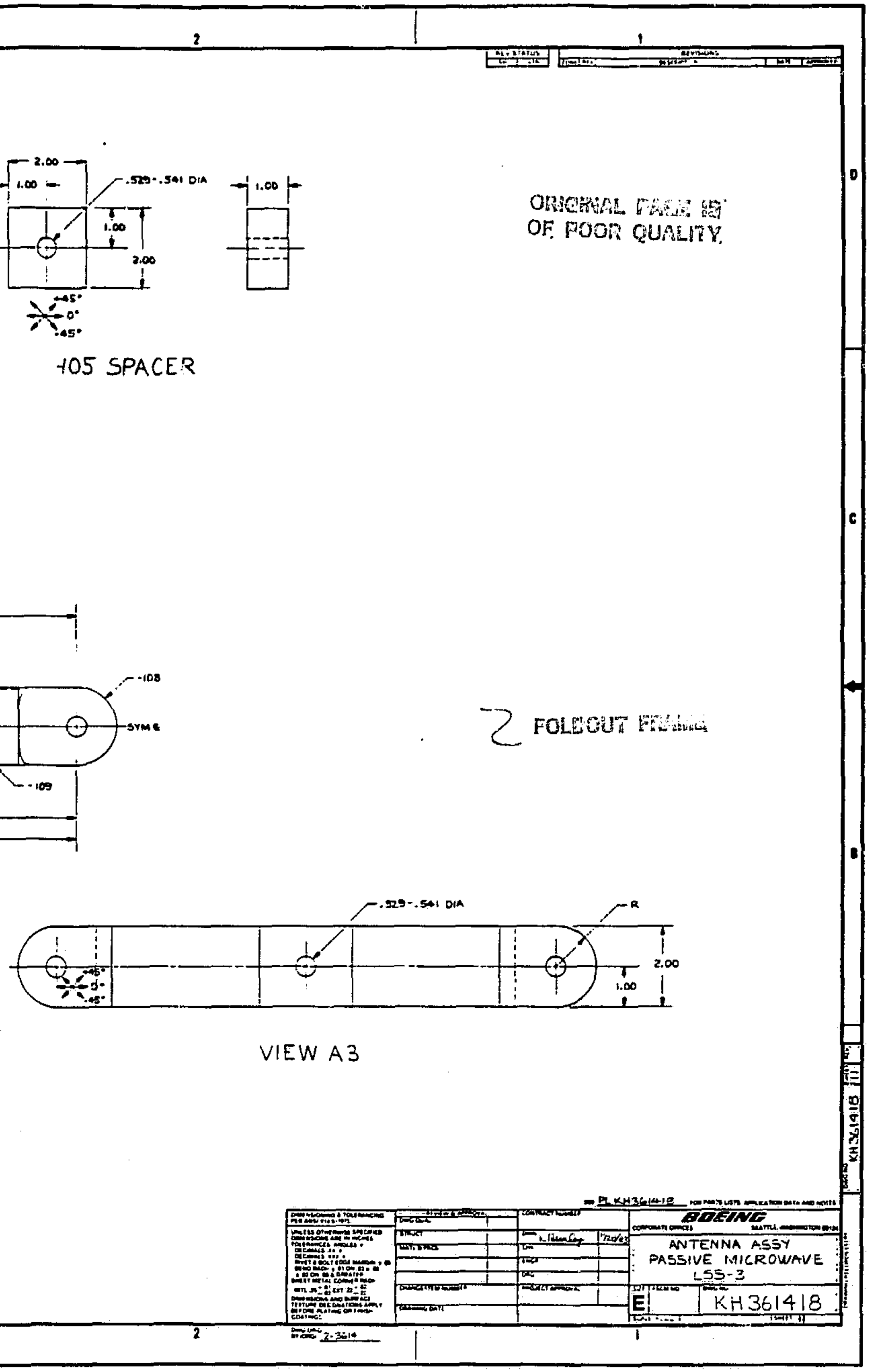
FOLDOUT FRAME



ORIGINAL PAGE IS OF POOR QUALITY
-89 LATCH
.312-.316 DIA
.342-.354 DIA
SERT FITTING
1.560-1.955 DIA
.342-.345 DIA
-90 LATCH HOLDER
.312-.316 DIA
.45 (REF)
1.000 R
-91 LATCH LUG
FOLDOUT FRAME
SEE PL KH361418 FOR PARTS LISTS APPLICATION DATA AND NOTES
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH 361418
SHEET 10

KH 361418 10

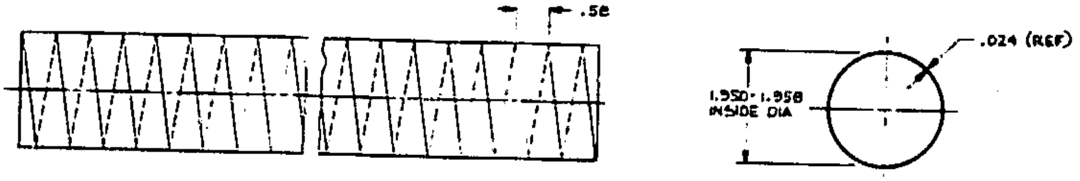

ORIGINAL PAGE IS
OF POOR QUALITY
72.440 (-73)
83.715 (-74)
69.44 (-73)
80.72 (-74)
-88
-109
-76
-73 LINK TUBE ASSY
-74 END TUBE ASSY
2.00
1.00
2.00
+45°
0°
-45°
-105 SPAC
103.020
85.02
-106
-109
-76
-104 DIAGONAL TUBE
105.433
88.43
-83-84-85
-92
-90
-109
-108
SYM ℄
-77
-91
-89
15.50
72.00
-75 TELESCOPE TUBE
1.00
6.093
.13 R (TYP)
.380
5.211
6.211
℄ SYM
A3
-106 ANGLE FITTING
FOLDOUT FRAME



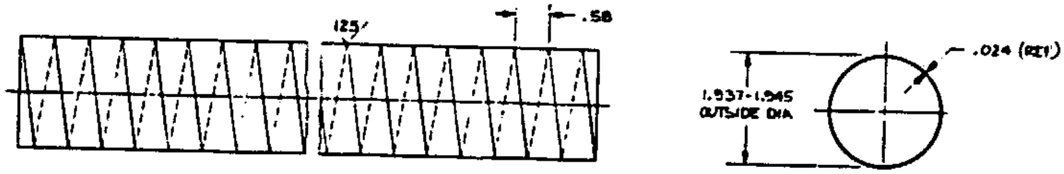
FOLDOUT FRAME

KH 361418

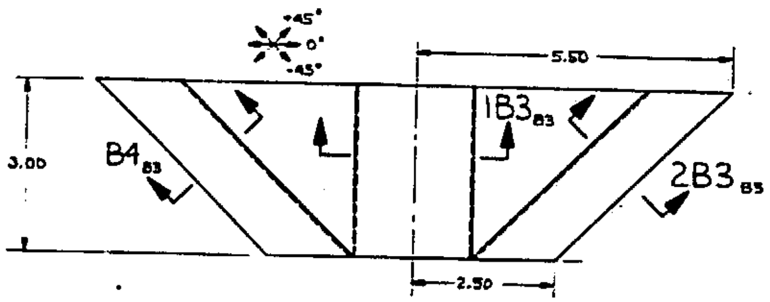
KH 301418



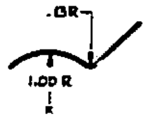
-76 TUBING



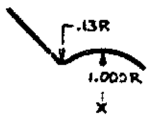
-77 TUBING



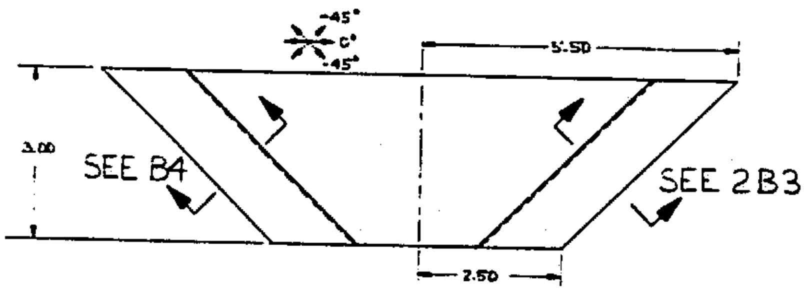
-78 CORNER TIE



SECTION B4



SECTION 2B3



-79 CORNER TIE

SECTION 1B3

FOLDOUT FRAME

REF)

ET)

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FOLDOUT FRAME

.13R

PL KH361418

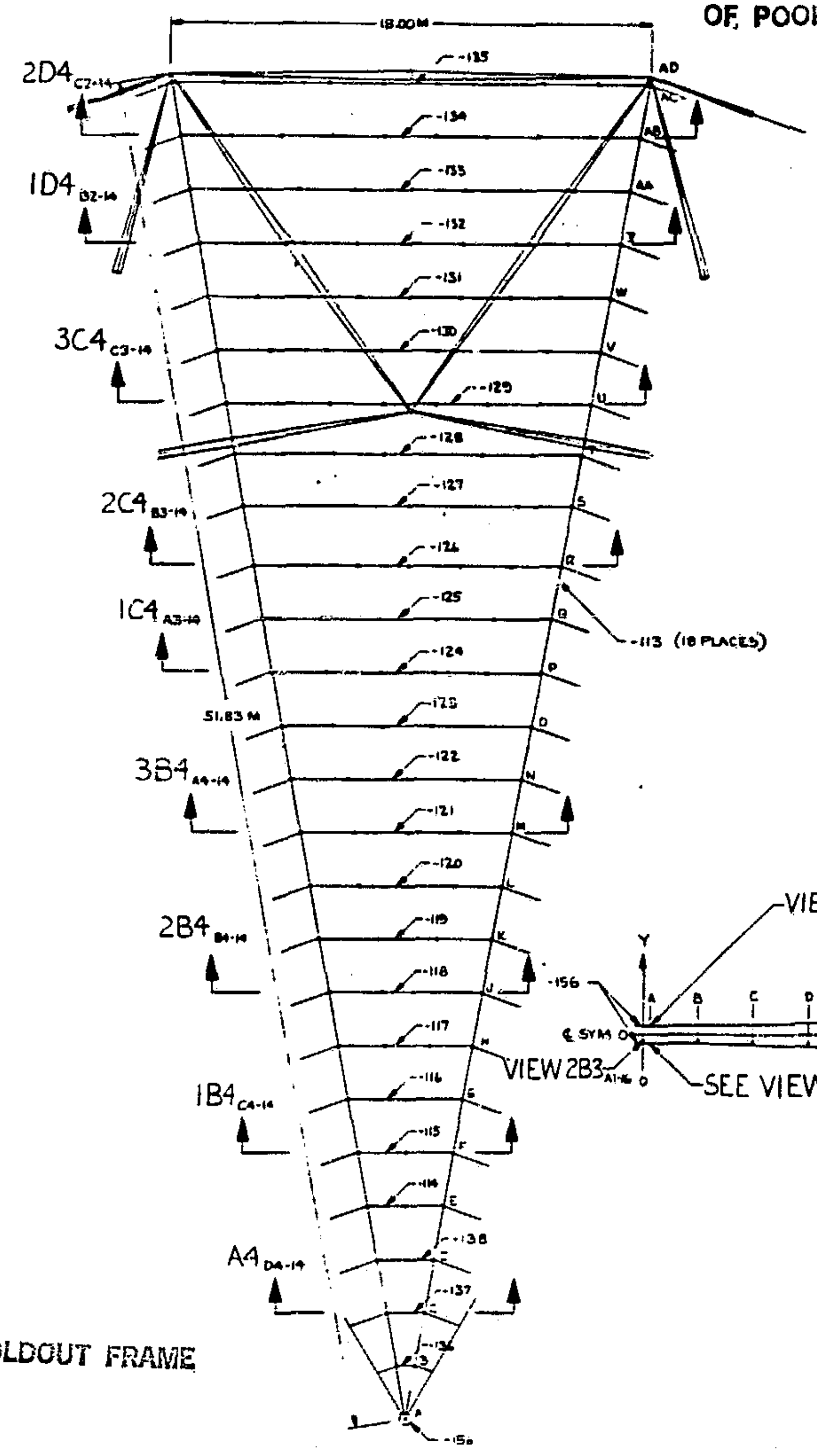
BOEING

ANTENNA ASSY
PASSIVE MICROWAVE
LSS-S

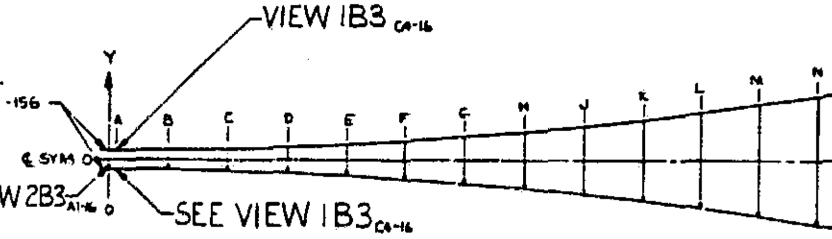
E

KH361418

KH 361418 15



-112 SUPPORT CABLE ASSY
1 INCH = 2 METERS
1 OF 18 SECTORS SHOWN



-113 RADIAL CABLE
SEE TABLE I ZONE C2 FOR DIMEN
1 INCH = 2 METERS

TAB

POINT
A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
Z
AA
AB
AC
AD

FOLDOUT FRAME

2 | 1

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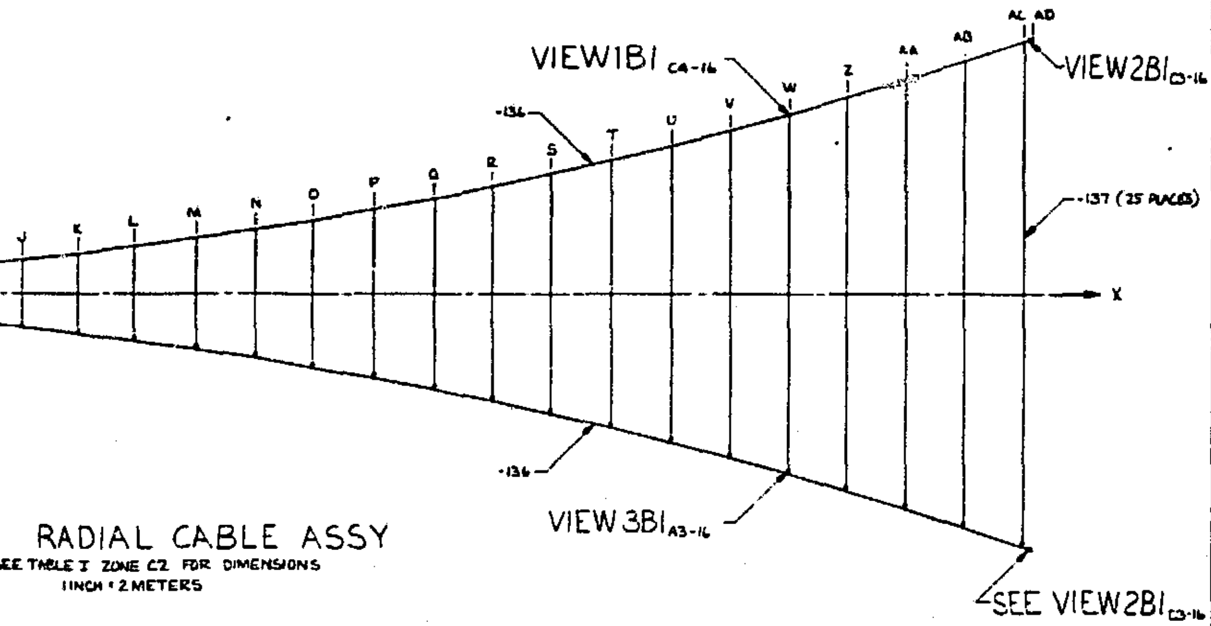
TABLE I
IN METERS

POINT	X	Y
A	.054	.252
B	2.661	.305
C	4.122	.346
D	6.184	.415
E	8.245	.506
F	10.306	.627
G	12.367	.775
H	14.428	.950
J	16.490	1.152
K	18.551	1.381
L	20.612	1.637
M	22.673	1.921
N	24.734	2.233
O	26.796	2.572
P	28.857	2.940
Q	30.918	3.335
R	32.980	3.755
S	35.040	4.211
T	37.102	4.675
U	39.163	5.203
V	41.224	5.743
W	43.285	6.313
Z	45.346	6.915
AA	47.408	7.543
AB	49.469	8.204
AC	51.530	8.936
AD	51.770	8.975

FOLDOUT FRAME



RADIAL CABLE ASSY
SEE TABLE I ZONE C2 FOR DIMENSIONS
1 INCH = 2 METERS

SEE PL KH361418 FOR PARTS LISTS, APPLICATION DATA AND NOTES

BOEING
CORPORATE OFFICES SEATTLE, WASHINGTON

ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3

E KH361418
SHEET 13

2-3614

2 | 1

1-23-84

KH 361418 13

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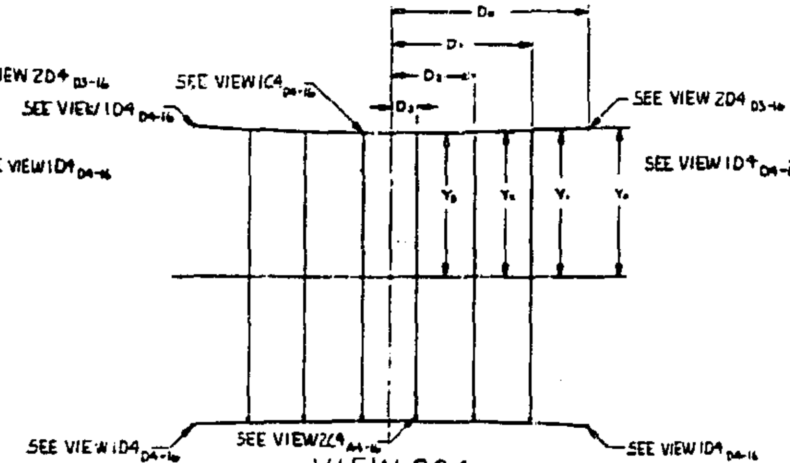
OF POOR QUALITY

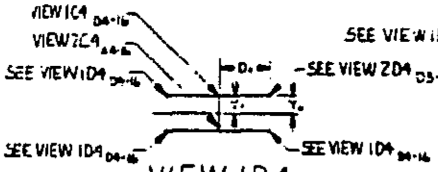
VIEW A4

ASSY	D_0	Y_0
-136	.462	.305
-137	.716	.346
-138	1.074	.412



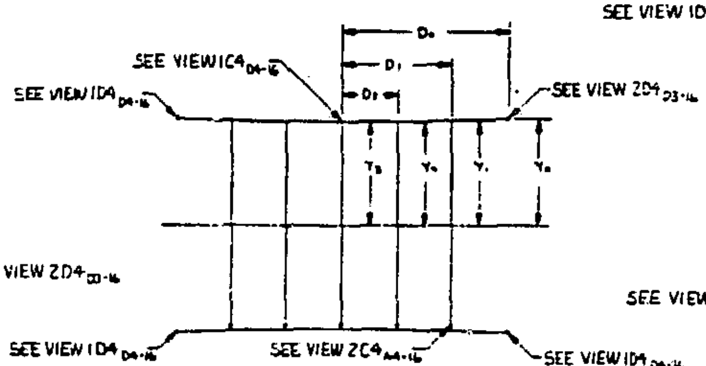
VIEW 3C4

ASSY	D_0	Y_0	D_1	Y_1	D_2	Y_2	D_3	Y_3
-128	6.443	4.693	4.602	4.627	2.761	4.583	.920	4.561
-129	6.801	5.203	4.861	5.130	2.915	5.081	.971	5.056
-130	7.158	5.743	5.113	5.661	3.068	5.607	1.023	5.579



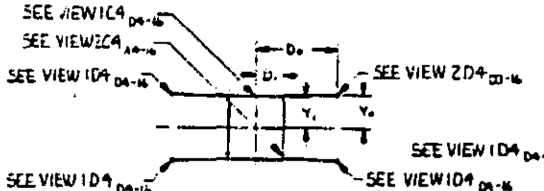
VIEW 1B4

ASSY	D_0	Y_0	Y_1
-114	1.432	.516	.499
-115	1.790	.627	.716
-116	2.148	.775	.760



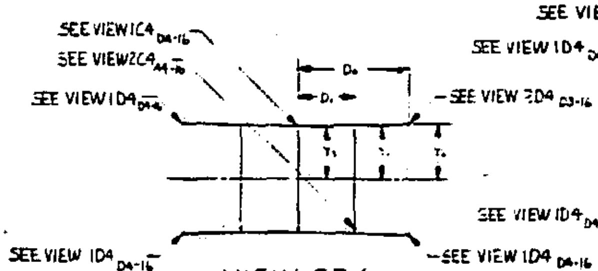
VIEW 2C4

ASSY	D_0	Y_0	D_1	Y_1	D_2	Y_2	Y_3
-126	5.727	3.759	3.819	3.700	1.909	3.665	3.655
-127	6.085	4.211	4.056	4.144	2.078	4.108	4.091



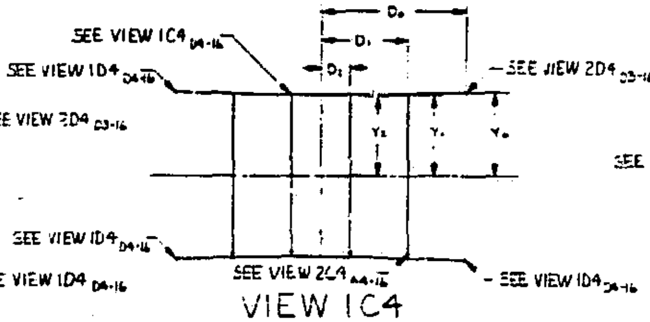
VIEW 2B4

ASSY	D_0	Y_0	D_1	Y_1
-117	2.506	.950	.835	.932
-118	2.864	1.152	.954	1.129
-119	3.222	1.381	1.074	1.352



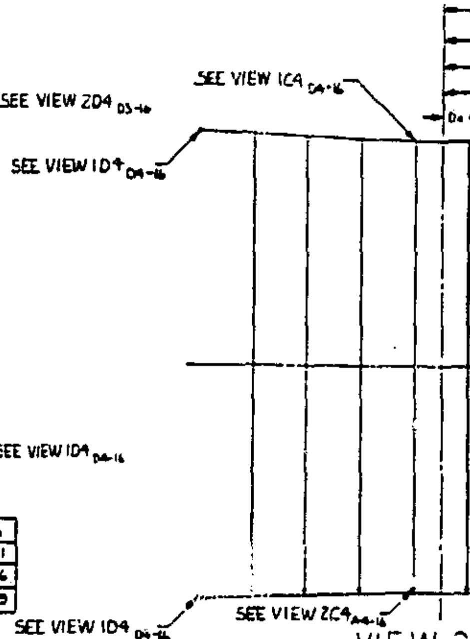
VIEW 3B4

ASSY	D_0	Y_0	D_1	Y_1	Y_2
-120	3.579	1.637	1.790	1.606	1.596
-121	3.937	1.921	1.969	1.884	1.872
-122	4.295	2.233	2.148	2.189	2.174



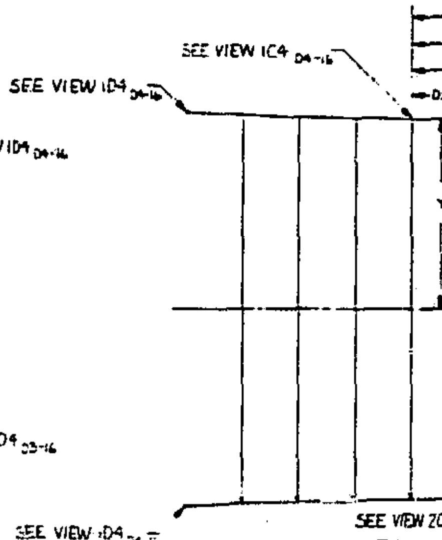
VIEW 1C4

ASSY	D_0	Y_0	D_1	Y_1	D_2	Y_2
-123	4.653	2.572	2.792	2.528	.931	2.505
-124	5.001	2.940	3.007	2.865	1.002	2.863
-125	5.369	3.335	3.221	3.275	1.074	3.245



VIEW 2

ASSY	D_0	Y_0	D_1	Y_1	D_2
-134	8.590	8.229	6.681	4.772	4.772
-135	9.348	8.938	6.960	4.971	4.971



VIEW 1

ASSY	D_0	Y_0	D_1	Y_1	D
-131	7.516	6.313	5.637	5.933	3.7
-132	7.874	6.313	5.906	6.224	3.9
-133	8.245	7.543	6.123	7.445	4.1

FOLDOUT FRAME

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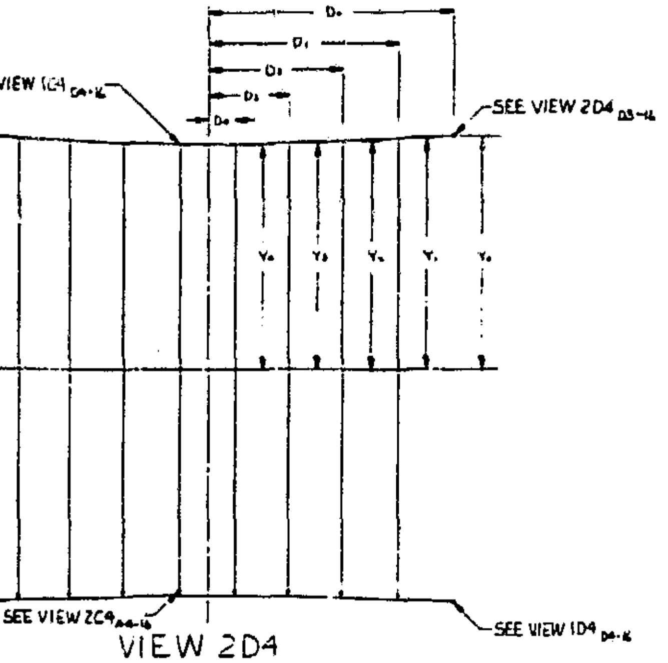
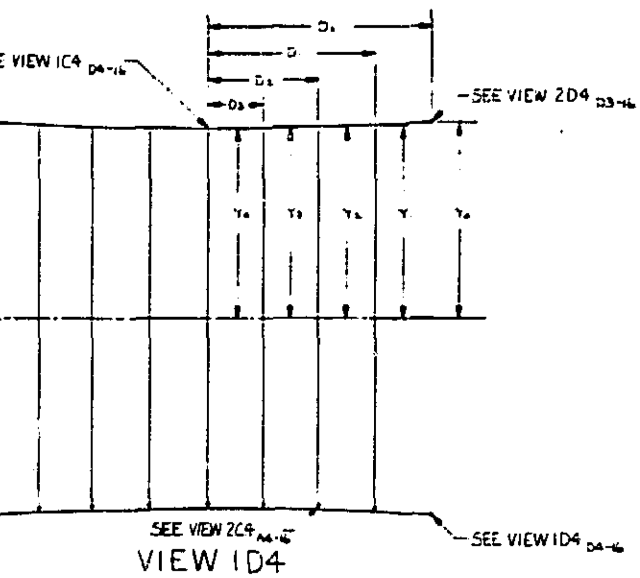


VIEW 2D4

Y_0	D_1	Y	D_2	Y_2	D_3	Y_3	D_4	Y_4
8.209	6.681	4.772	4.772	5.034	2.363	7.984	.859	7.962
8.938	6.960	4.971	4.971	6.753	7.967	8.701	.994	8.074



VIEW 1D4

D_0	Y_0	D_1	Y_1	D_2	Y_2	D_3	Y_3	Y_4
.516	6.313	3.637	5.933	3.758	5.874	1.379	5.840	5.828
.874	6.313	3.906	6.224	3.937	6.760	1.965	6.722	6.703
.245	7.543	6.123	7.445	4.122	7.375	2.561	7.332	7.318

FOLDOUT FRAME

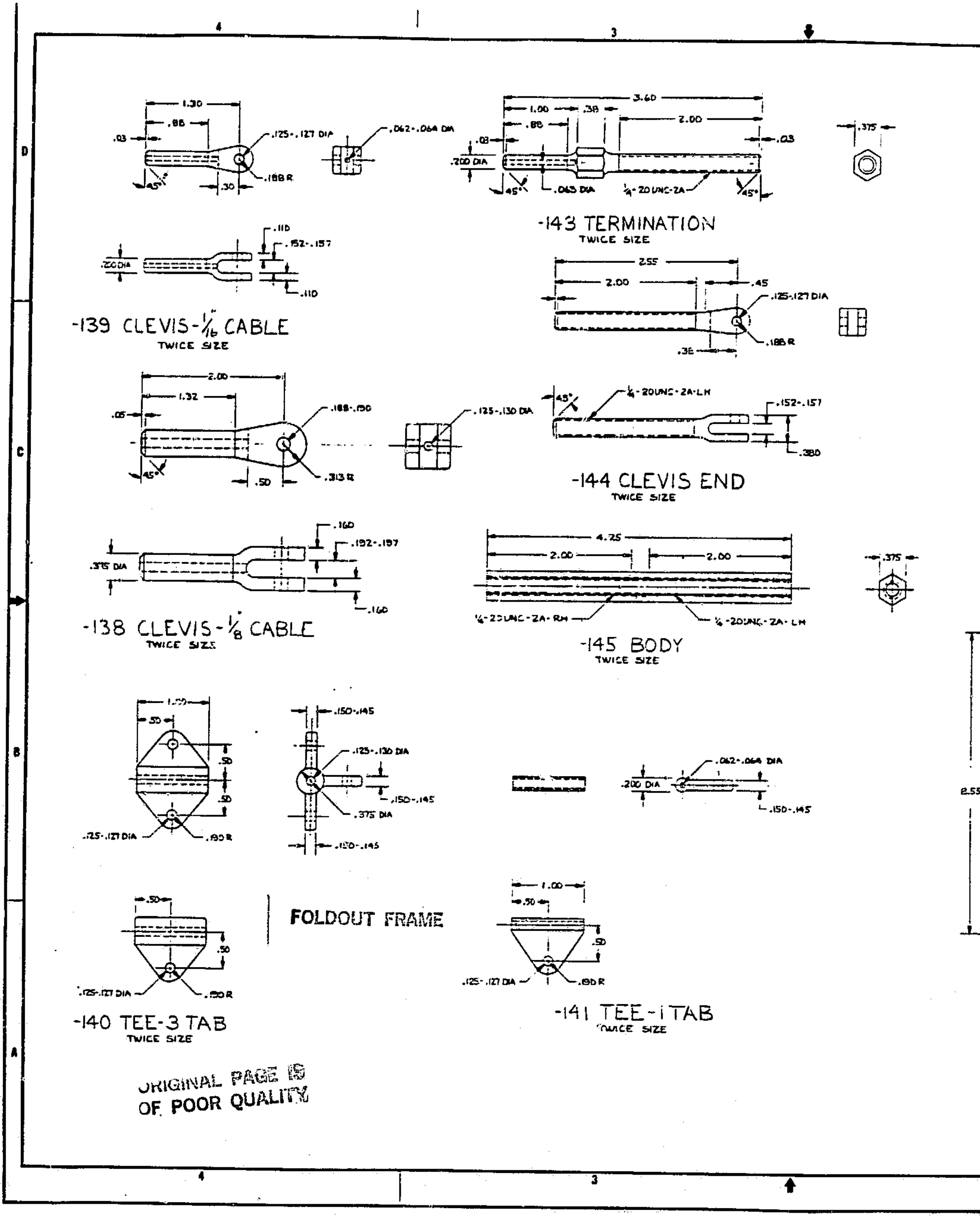
PL KH361418

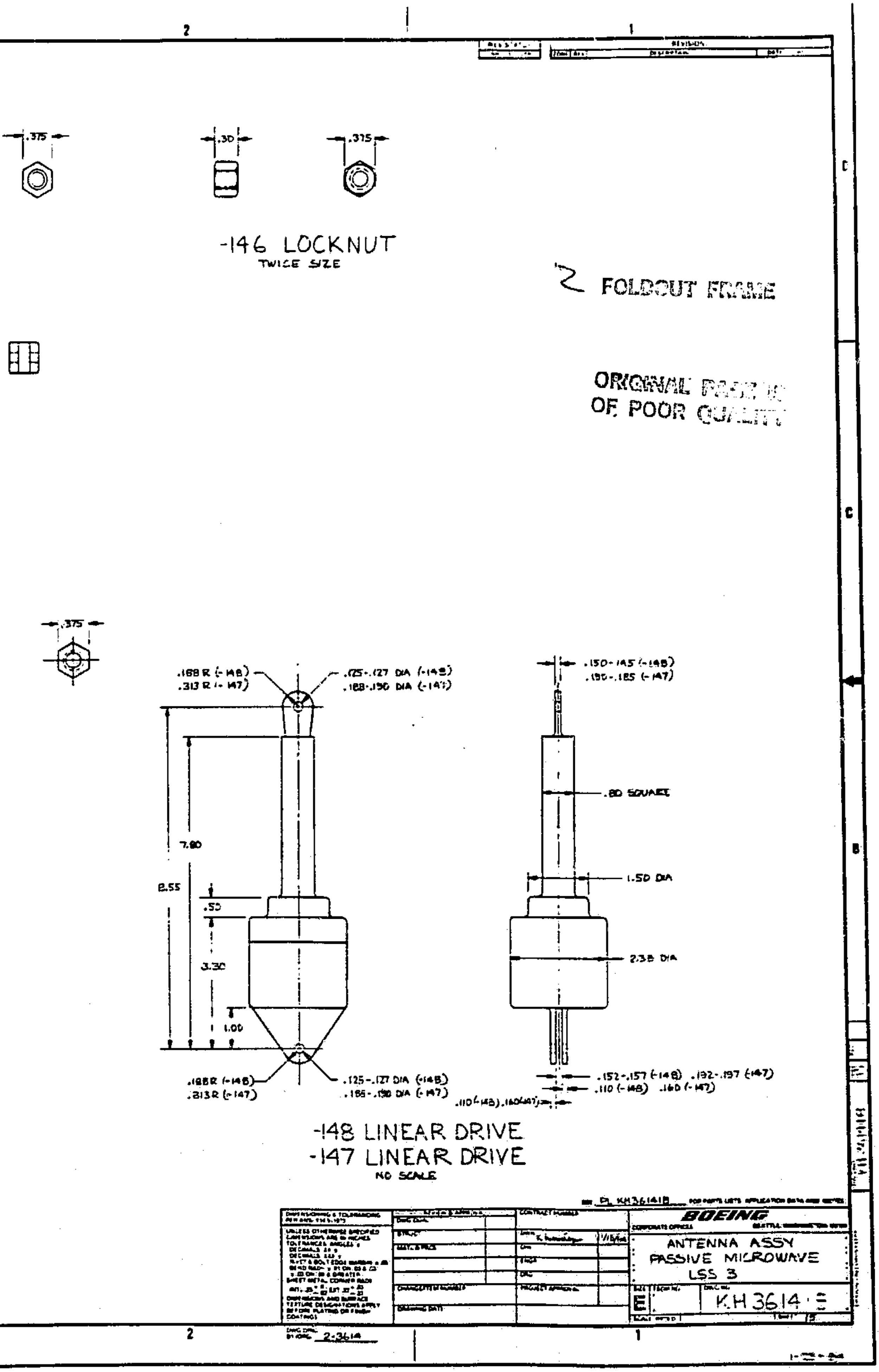
BOEING

ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3

E KH 361418

KH 361418


-143 TERMINATION
TWICE SIZE
-139 CLEVIS-1/16 CABLE
TWICE SIZE
-144 CLEVIS END
TWICE SIZE
-138 CLEVIS-1/8 CABLE
TWICE SIZE
-145 BODY
TWICE SIZE
1/4-20UNC-2A-RH
1/4-20UNC-2A-LH
-140 TEE-3 TAB
TWICE SIZE
-141 TEE-1 TAB
TWICE SIZE
FOLDOUT FRAME


-146 LOCKNUT
TWICE SIZE
2 FOLDOUT FRAME
ORIGINAL PAGE IS
OF POOR QUALITY
.375
.30
.375
.188 R (-148)
.313 R (-147)
.125-.127 DIA (-148)
.188-.190 DIA (-147)
.150-.145 (-148)
.190-.185 (-147)
.80 SQUARE
7.80
8.55
.50
3.30
1.00
1.50 DIA
2.38 DIA
.188R (-148)
.313R (-147)
.125-.127 DIA (-148)
.185-.190 DIA (-147)
.152-.157 (-148) .192-.197 (-147)
.110 (-148) .160 (-147)
-148 LINEAR DRIVE
-147 LINEAR DRIVE
NO SCALE
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS 3
KH3614
2-3614

KH3614-18

KH 361418

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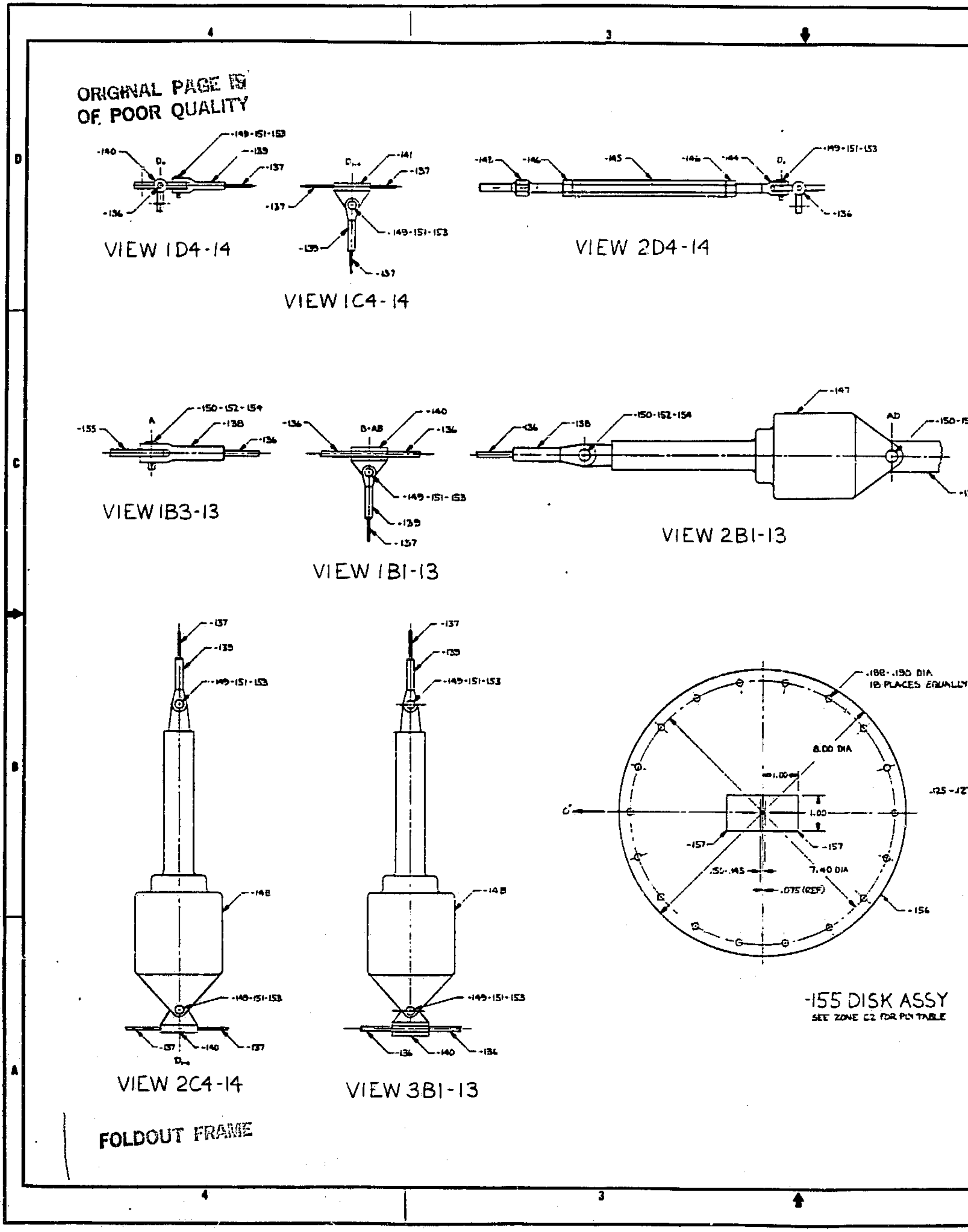


VIEW 1D4-14

VIEW 1C4-14

VIEW 2D4-14

VIEW 1B3-13

VIEW 1B1-13

VIEW 2B1-13

VIEW 2C4-14

VIEW 3B1-13

-155 DISK ASSY
SEE ZONE C2 FOR PT TABLE

FOLDOUT FRAME

ORIGINAL PAGE IS
OF POOR QUALITY

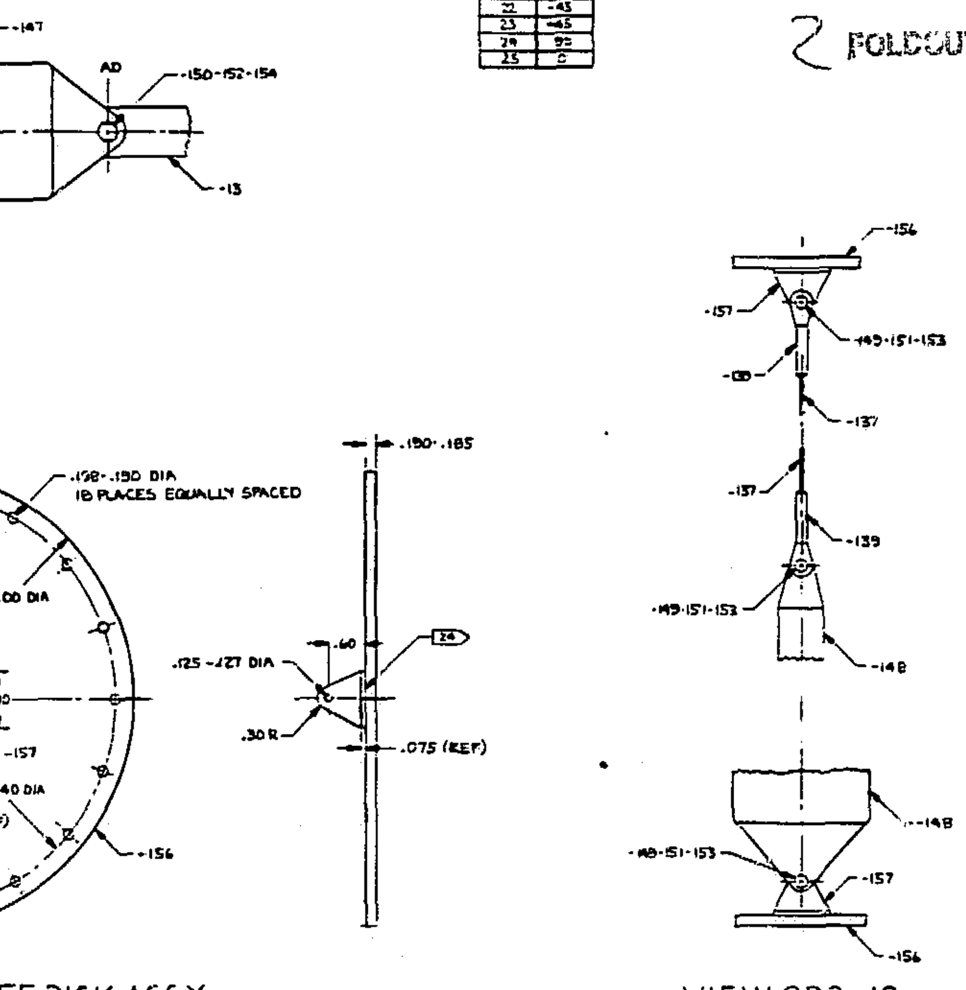
-149-151-153

-156

-157 PLY TABLE	
PLY NO	WARP ORIENT
1	0
2	90
3	+45
4	-45
5	0
6	0
7	+45
8	+45
9	90
10	0

-156 PLY TABLE	
PLY NO	WARP ORIENT
1	0
2	90
3	+45
4	+45
5	0
6	90
7	+45
8	-45
9	0
10	90
11	+45
12	-45
13	0
14	-45
15	+45
16	90
17	0
18	+45
19	+45
20	90
21	0
22	-45
23	+45
24	90
25	0

2 FOLDOUT FRAME



-155 DISK ASSY
SEE ZONE C2 FOR PLY TABLE

VIEW 2B3-13

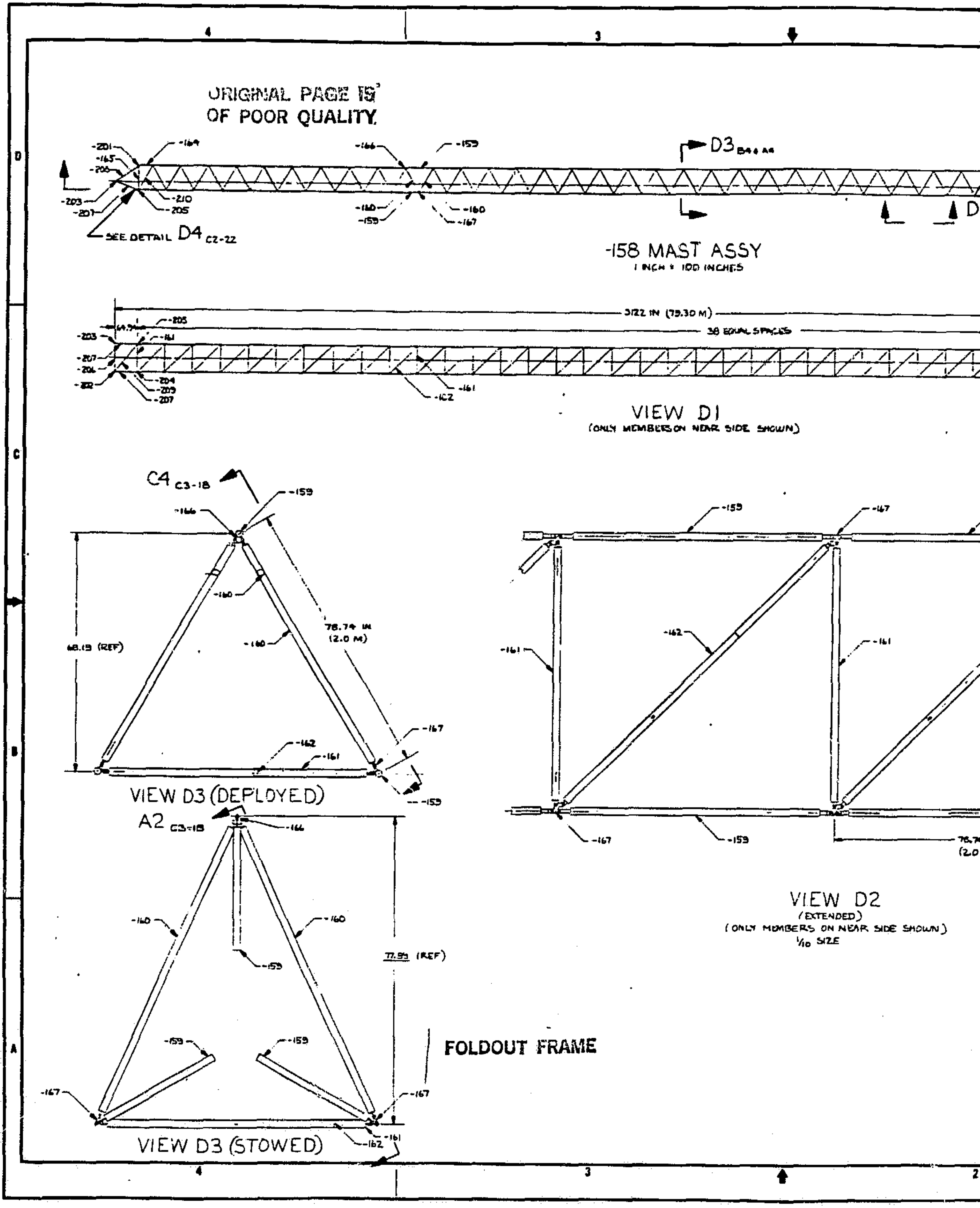
PL KH361418

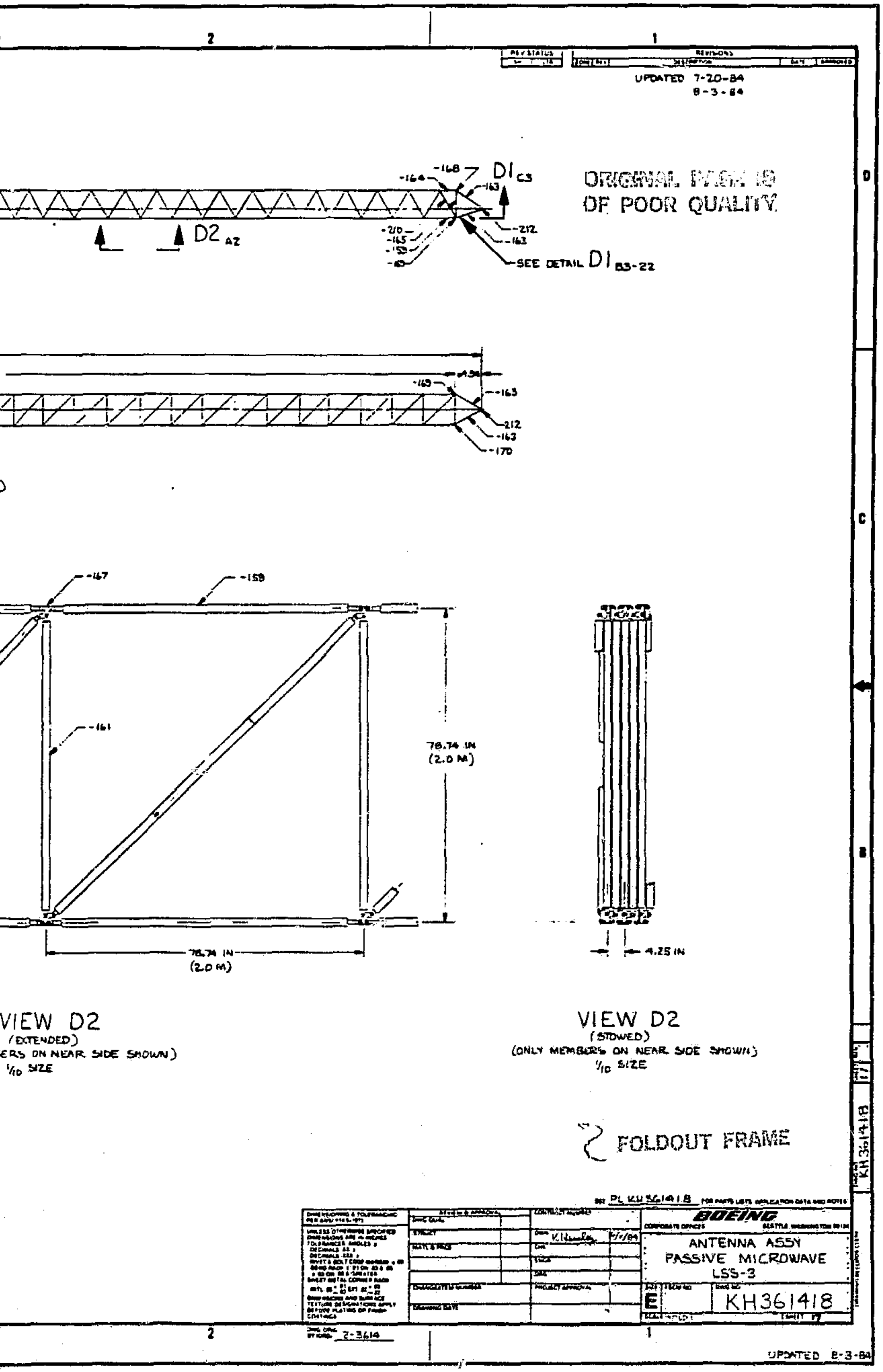
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3

E KH361418

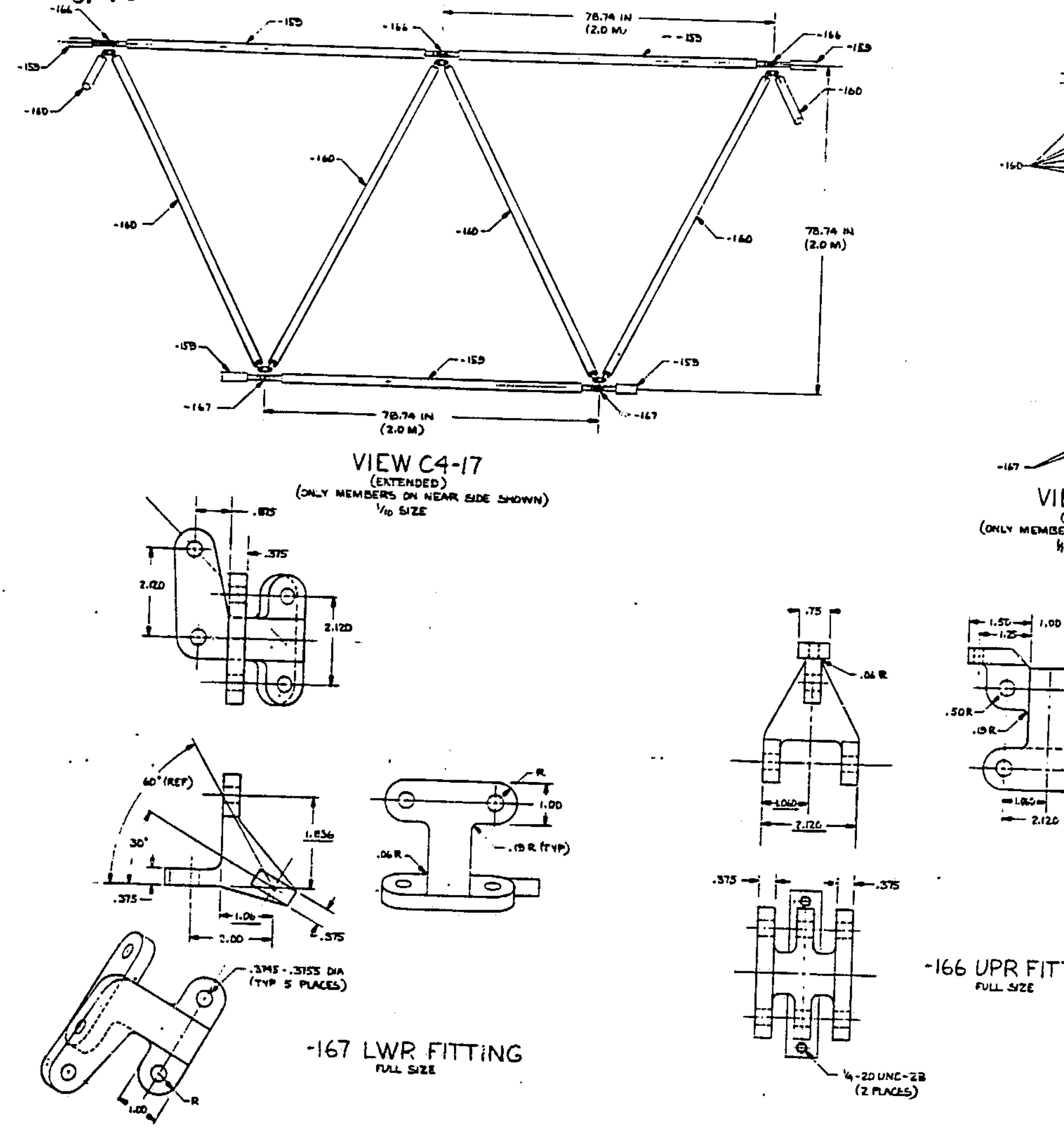
2-3614

KH361418


SEE DETAIL D4 C2-22
D3 B4 & A4
-158 MAST ASSY
1 INCH = 100 INCHES
3122 IN (79.30 M)
38 EQUAL SPACES
VIEW D1
(ONLY MEMBERS ON NEAR SIDE SHOWN)
C4 C3-18
78.74 IN
(2.0 M)
68.19 (REF)
VIEW D3 (DEPLOYED)
A2 C3-18
77.99 (REF)
VIEW D3 (STOWED)
VIEW D2
(EXTENDED)
(ONLY MEMBERS ON NEAR SIDE SHOWN)
1/10 SIZE


UPDATED 7-20-84
8-3-84
ORIGINAL PAGE IS
OF POOR QUALITY
D1 C3
D2 A2
SEE DETAIL D1 B3-22
78.74 IN
(2.0 M)
4.25 IN
VIEW D2
(EXTENDED)
ERS ON NEAR SIDE SHOWN)
1/10 SIZE
VIEW D2
(STOWED)
(ONLY MEMBERS ON NEAR SIDE SHOWN)
1/10 SIZE
FOLDOUT FRAME
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH361418
UPDATED 8-3-84

KH361418



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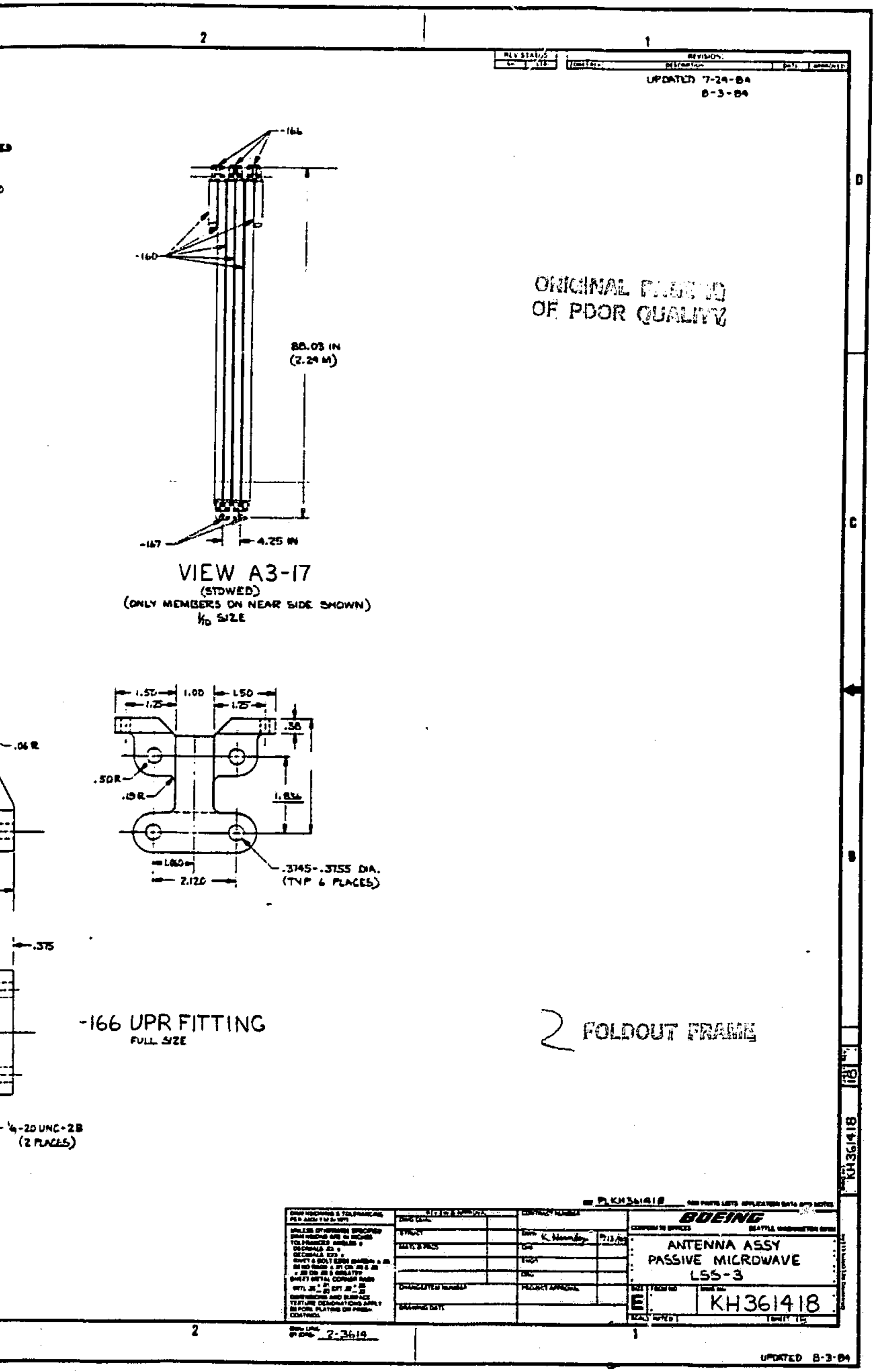

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2 FOLDOUT FRAME

KH361418

KH3614180

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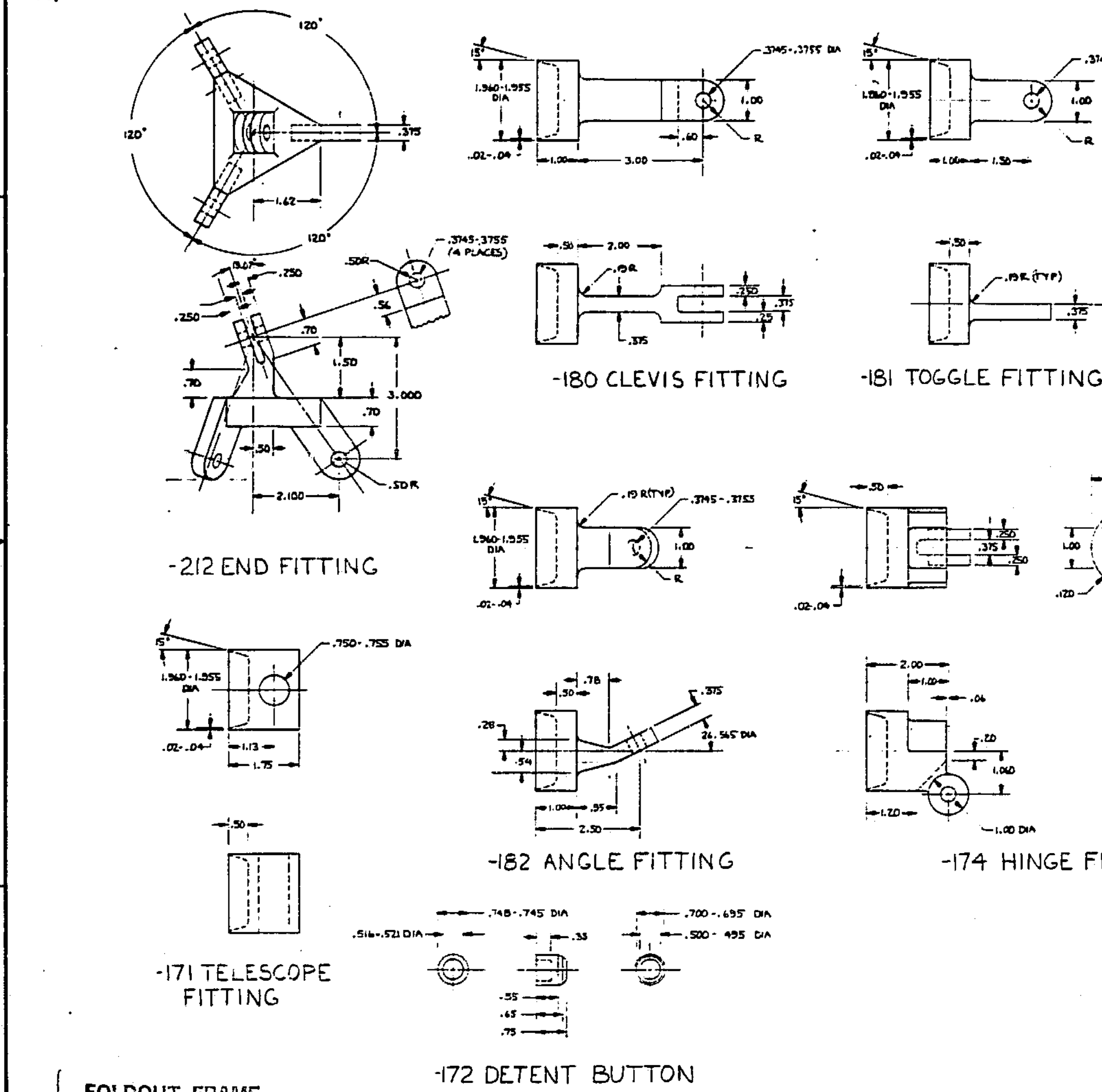
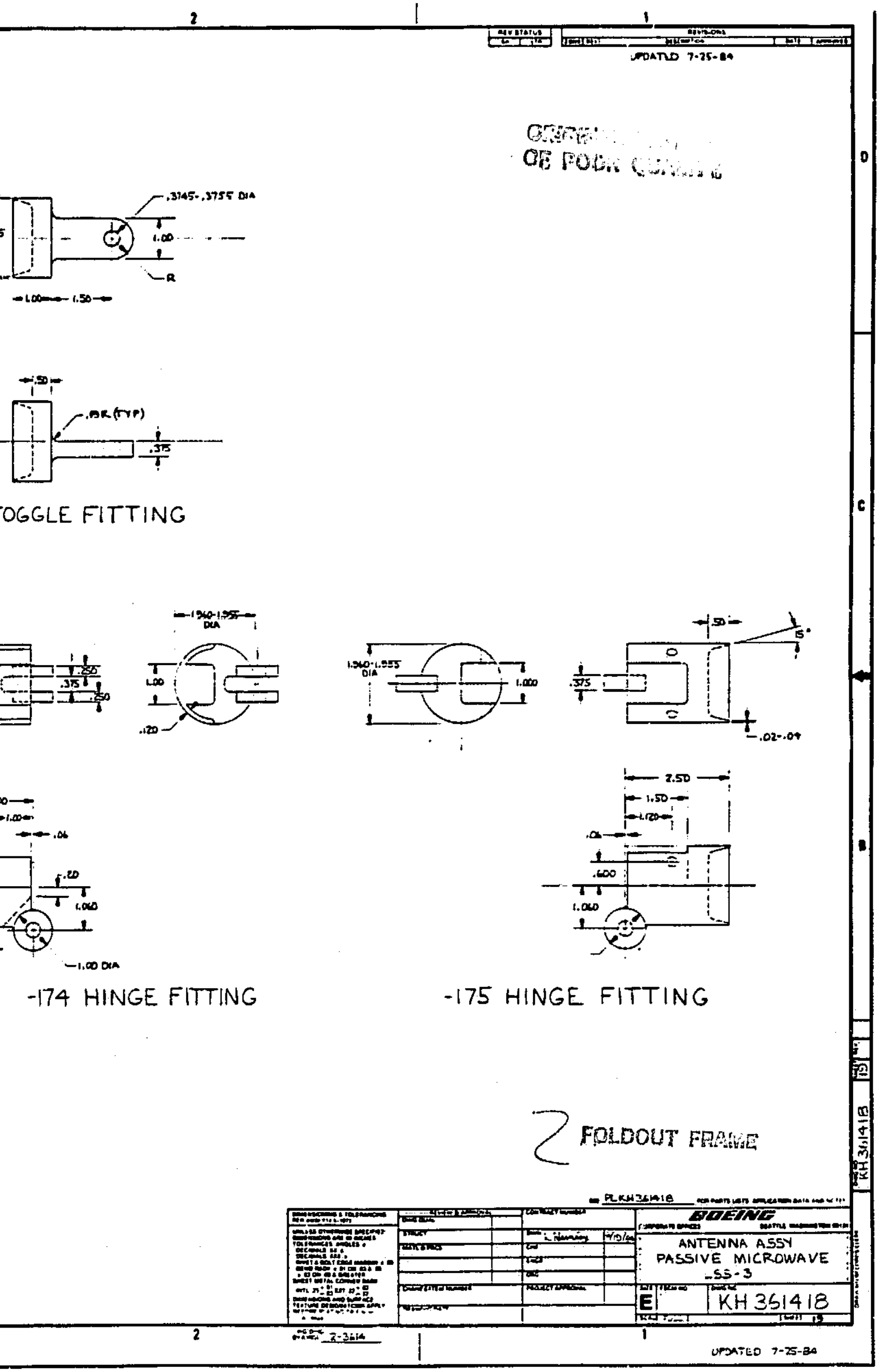


FOLDOUT FRAME


UPDATED 7-25-84
ORIGINAL ... OF POOR QUALITY
.3145-.3755 DIA
1.00
R
1.00
1.50
.50
.19R (TYP)
.375
TOGGLE FITTING
1.960-1.955 DIA
1.00
.120
.250
.375
.250
1.960-1.955 DIA
1.000
.375
.50
15°
.02-.09
2.50
1.50
1.120
.06
.600
1.060
.06
.20
1.060
1.00 DIA
-174 HINGE FITTING
-175 HINGE FITTING
FOLDOUT FRAME
PL KH361418
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH 361418
2-3614
UPDATED 7-25-84

KH361418

KH381418

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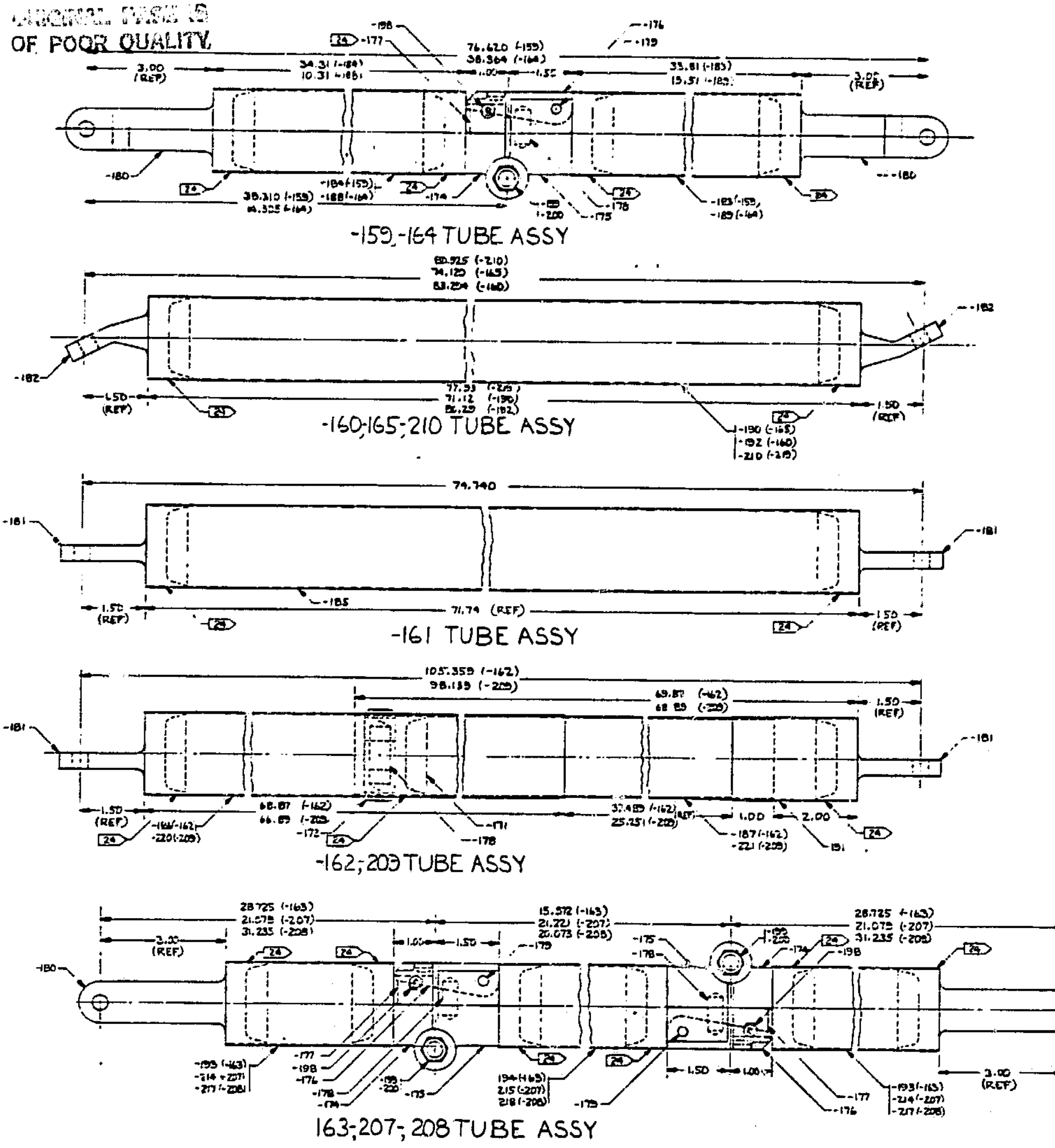
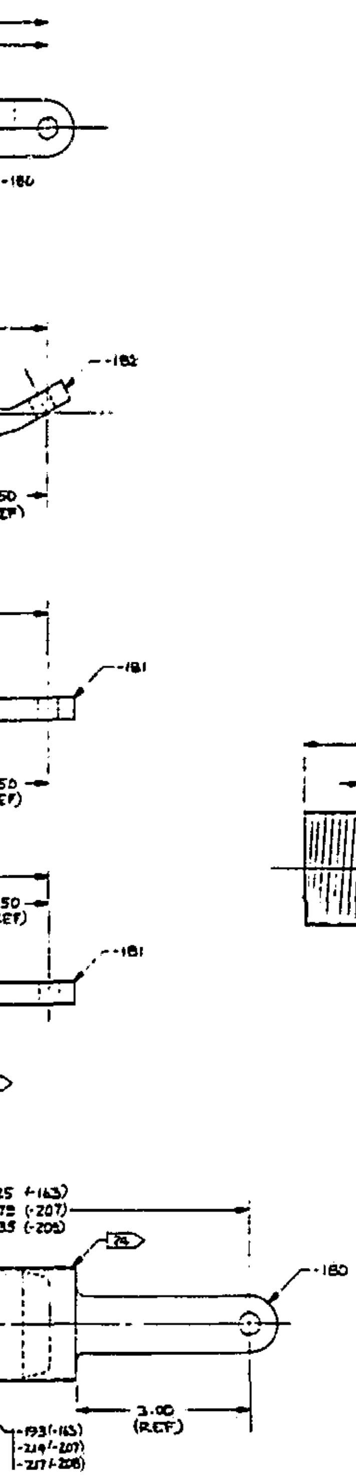
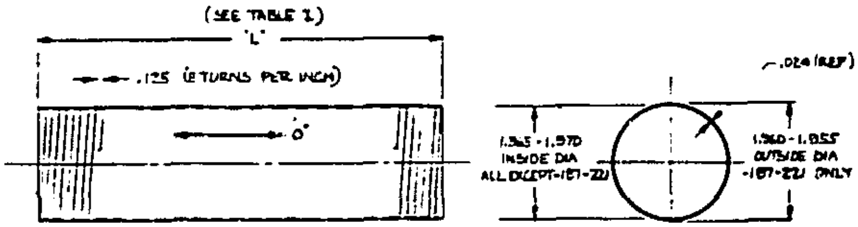


FOLDOUT FRAME

UPDATED 8-9-84



FOLDOUT FRAME



-183 THRU -195 TUBE
-213 THRU -222 TUBE

TABLE I			
TUBE	L	TUBE	L
-183	133.81	-213	
-184	134.31	-214	17.08
-185	71.74	-215	18.22
-186	65.87	-216	
-187	66.89	-217	27.24
-188	10.31	-218	17.07
-189	12.51	-219	77.93
-190	71.12	-220	66.89
-191	3.00	-221	66.89
-192	90.29		
-193	24.73		
-194	12.57		
-195			

PL KH361418

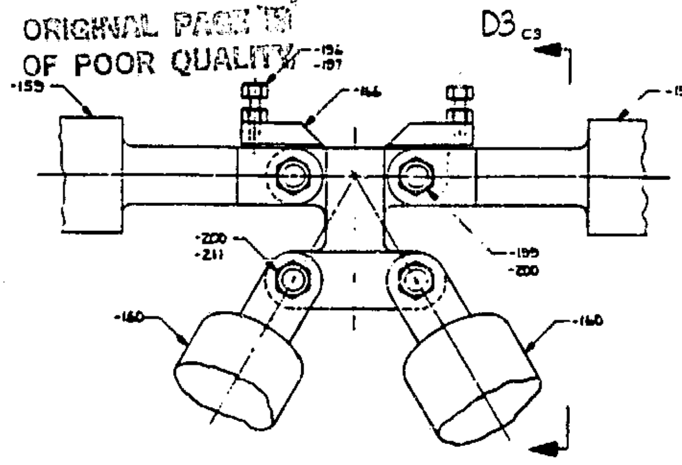
BOEING

ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3

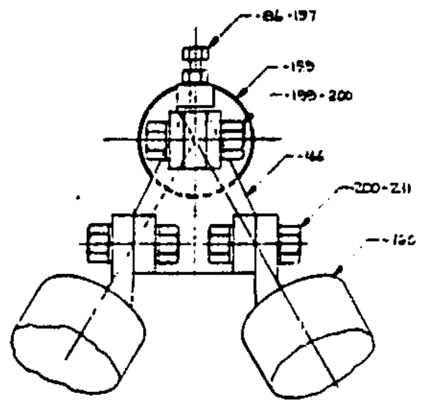
E KH361418

2-3614

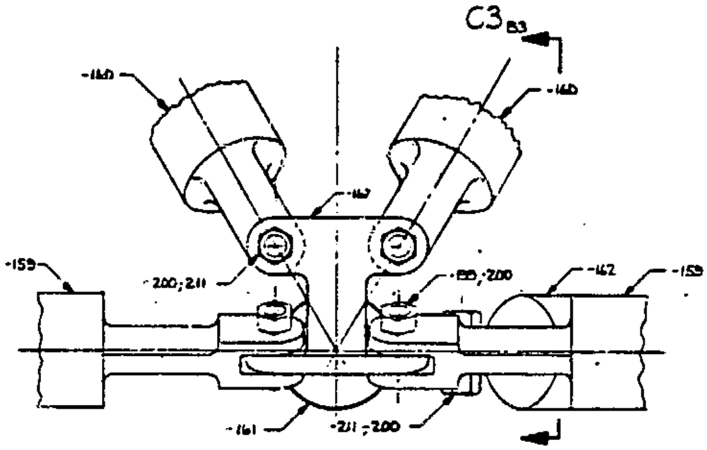
KH361418



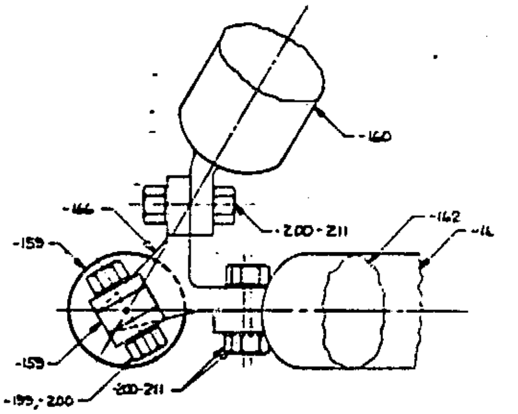
VIEW 4D4-20



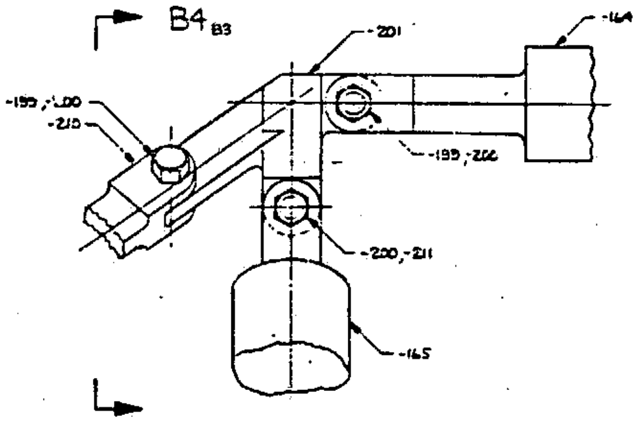
VIEW D3



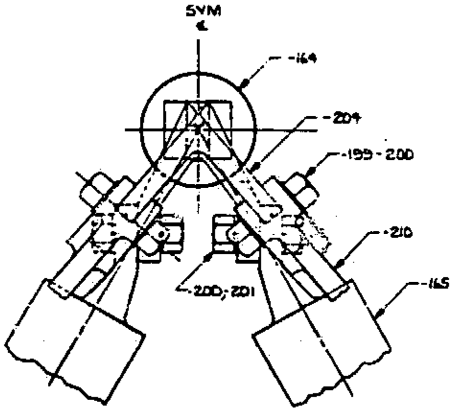
VIEW 5D4-20



VIEW C3



VIEW 2D4-20



VIEW B4

FOLDOUT FRAME

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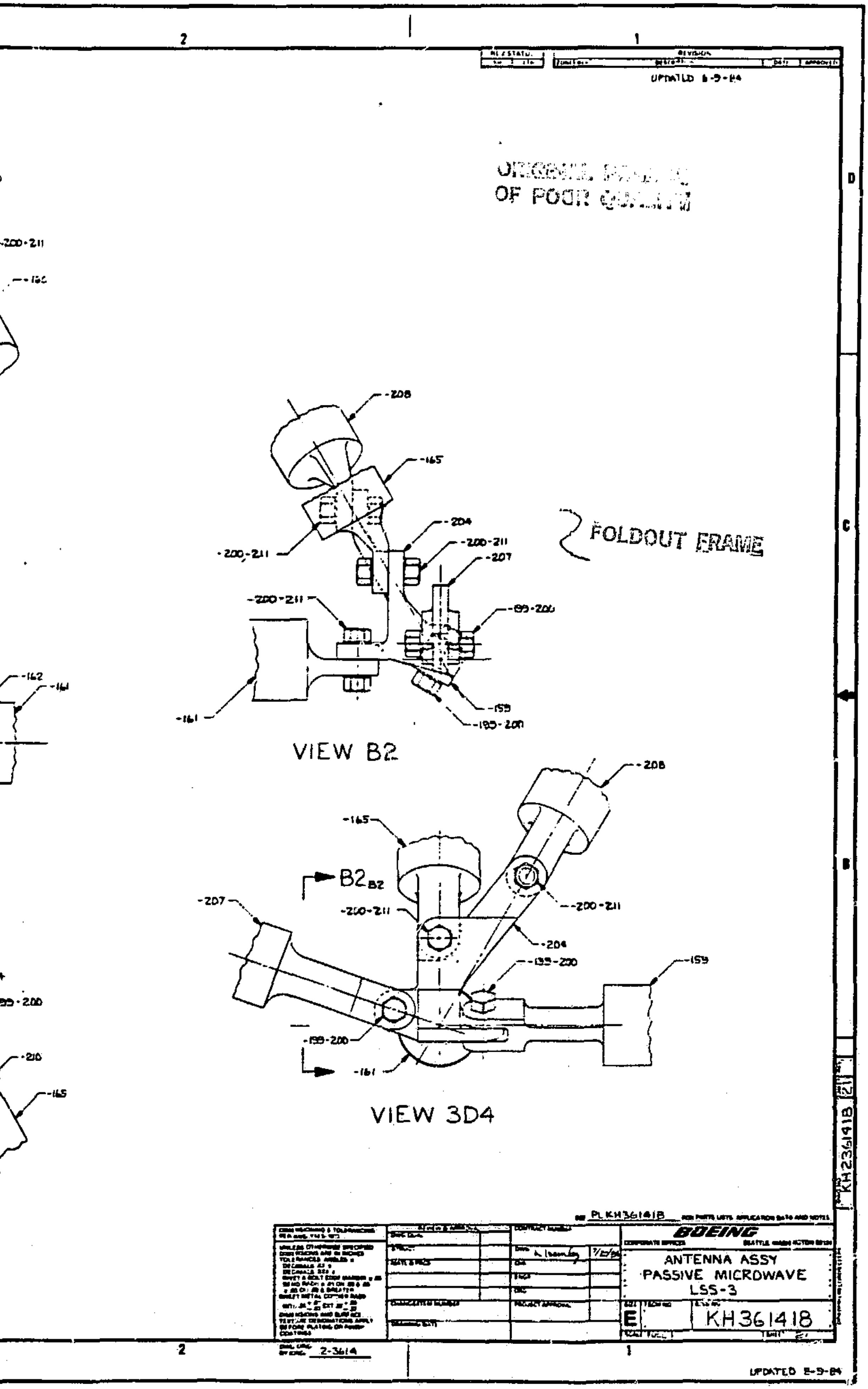
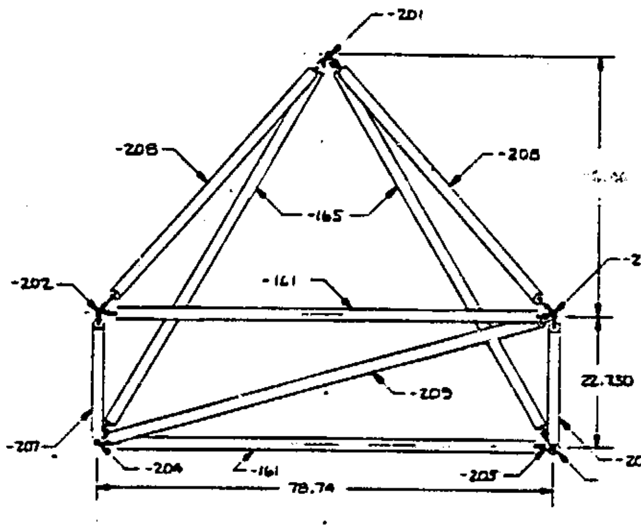
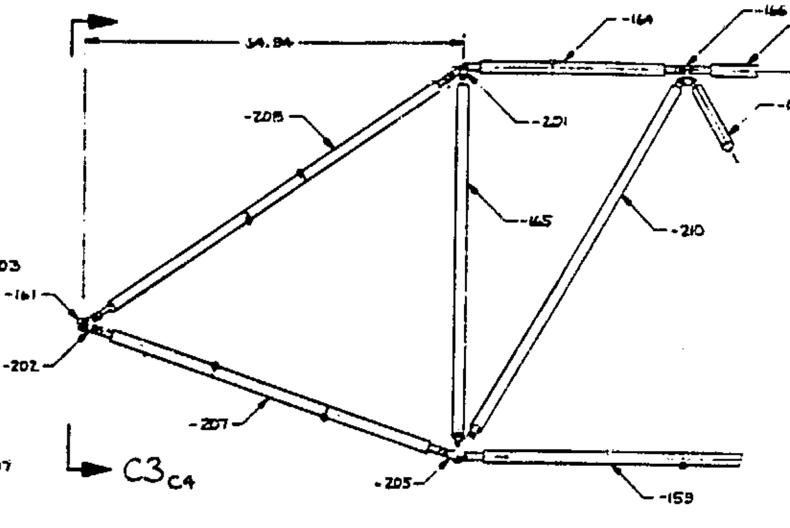
FOLDOUT FRAME

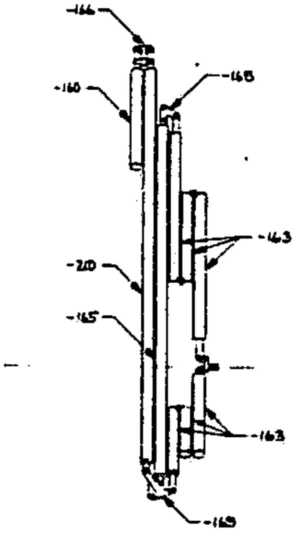




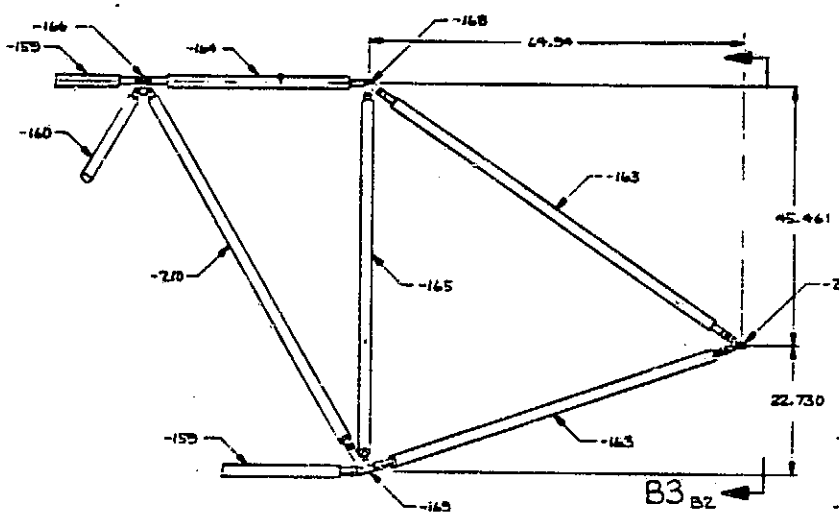
VIEW C3



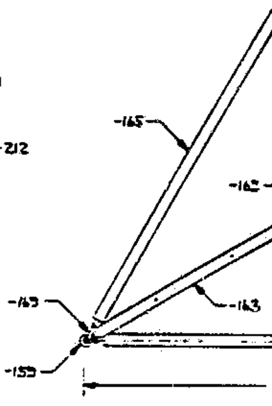
DETAIL D4-17 (DEPLOYED)



DETAIL D1-17 (STOWED)



DETAIL D1-17 (DEPLOYED)



VI

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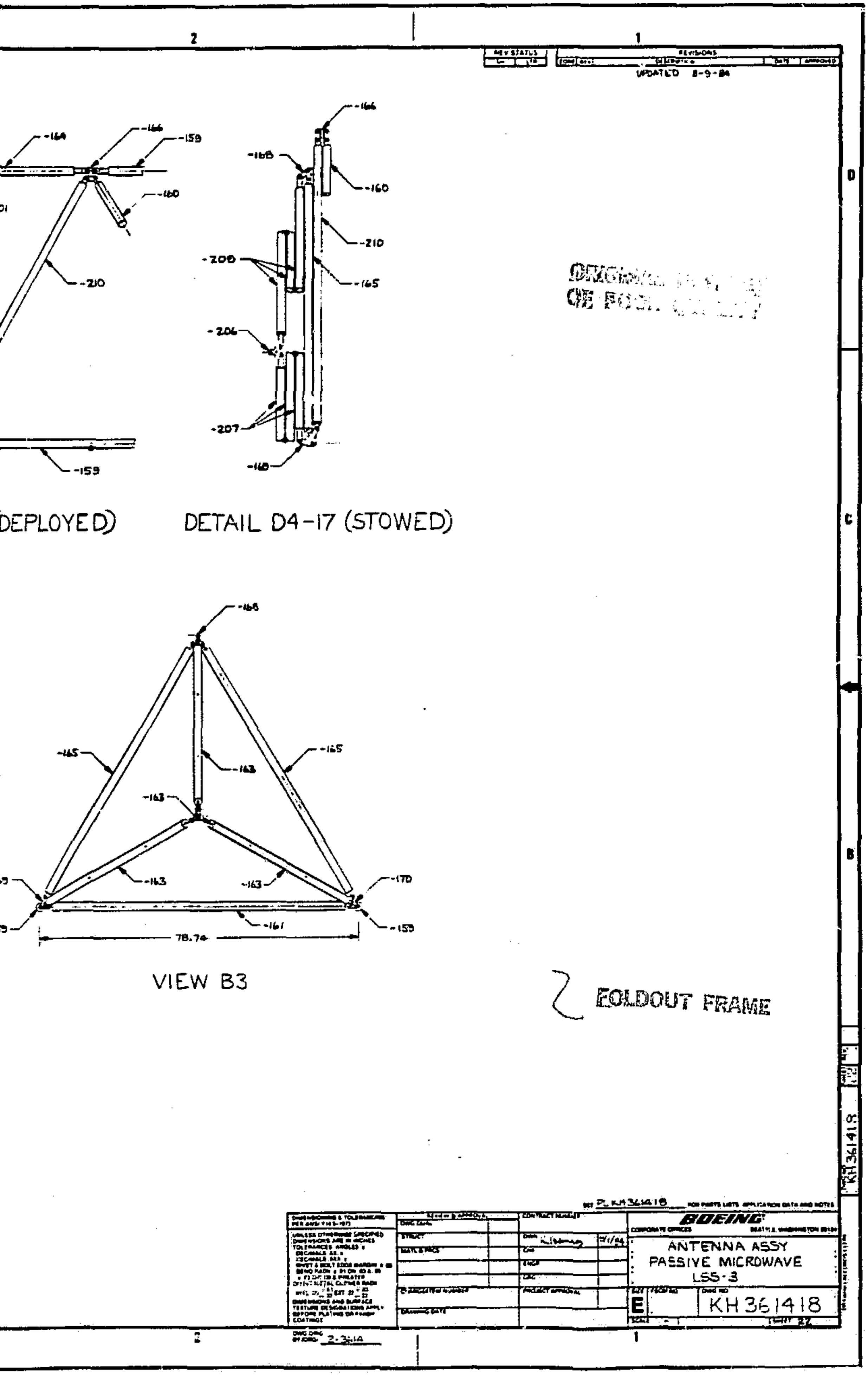
OF POOR QUALITY

FOLDOUT FRAME



UPDATED 8-9-84
-164
-166
-159
-160
-210
-166
-168
-160
-210
-208
-165
-206
-207
-168
-159
DEPLOYED)
DETAIL D4-17 (STOWED)
-168
-165
-165
-163
-163
-163
-163
-170
-161
-159
78.74
VIEW B3
FOLDOUT FRAME
PL KH361418
BOEING
ANTENNA ASSY
PASSIVE MICROWAVE
LSS-3
E
KH361418
KH361418

KH361418

UPDATED 11-29-85
6-20-84
8-3-84

PARTS LIST

BOEING — SEATTLE, WASHINGTON 98124

DWN K Hensley 11/29/85	MATL & PPCS	DWG QUAL	FSCM NUMBER 81205 — PL KH361418
CHK	STRUCT	ORG APPVL	TITLE ANTENNA ASSY PASSIVE MICROWAVE LSS-3
ENGR		PROJ APPVL	CONTRACT NUMBER — DWG ORIG BY ORG 2-3614

REMARKS

DEPENDENT DRAWING

RELEASE CONTROL NUMBER — RELEASE
1
2
3

APPLICATION AND PARTS RELEASE

PART NUMBER	QTY PER NEXT ASSY	QTY PER END ITEM	NEXT HIGHER ASSEMBLY DWG	END ITEM NUMBER CI	END ITEM NUMBER PEI	PROGRAM DESIGNATOR	USED ON MODEL	END ITEM EFFECTIVITIES	DWG SHEET NUMBERS	SCN	LTR
-1	—	1	END ITEM					NONE			

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D1 5007 3205 ORIG 9/77

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 | PL KH361418 | SHEET 2 | REV LTR

NOTE NUMBER	NOTE CODE	NOTE
1		3K TOW OF P75S GRAPHITE FIBER IMPREGNATED WITH 35-38 % BY VOLUME E773 EPOXY RESIN. US POLYMERIC CO. 706 EAST DYER ROAD, SANTA ANA, CALIF
2		LONGO WIND 260 TOWS EQUALLY SPACED ABOUT CIRCUMFERENCE AT 0° TO 2° ORIENTATION.
3		LONGO WIND 200 TOWS EQUALLY SPACED ABOUT CIRCUMFERENCE AT 0° TO 2° ORIENTATION
4		CIRC WIND WITH .584 ±.03 INCH PITCH PER REVOLUTION
5		CIRC WIND WITH 25±1 TOWS PER INCH.
6		APPLY CIRC WINDS TO FORM FLANGES AS SHOWN. PROVIDE EXCESS MATERIAL FOR A MINIMUM .05 IN MACHINE ALLOWANCE.
7		CIRC WIND AS SHOWN WITH A RIGHT HAND THREAD ADVANCE.
8		CIRC WIND AS SHOWN WITH A LEFT HAND THREAD ADVANCE.

NOTE NUMBER	NOTE CODE	NOTE
9		CURE CYCLE: PLACE THERMOCOUPLES TO READ MANDREL & PART TEMP. ROTATE PART DURING CURE. RAISE TEMP FROM 120°F TO 275°F AT 3-4° PER MINUTE. START CURE TIME WHEN LAGGING THERMOCOUPLE REACHES 265°F. CURE AT 275°F ± 10°F FOR ONE HOUR. COOL TO 125°F AT 3-4°F PER MINUTE
10		MS21252-4LS MATERIAL - INVAR
11		MS21251-5S MATERIAL - INVAR
12		MS21260L4RH MATERIAL - INVAR
13		MS20667-4 MATERIAL - INVAR
14		PULTRUDE 18 TOWS OF CELION 6000 OR 36 TOWS OF CELION 3000 TO FORM A 0.116 INCH DIA UNIDIRECTIONALLY ORIENTED CABLE. CUT TO REQUIRED LENGTH AND BURN TEFLON OFF ENDS TO BE INSERTED IN FITTINGS
15		SOLVENT CLEAN BORES IN FITTINGS. INJECT BMS5-109 TYPE I, CLASS I, GRADE B EPOXY ADHESIVE TO FILL BORE. INSERT FLAME CLEANED CABLE END INTO BORE AND WIPE AWAY EXCESS ADHESIVE. CURE PER VENDOR INSTRUCTIONS. ELEVATED TEMP CURE TO 150°F MAY BE USED.

D1 5007 3215 ORIG. 9/77

UPDATED 11-29-83

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER | FSCM NUMBER 81205 | PL KH361418 | SHEET 3 | REV LTR

NOTE NUMBER	NOTE CODE	NOTE
16		MS 20392-2C13 MATERIAL INVAR
17		AN 415-4 MATERIAL INVAR
18		V RETAINER COUPLING, WITH VOSS SERIES 3100 BAND AND STYLE NO 7 T BOLT OVER CENTER LATCH OR EQUIVALENT. FABRICATE ALL DETAIL PARTS FROM INVAR. SOURCES: VOSS INDUSTRIES INC, AEROQUIP, JANITROL AND NUCO
19		MACHINE FROM INVAR CASTING
20		LONGO WIND 22 TOWS EQUALLY SPACED ABOUT CIRCUMFERENCE AT 0° TO 5° ORIENTATION.
21		MACHINE TO MATCH MATING END OF -54 OR -55 WITH .01 TO .03 INCH DIAMETRAL CLEARANCE FOR ADHESIVE BOND.
22		MACHINE TO MATCH MATING END OF -57 WITH .01 TO .03 DIAMETRAL CLEARANCE FOR ADHESIVE BOND.
23		MACHINE FROM INVAR BAR STOCK
24		SOLVENT CLEAN FAYING SURFACES ON ALL DETAIL PARTS. APPLY BMS 5-109 TYPE I, CLASS I GRADE B EPOXY ADHESIVE TO ALL FAYING SURFACES. ASSEMBLE DETAIL PARTS AND POSITION WITH BONDING FIXTURES WHERE REQUIRED. WIPE OFF EXCESS

NOTE NUMBER	NOTE CODE	NOTE
24		ADHESIVE. CURE PER ADHESIVE VENDOR DIRECTIONS. ELEVATED TEMPERATURE CURE TO 150°F MAY BE USED.
25		MAKE FROM 12 GA (.1046 IN) INVAR SHEET
26		SHIM WITH BAC S40036-5C.
27		10-32 × 1/4 ROUND HEAD MACHINE SCREW 18-8 CRES CAT NO 91783A825. SOURCE: NOTE 28
28		McMASTER-CARR SUPPLY CO. P.O. BOX 54960 LOS ANGELES CA 90054
29		1/4-20 × 1/2 HEX HEAD MACHINE SCREW, 18-8 CRES CAT. NO. 92196 A 537. SOURCE: NOTE 28
30		1/4-20 HEX LOCK NUT 18-8 CRES CAT. NO 91839A029 SOURCE: NOTE 28
31		1/4" FLAT WASHER, 18-8 CRES CAT NO 92141A029 SOURCE: NOTE 28
32		1/4-20 × 1 1/2 HEX HEAD MACHINE SCREW 18-8 CRES CAT NO 92198A546 SOURCE: NOTE 28
33		MS 20392-3C37 MATERIAL: CRES
34		HAIR PIN-COTTER MATERIAL: CRES CAT NO 98391003 4 SOURCE: NOTE 28

D1 5007 3215 ORIG. 9/77

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 **PL** KH361418 | 41

NOTE NUMBER	NOTE CODE	NOTE
35		MACHINE FROM BLOCK OF MATERIAL LAMINATED WITH BMS 8 247, TYPE P75 GRADE 155, CLASS 40 PER BAC 5562. FILAMENT ORIENTATION ± 45° AS INDICATED ON DRAWING.
36		LONGO WIND WITH 157 TOWS EQUALLY SPACED ABOUT CIRCUMFERENCE AT 0° TO 2° FROM AXIS OF TUBE. CIRC WIND WITH A RIGHT HAND THREAD ADVANCE WITH A PITCH OF .53 TO .55 INCHES PER REVOLUTION
37		LAMINATE WITH 8 PLIES OF BMS 8-247, TYPE P75, GRADE 155, CLASS 40. FILAMENT ORIENTATION ± 45° AS INDICATED ON DRAWING
38		PULTRUDE 18 TOWS OF CELION 6000 OR 36 TOWS OF CELION 3000 WITH 7% TO 10% BY WEIGHT OF POLYETHERETHERKETONE RESIN (PEEK) TO FORM 0.116 DIA UNIDIRECTIONALY ORIENTED CABLE.
39		PULTRUDE 4 TOWS OF CELION 6000 OR 8 TOWS OF CELION 3000 WITH 7% TO 10% BY WEIGHT OF POLYETHERETHERKETONE RESIN (PEEK) TO FORM 0.055 DIA UNIDIRECTIONALLY ORIENTED CABLE
40		INJECTION MOLD USING POLYETHERETHERKETONE RESIN FILLED 30% TO 35% BY WEIGHT WITH PAN GRAPHITE FIBER.

NOTE NUMBER	NOTE CODE	NOTE
41		SOLVENT WIPE AND DRY CABLE ENDS AND FITTING BORES. INSERT CABLE TO FULL DEPTH IN FITTING BORE. ULTRASONIC SWAGE THE FITTING TO THE CABLE PER ENGINEERS INSTRUCTIONS.
42		CUT CABLES TO LENGTH AND ASSEMBLE FITTINGS PER DRAWING DETAILS AND TABULATED DIMENSIONS.
43		SCREW ACTUATOR: MODIFIED HURST 3202-007 GEARMOTOR, 14 OZ-IN, 2 RPM. OUTPUT: 470 LB AT .10 IN. PER MIN.
44		SCREW ACTUATOR: MODIFIED HURST 3202-025 GEARMOTOR, 64 OZ-IN, 30 RPM. OUTPUT: 170 LB AT 1.50 IN. PER MIN.
45		MS 20392-1C13 MATERIAL: INVAR
46		MS 20392-2C19 MATERIAL: INVAR
47		LAMINATE WITH BMS 8-212, TYPE II, CLASS 2 STYLE 3K-70-P PREIMPREGNATED GRAPHITE FABRIC PER BAC 5562
48		THE -3 ASSY IS SUPERSEDED BY THE -158 ASSY.
49		INJECTION MOLD OR MACHINE BOLT TO THE DIMENSIONS OF AN 6 AND NUT TO DIMENSIONS OF AN 315-6

D1 5007 3215 ORIG. 9/77

8-3-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 PL KH361418 SHEET 4A REV LTR

NOTE NUMBER	NOTE CODE	NOTE
50		INJECTION MOLD OR MACHINE BOLT TO
		THE DIMENSIONS OF AN5 AND NOT TO THE
		DIMENSIONS OF AN 315-5
51		PAN HEAD PHILLIPS MACHINE SCREW
		18-8 STAINLES STEEL. 10-32 × 1/2
		CAT NO 91772D828 OR EQUAL.
		MCMASTER CARR SUPPLY CO
		PO BOX 54960 LOS ANGELES CA 90054

NOTE NUMBER	NOTE CODE	NOTE

D1 5007 3215 ORIG. 9/77

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE WASHINGTON 98124

CONTROL NUMBER | FSCM NUMBER 81205 | PL KH361418 | SHEET 5 | REV LTR

QTY REQD -68	QTY REQD -67	QTY REQD -15	QTY REQD -8	QTY REQD -7	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PI MK	FINISH	TR	RCN	EAMB
						—	-1	ANTENNA ASSY	A4-1											
					1		-2	RING ASSY	A4-2											
							-3	MAST ASSY	D3-4						48					
					1		-4	ARRAY ASSY												
					1		-5	MEMBRANE ASSY												
					2		-6	GUY CABLE ASSY												
					126		-7	STRUT TUBE ASSY	D3-2											
					18		-8	STRUT TUBE ASSY	C3-2											
				1			-9	STRUT TUBE	D3-2						1,2,4,5,6,7,9					
				1			-10	STRUT TUBE	D3-2						1,2,4,5,6,8,9					
			1				-11	STRUT TUBE	C3-2						1,3,4,5,6,7,9					
			1				-12	STRUT TUBE	C3-2						1,3,4,5,6,8,9					
					30		-13	JOINT FITTING	B3-3						19					
					14		-14	JOINT FITTING	B4-3						19					
		—			36		-15	CABLE ASSY	D4-3						15					
AR	AR	AR					-16	CABLE	D4-3						14					
1	1	1					-17	CLEVIS	D4-3						10					
1	1	1					-18	TURNBUCKLE	D4-3						11					
				1			-19	CLAMP- 12" DIA	B2-2						18					
			1				-20	CLAMP- 9.25 DIA	B2-2						18					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5007 3210 ORIG. 9 77

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418

SHEET 6

REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																								-69			
																										-1	
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																										-10	
																										-11	
																										-12	
																										-13	
																										-14	
																										-15	
																								AR		-16	
																								1		-17	
																								1		-18	
																										-19	
																										-20	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

DO 6000 3420 ORIG. 4/73

PARTS LIST

THE BOEING COMPANY CORPORATE OFFICES SEATTLE WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 | PL KH361418 | SHEET 7

EAMR NUMBER	QTY REQD -11	QTY REQD -10	QTY REQD -9	QTY REQD -8	QTY REQD -7	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PI MK	FINISH	IR	PCN	EAMR
	2	2	2					-21	END FITTING ASSY	A2-2											
								-22	SPHERICAL END STUD	A2-2						23					
								-23	SPHERICAL NUT	A2-2						23					
								-24	JAM NUT	A2-2						23					
								-25	PLUG	A2-2						23					
								-26	HEADED PIN	D4-3						16					
								-27	LOCK PIN	D4-3						17					
								-28	TERMINAL-STUD END	D4-3						12					
								-29	TERMINAL-FORK END	D3-3						13					
								-30	CLIP-LOCKING	D3-3						14					
						2		-31	JOINT FITTING	A4-3						19					
						2		-32	JOINT FITTING	A2-3						19					
						2		-33	JOINT FITTING	A1-3						19					
								-34	TUBE ASSY	A4-4						24					
								-35	TUBE ASSY	A3-4						24					
								-36	TUBE ASSY	A3-4						24					
								-37	TUBE ASSY	A3-4						24					
								-38	TUBE ASSY	A2-4						24					
								-39	END FITTING	B4-6						24					
								-40	SEGMENT	C4-4						25					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5001 3210 ORIG. 9 77

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418 SHEET 8 RE / LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
							-69	-68	-67	-45	-44	-43	-42	-41	-40	-38	-37	-36	-35	-34	-3	15	21	12			
																								2		-21	
																							1			-22	
																							1			-23	
																							2			-24	
																							1			-25	
							2	2	2													2				-26	
							2	2	2													2				-27	
							1	1	1													1				-28	
							1	1	1													1				-29	
							2	2	2													2				-30	
																										-31	
																										-32	
																										-33	
																					1					-34	
																					1					-35	
																					2					-36	
																					2					-37	
																					1					-38	
																1				1						-39	
										1	1	1	1	1	1	1	3	3	3	2						-40	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

DO 6300 3420 ORIG. 4/73

PARTS LIST — THE BOEING COMPANY, CORPORATE OFFICES, SEATTLE WASHINGTON 98124 — CONTRACT NUMBER — FSCM 81205 — PL KH361418 — SHEET 9

EAMR NUMBER	QTY REQD -35	QTY REQD -34	QTY REQD -33	QTY REQD -32	QTY REQD -3	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PT MR	FINISH	TR	RCN
	1							-41	SEGMENT ASSY	C3-4						24				
	1							-42	SEGMENT ASSY	C3-4						24				
		1						-43	SEGMENT ASSY	C2-4						24				
								-44	SEGMENT ASSY	C4-4						24				
	1							-45	SEGMENT ASSY	C3-4						24				
								-46	PIVOT LUG	C2-4						25				
								-47	PIVOT LUG	B1-4						25				
								-48	LATCH	C2-4						25				
								-49	ROUND HD SCREW	C2-5						27				
	3							-50	SPACER-SHIM	A2-4						26				
	3							-51	BOLT	A2-4						29				
	3							-52	LOCKNUT	A2-4						30				
	3							-53	WASHER	A2-4						31				
		1						-54	TUBE	C3-6						1,2,4,5,9				
	1							-55	TUBE	C3-6						1,2,4,5,9				
					18			-56	SPREADER ASSY	A3-5						24				
								-57	TUBE	A3-6						1,2,4,5,9,20				
								-58	LUG FITTING	B4-2						23				
								-59	CLEVIS FITTING	B4-4						23				
								-60	TEE	B2-6						25				

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5007 3210 ORIG 9 77

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES
SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH 361418

SHEET 10

REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD 56	QTY REQD -46	QTY REQD -45	QTY REQD -44	QTY REQD -43	QTY REQD -42	QTY REQD -41	QTY REQD -38	QTY REQD -37	QTY REQD -36	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																					1	1	1		-41	
																						1	1		-42	
																									-43	
																					1	1	1		-44	
																									-45	
																		1	1						-46	
																1	1								-47	
																				1					-48	
																				1					-49	
																					3	3	3		-50	
																					3	3	3		-51	
																					3	3	3		-52	
																				1	3	3	3		-53	
																					1				-54	
																						1	1		-55	
																									-56	
														1											-57	
														1											-58	
														1											-59	
														1											-60	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

DO 6000 3422 ORIG. 4/73

UPDATED 11-29-83

PARTS LIST — THE BOEING COMPANY, CORPORATE OFFICES, SEATTLE, WASHINGTON 98124 — FSCM NUMBER 81205 — PL KH361418 — SHEET 11

EAMR NUMBER	QTY REQD -71	QTY REQD -70	QTY REQD -4	QTY REQD -56	QTY REQD -3	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICAB. NOTES	PT MK	FINISH	TR	RCN	EAMR
				2				-61	LUG-ANGLE	A2-6						19					
				1				-62	BOLT	B4-4						32					
				1				-63	LOCKNUT	B4-4						30					
				4				-64	WASHER	B4-4						31					
				1				-65	PIN	B4-4						33					
				1				-66	HITCH PIN	B4-4						34					
					6			-67	CABLE ASSY END	D4-3						15					
					15			-68	CABLE ASSY CHORD	D4-3						15					
					30			-69	CABLE ASSY BRACE	D4-3						15					
			12					-70	BHD PANEL ASSY	A2-7						24					
			11					-71	BHD PANEL ASSY	C4-8						24					
			2					-72	BHD PANEL ASSY	C4-8						24					
			96					-73	LINK TUBE ASSY	D3-11						24					
			8					-74	END TUBE ASSY	D3-11						24					
			48					-75	TELESCOPE TUBE	B3-11						24					
	AR	AR						-76	TUBING	D4-12						1,9,36					
								-77	TUBING-INNER	C4-12						1,9,36					
	4	4						-78	CORNER TIE	B4-12						37					
	2	2						-79	CORNER TIE	A4-12						37					
		2						-80	TEE PLATE LG	C3-9						35					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

U1 5007 3210 ORIG. 9 77

UPDATED 11-29-83

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418 SHEET 12 REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																					-75	-74	-73	-72			
																										-61	
																										-62	
																										-63	
																										-64	
																										-65	
																										-66	
																										-67	
																										-68	
																										-69	
																										-70	
																										-71	
																										-72	
																										-73	
																										-74	
																										-75	
																					AR	AR	AR	AR		-76	
																					AR					-77	
																								4		-78	
																								2		-79	
																										-80	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

DO 6000 5423 ORIG. 6/73

UPDATED 11-29-83

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER | FSCM NUMBER 81205 | PL KH361418 | SHEET 13

EAMR NUMBER	QTY REQD -73	QTY REQD -72	QTY REQD -71	QTY REQD -70	QTY REQD -4	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PI MK	FINISH	TR	RCN	EAMR
			2					-81	TEE PLATE MED	B4-9						35					
			2	2				-82	TEE PLATE SM	A4-9						35					
		2						-83	ANGLE TEE PLATE	B2-9						35					
		2						-84	ANGLE TEE PLATE	A3-9						35					
			2					-85	INSERT FITTING	C2-10						35					
			2					-86	TEE FITTING	C3-10						35					
					2			-87	END FITTING	A4-10						35					
	2							-88	CLEVIS FITTING	C4-10						35					
								-89	LATCH	C2-10						35					
								-90	LATCH HOLDER	B2-10						35					
								-91	LATCH LUG	A2-10						35					
								-92	LATCH SPRING	C3-11											
								-93	LATCH PIN	C3-11											
								-94	HITCH PIN	C3-11											
								-95	WASHER	C3-11											
								-96	PIN												
								-97	PIN												
								-98	INSERT												
								-99	SHEAVE												
								-100	HITCH PIN												

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5001 3210 ORIG. 9 77

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418

SHEET 14

REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD -85	QTY REQD -75	QTY REQD -74	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																										-81	
																										-82	
																										-83	
																										-84	
																										-85	
																										-86	
																										-87	
																										-88	
																							1			-89	
																							1			-90	
																							1			-91	
																							1			-92	
																							1			-93	
																							2			-94	
																							2			-95	
																										-96	
																										-97	
																						1	-			-98	
																										-99	
																										-100	

DO 6000 3425 ORIG. 4/73

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

UPDATED 1-18-84

PARTS LIST

COMPANY
CORPORATE OFFICES SEATTLE WASHINGTON

CONTRACT NUMBER

FSCM NUMBER 81205 | FL KH361418 | SHEET 15

EAME NUMBER	QTY REQD 39	QTY REQD 38	QTY REQD 37	QTY REQD 36	QTY REQD 35	QTY REQD -1	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PI MK	FINISH	IR	RCN	EAMR
								-101	CAP SCREW												
								-102	WASHER												
								-103	LOCK TITE												
						24		-104	DIAGONAL TUBE	C3-11						24					
						24		-105	SPACER	D2-12											
						12		-106	ANGLE FITTING	A3-11											
								-107	CAP SCREW												
								-108	CLEVIS FITTING	C4-10						35					
	AR	AR	AR	AR	AR	AR		-109	EPOXY ADHESIVE							24					
								-110	REFLECTOR ASSY												
								-111	GORE ASSY												
						1		-112	SUPPORT CABLE ASSY	A4-13											
								-113	RADIAL CABLE ASSY	A2-13						41,42					
								-114	WEB CABLE ASSY	C4-14						41, 42					
								-115	" " "	C4-14						41,42					
								-116	" " "	C4-14						41,42					
								-117	" " "	B4-14						41,42					
								-118	" " "	B4-14						41,42					
								-119	" " "	B4-14						41,42					
								-120	" " "	A4-14						41,42					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5007 3210 ORIG. 9 77

UPDATED 1-18-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418 SHEET 16 PE/LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD 113	QTY REQD 112	QTY REQD 105	QTY REQD 75	QTY REQD 74	QTY REQD 73	QTY REQD 72	QTY REQD 71	QTY REQD 45	QTY REQD 44	QTY REQD 43	QTY REQD 42	QTY REQD 41	QTY REQD 40	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																										-101	
																										-102	
																										-103	
																										-104	
																										-105	
																										-106	
																										-107	
																										-108	
													AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	-109	
																										-110	
																										-111	
																										-112	
												18														-113	
												18														-114	
												18														-115	
												18														-116	
												18														-117	
												18														-118	
												18														-119	
												18														-120	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

BO 6000 3420 ORIG. 4/73

1-18-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 | PL KH361418 | SHEET 17 | REV LTR

EASIER NUMBER	QTY REQD -117	QTY REQD -116	QTY REQD -115	QTY REQD -114	QTY REQD -113	QTY REQD -112	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	FI MK	FINISH	TR	RCN	EAMR
						18		-121	WEB CABLE ASSY	A4-14						41,42					
						18		-122	" " "	A4-14						41,42					
						18		-123	" " "	A3-14						41,42					
						18		-124	" " "	A3-14						41,42					
						18		-125	" " "	A3-14						41,42					
						18		-126	" " "	B3-14						41,42					
						18		-127	" " "	B3-14						41,42					
						18		-128	" " "	C3-14						41,42					
						18		-129	" " "	C3-14						41,42					
						18		-130	" " "	C3-14						41,42					
						18		-131	" " "	A2-14						41,42					
						18		-132	" " "	A2-14						41,42					
						18		-133	" " "	A2-14						41,42					
						18		-134	" " "	C2-14						41,42					
						18		-135	WEB CABLE ASSY	C2-14						41,42					
					AR			-136	1/8" DIA CABLE							38					
	AR	AR	AR	AR	AR			-137	1/16" DIA CABLE							39					
					4			-138	CLEVIS-1/8" CABLE	B4-15						40					
	8	6	6	6	52			-139	CLEVIS-1/16" CABLE	C4-15						40					
					50			-140	TEE - 3 TAB	A4-15						40					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

ORIGINAL PAGE IS OF POOR QUALITY

D1 5007 3210 ORIG. 9/77

1-18-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418 SHEET 18 REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD -138	QTY REQD -137	QTY REQD -136	QTY REQD -135	QTY REQD -134	QTY REQD -133	QTY REQD -132	QTY REQD -131	QTY REQD -130	QTY REQD -129	QTY REQD -128	QTY REQD -127	QTY REQD -126	QTY REQD -125	QTY REQD -124	QTY REQD -123	QTY REQD -122	QTY REQD -121	QTY REQD -120	QTY REQD -119	QTY REQD -118	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																					—					-121	
																				—						-122	
																			—							-123	
																		—								-124	
																	—									-125	
																—										-126	
															—											-127	
														—												-128	
													—													-129	
												—														-130	
											—															-131	
										—																-132	
									—																	-133	
								—																		-134	
							—																			-135	
																										-136	
							AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR	AR		-137	
																										-138	
				4	4	4	20	20	18	18	18	16	16	16	14	14	12	12	12	10	10	10	8	8		-139	
																										-140	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

1-23-84
6-20-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NO.

FSCM NUMBER 81205 PL KH361418 SHEET 19 REV LTR

EAMR NUMBER	QTY REQD -117	QTY REQD -116	QTY REQD -115	QTY REQD -114	QTY REQD -113	QTY REQD -112	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PT MA	FINISH	TR	RCN	EAMR
	4	2	2	2				-141	TEE - I TAB	A3-15						40					
					36			-142	TURNBUCKLE ASSY												
								-143	TERMINATION	D3-15						40					
								-144	CLEVIS END	C3-15						40					
								-145	BODY	B3-15						40					
								-146	LOCKNUT	D2-15						40					
					2			-147	LINEAR DRIVE	A1-15						43					
	2	1	1	1	26			-148	LINEAR DRIVE	A1-15						44					
	10	7	7	7	150			-149	PIN HEADED							45					
					6			-150	PIN - HEADED							46					
	7	7	7	7	150			-151	AN960C6 WASHER												
					6			-152	AN960C102 WASHER												
	7	7	7	7	150			-153	MS 24665 -1011 COTTER PIN												
					6			-154	MS 24665 - 1012 COTTER PIN												
						1		-155	DISK ASSY	A2-16						24					
								-156	DISK	A2-16						47					
								-157	ANGLE TAB	A2-16						47					
								-158	MAST ASSY	D3-17						48					
								-159	TUBE ASSY - LONGD	A3-20						24					
								-160	TUBE ASSY - DIAG	C3-20						24					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

D1 5007 3210 ORIG 9 77

1-23-84
6-20-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418 SHEET 20 REV LTR

QTY REQD -158	QTY REQD -1	QTY REQD -155	QTY REQD -142	QTY REQD -138	QTY REQD -137	QTY REQD -136	QTY REQD -135	QTY REQD -134	QTY REQD -133	QTY REQD -132	QTY REQD -131	QTY REQD -130	QTY REQD -129	QTY REQD -128	QTY REQD -127	QTY REQD -126	QTY REQD -125	QTY REQD -124	QTY REQD -123	QTY REQD -122	QTY REQD -121	QTY REQD -120	QTY REQD -119	QTY REQD -118	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
							16	16	14	14	14	12	12	12	10	10	8	8	8	6	6	6	4	4		-141	
																										-142	
			1																							-143	
			1																							-144	
			1																							-145	
			2																							-146	
																										-147	
							8	8	7	7	7	6	6	6	5	5	4	4	4	3	3	3	2	2		-148	
							28	28	25	25	25	22	22	22	19	19	16	16	16	13	13	13	10	10		-149	
																										-150	
							28	28	25	25	25	22	22	22	19	19	16	16	16	13	13	13	10	10		-151	
																										-152	
							28	28	25	25	25	22	22	22	19	19	16	16	16	13	13	13	10	10		-153	
																										-154	
																										-155	
		1																								-156	
		2																								-157	
	2																									-158	
114																										-159	
152																										-160	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

6-20-84
8-3-84
8-9-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER | FSCM NUMBER 81205 | PL KH361418 | SHEET 21 | REV LTR

EAMR NUMBER	QTY REQD -163	QTY REQD -162	QTY REQD -161	QTY REQD -160	QTY REQD -159	QTY REQD 158	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PT MK	FINISH	TR	R	EAMR
						40		-161	TUBE ASSY - CROSS	B3-20						24					
						38		-162	TUBE ASSY - TEL	B3-20						24					
						3		-163	TUBE ASSY - END	A3-20						24					
						2		-164	TUBE ASSY-UPR END	D3-20						24					
						4		-165	TUBE ASSY-SIDE END	C3-20						24					
						38		-166	FITTING - UPR	A2-18						40					
						74		-167	FITTING - LWR	A3-19						40					
						1		-168	FITTING-UPR END	A2-17						40					
						1		-169	FITTING-LWR END	A3-17						40					
						1		-170	OPP -169							40					
		1						-171	FITTING - TEL	A4-19						40					
		2						-172	BUTTON- DETENT	A3-19						40					
		1						-173	SPRING												
	2				1			-174	FITTING, HINGE CL	B2-19						40					
	2				1			-175	FITTING, HINGE TO	B1-19						40					
	2				1			-176	LATCH							40					
	2				1			-177	STRIKER PLATE							40					
	2				1			-178	SPRING												
	2				1			-179	PIN							23					
	2				2			-180	FITTING-CLEVIS	C3-19						40					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

01 5007 3210 ORIG. 8 77

6-20-84
8-3-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418

SHEET 22

REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD 209	QTY REQD 208	QTY REQD -207	QTY REQD -206	QTY REQD -165	QTY REQD -164	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																										-161	
																										-162	
																										-163	
																										-164	
																										-165	
																										-166	
																										-167	
																										-168	
																										-169	
																										-170	
																			1							-171	
																			1							-172	
																										-173	
																				2	2			1		-174	
																				2	2			1		-175	
																				2	2			1		-176	
																				2	2			1		-177	
																			1	2	2			1		-178	
																				2	2			1		-179	
																				2	2			2		-180	

CO 9033 3425 ORIG. 4/73

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

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8-3-84
8-9-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER | FSCM NUMBER 81205 | **PL** KH361418 | SHEET 23 | REV LTR

EAMR NUMBER	QTY REQD -163	QTY REQD -162	QTY REQD -161	QTY REQD -160	QTY REQD -159	QTY REQD -158	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	FT MK	FINISH	TR	RCN	EAMR
		2	2					-181	FITTING - TOGGLE	C2-19						40					
				2				-182	FITTING - ANGLE	B3-19						40					
					1			-183	TUBE - LONG	B2-20						1,2,48					
					1			-184	TUBE - DIAG												
			1					-185	TUBE - CROSS												
		1						-186	TUBE - OUTER												
		1						-187	TUBE - INNER												
								-188	TUBE - END												
								-189	TUBE - UPR END												
								-190	TUBE - END SIDE												
		1						-191	TUBE												
				1				-192	TUBE - DIAG												
	2							-193	TUBE - END												
	1							-194	TUBE - END												
	1							-195	TUBE - END	B2-20						1,2,48					
						76		-196	SCREW - HEX HD							40,50					
						76		-197	NUT - HEX							40,50					
	2				2			-198	SCREW - PAN HD							51					
	2					244		-199	SCREW - HEX HD					.875 GRIP		40,49					
	2					486		-200	NUT - HEX							40,49					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

6-20-84
8-9-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418

SHEET 24

REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD 210	QTY REQD 209	QTY REQD 208	QTY REQD 207	QTY REQD 206	QTY REQD -165	QTY REQD -164	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																			2			2				-181	
																		2					2			-182	
																										-183	
																										-184	
																										-185	
																										-186	
																										-187	
																								1		-188	
																								1		-189	
																							1			-190	
																		1								-191	
																										-192	
																										-193	
																										-194	
																										-195	
																										-196	
																										-197	
																				2	2			2		-198	
																				2	2					-199	
																				2	2					-200	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

CO 6232 1425 ORIG. 4/73

C-3

8-3-84
8-9-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 PL KH361418 SHEET 25 REV LTR

EAMR NUMBER	QTY REQD -163	QTY REQD -162	QTY REQD -161	QTY REQD -160	QTY REQD -159	QTY REQD -158	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PT MK	FINISH	EE	RCN	EAMR
						1		-201	FITTING - UPR							40					
						1		-202	FITTING - END							40					
						1		-203	FITTING - END							40					
						1		-204	FITTING - LWR							40					
						1		-205	FITTING - LWR							40					
						2		-207	TUBE ASSY - LWR	A3-20						24					
						2		-208	TUBE ASSY - DIAG	A3-20						24					
						1		-209	TUBE ASSY - TEL	B3-20						24					
						4		-210	TUBE ASSY - DIAG	C3-20						24					
						242		-211	SCREW-HEX HD					.75 GRIP		40, 49					
						1		-212	FITTING - END	C4-19						40					
								-214	TUBE - SIDE	B2-20						1,2,4,8					
								-215	TUBE - SIDE												
								-216													
								-217	TUBE - UPR												
								-218	TUBE - UPR												
								-219	TUBE - DIAG												
								-220	TUBE - DIAG	B2-20						1,2,4,8					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

8-3-84
8-9-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER | CODE IDENT NUMBER | PL KH 361418 | SHEET 26 | REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																		-210	-209	-208	-207		-165	-164			
																										-201	
																										-202	
																										-203	
																										-204	
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																										-211	
																										-212	
																					2					-214	
																					1					-215	
																				2						-217	
																				1						-218	
																		1								-219	
																			1							-220	

ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

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8-3-84

PARTS LIST

THE BOEING COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

FSCM NUMBER 81205 PL KH361418 SHEET 27 REV LTR

EAMR NUMBER	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD -210	QTY REQD -209	FIND NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	ZONE	PART TYPE	FSCM NUMBER	STOCK SIZE WD	STOCK SIZE LG	STOCK SIZE U/M	APPLICABLE NOTES	PT MK	FINISH	TR	RCM	EAMR
						1		-221	TUBE - DIAG	BZ-20						1,2,4,8					

ADDITIONAL QTY REQD COLUMNS MAY BE SHOWN ON CONTINUATION SHEET IMMEDIATELY FOLLOWING

8-3-84

PARTS LIST

THE **BOEING** COMPANY
CORPORATE OFFICES SEATTLE, WASHINGTON 98124

CONTRACT NUMBER

CODE IDENT NUMBER

PL KH361418

SHEET 28

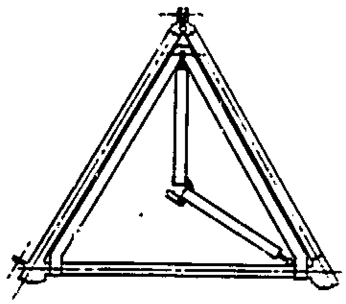
REV LTR

QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	QTY REQD	FIND NUMBER	PART OR IDENTIFYING NUMBER	REV LTR
																										-221	

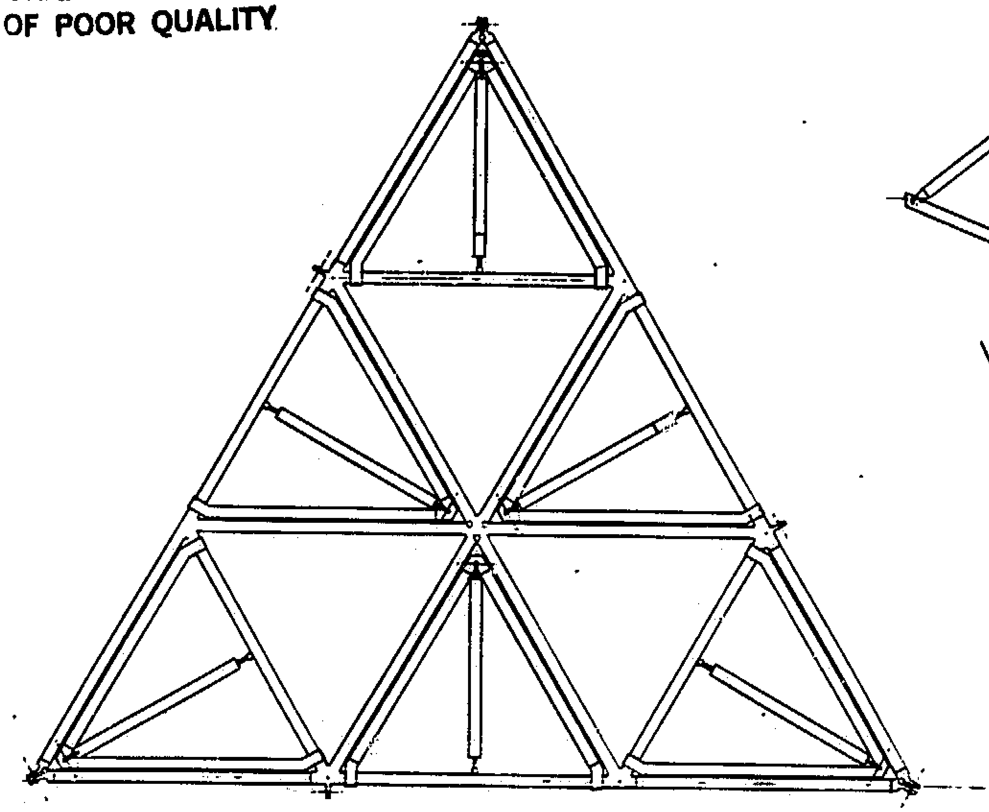
ENTRIES ON THIS SHEET ARE CONTINUATIONS OF ENTRIES ON PRECEDING SHEET

CO 6330 1435 ORIG. 4/73

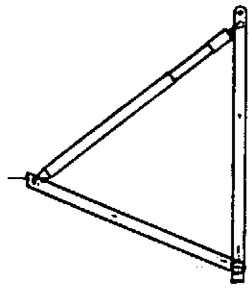
FOLDOUT FRAME



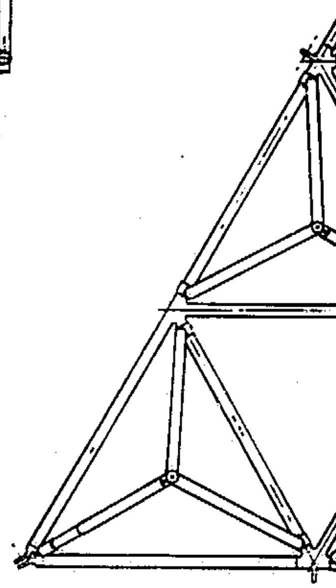
ALTERNATE LEG JOINT



CONCEPT I STOWED
SHOWN FLAT WITHOUT SPHERICAL CURVATURE



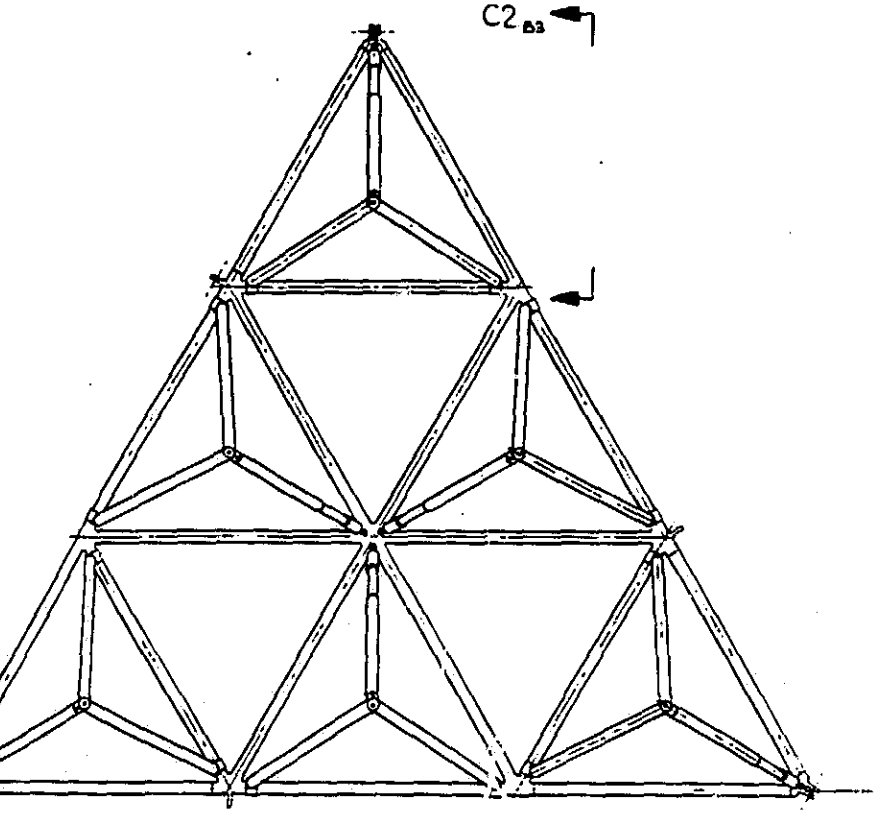
VIEW C2



CONCEPT I DEPLOYE
BASE TRIANGLE SHOWN FLAT WI
SPHERICAL CURVATURE

FOLDOUT FRAME 2

ORIGINAL PAGE IS OF POOR QUALITY



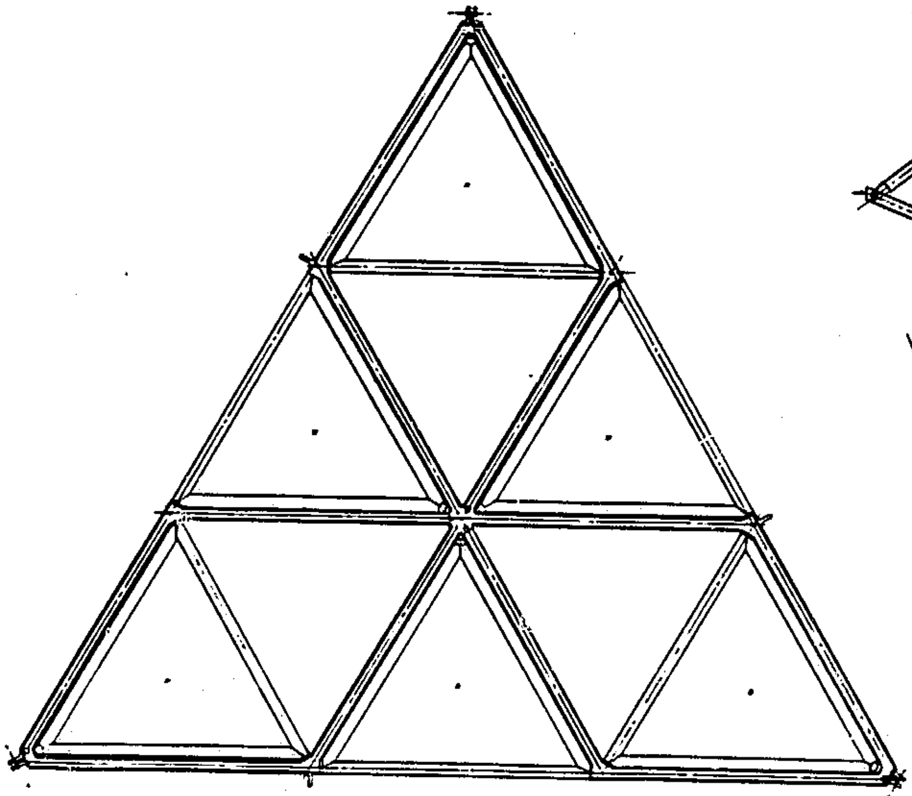
CEPT I DEPLOYED
TRIANGLE SHOWN FLAT WITHOUT
ICAL CURVATURE

BOEING
OPTICAL TELESCOPE
SUPPORT STRUCTURE
CONCEPT I LSS-4
KH 361419

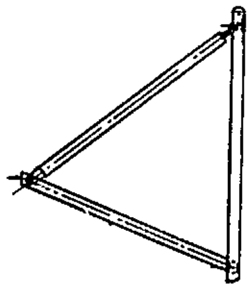
KH 361419

KH3214125

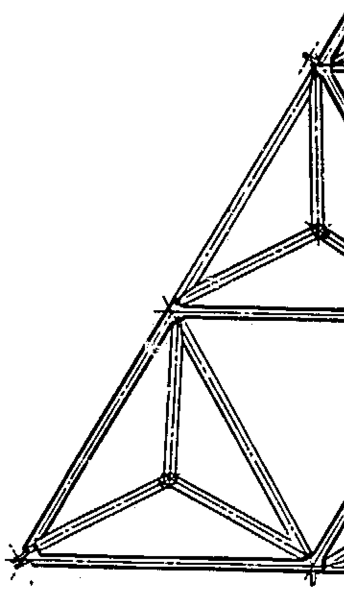
FOLDOUT FRAME



CONCEPT II STOWED
SHOWN FLAT WITHOUT SPHERICAL CURVATURE



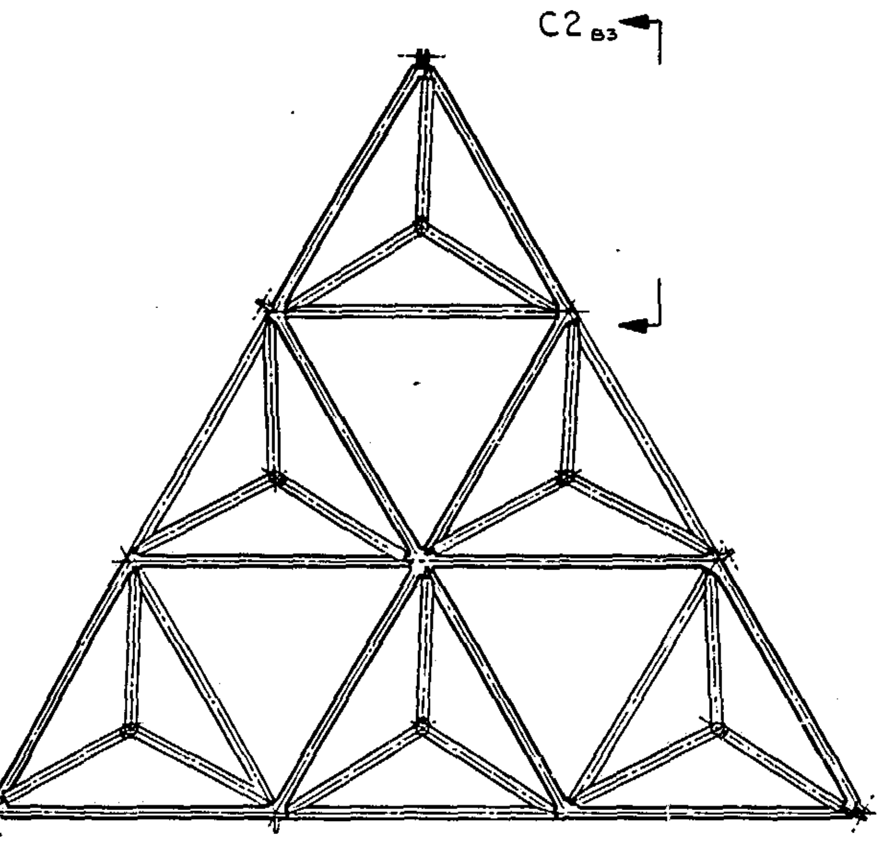
VIEW C2



CONCE
BASE TRIA
SPHERICA

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME



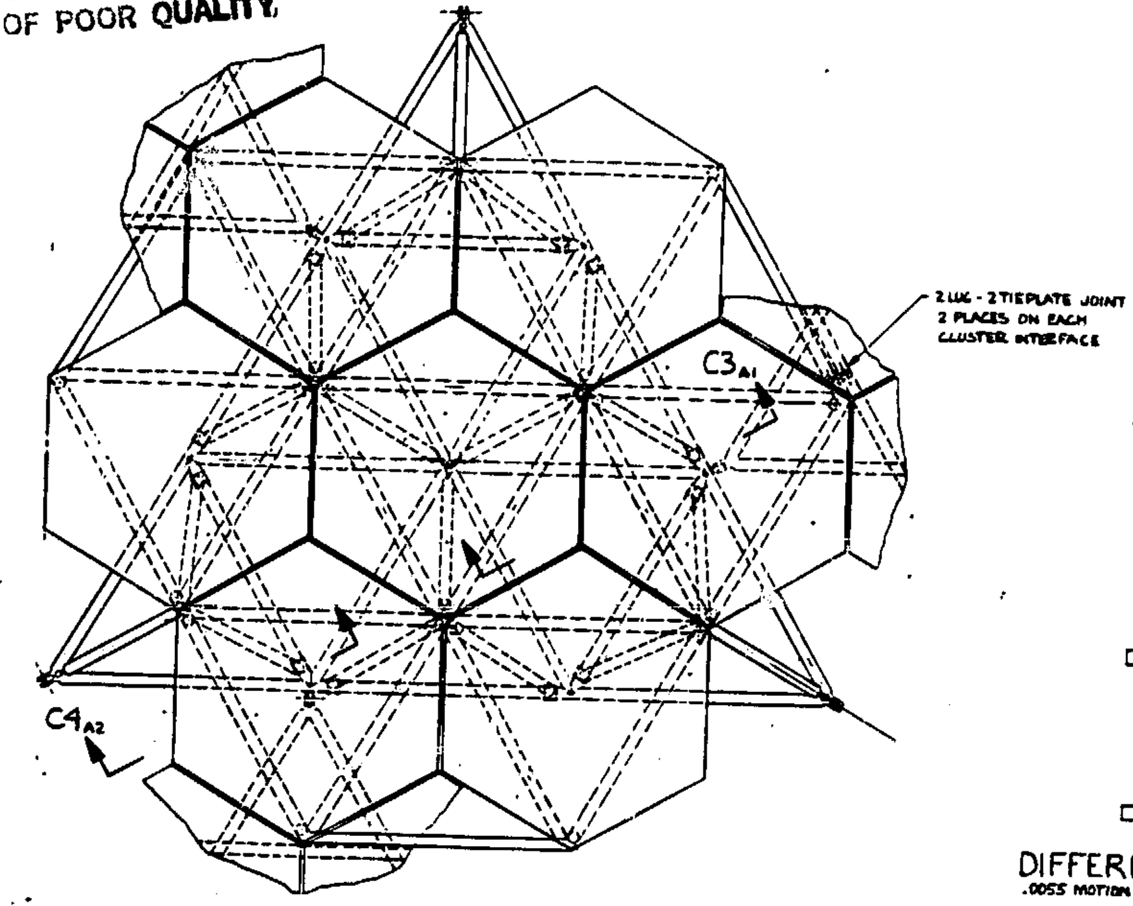
CONCEPT II DEPLOYED
BASE TRIANGLE SHOWN FLAT WITHOUT
SPHERICAL CURVATURE

BOEING
CORPORATE OFFICES SEATTLE, WASHINGTON

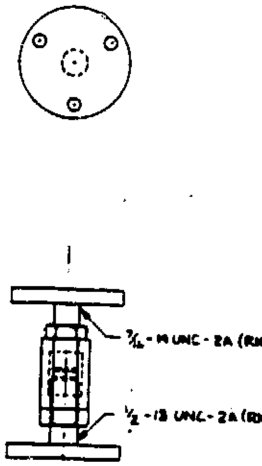
OPTICAL TELESCOPE
SUPPORT STRUCTURE
CONCEPT II LSS-4

E KH361419

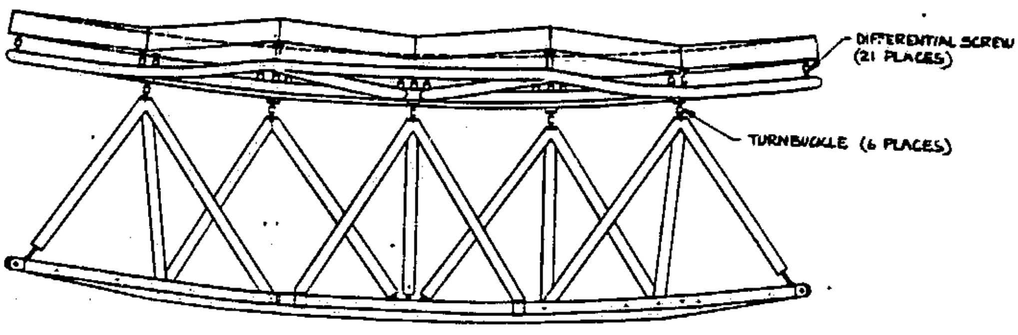
KH361419



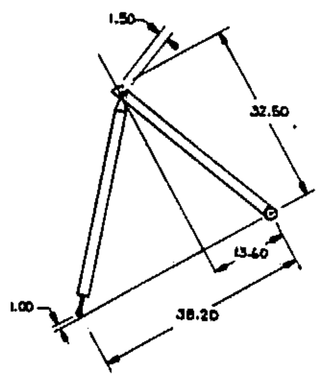
7 MIRROR CLUSTER
FRONT VIEW



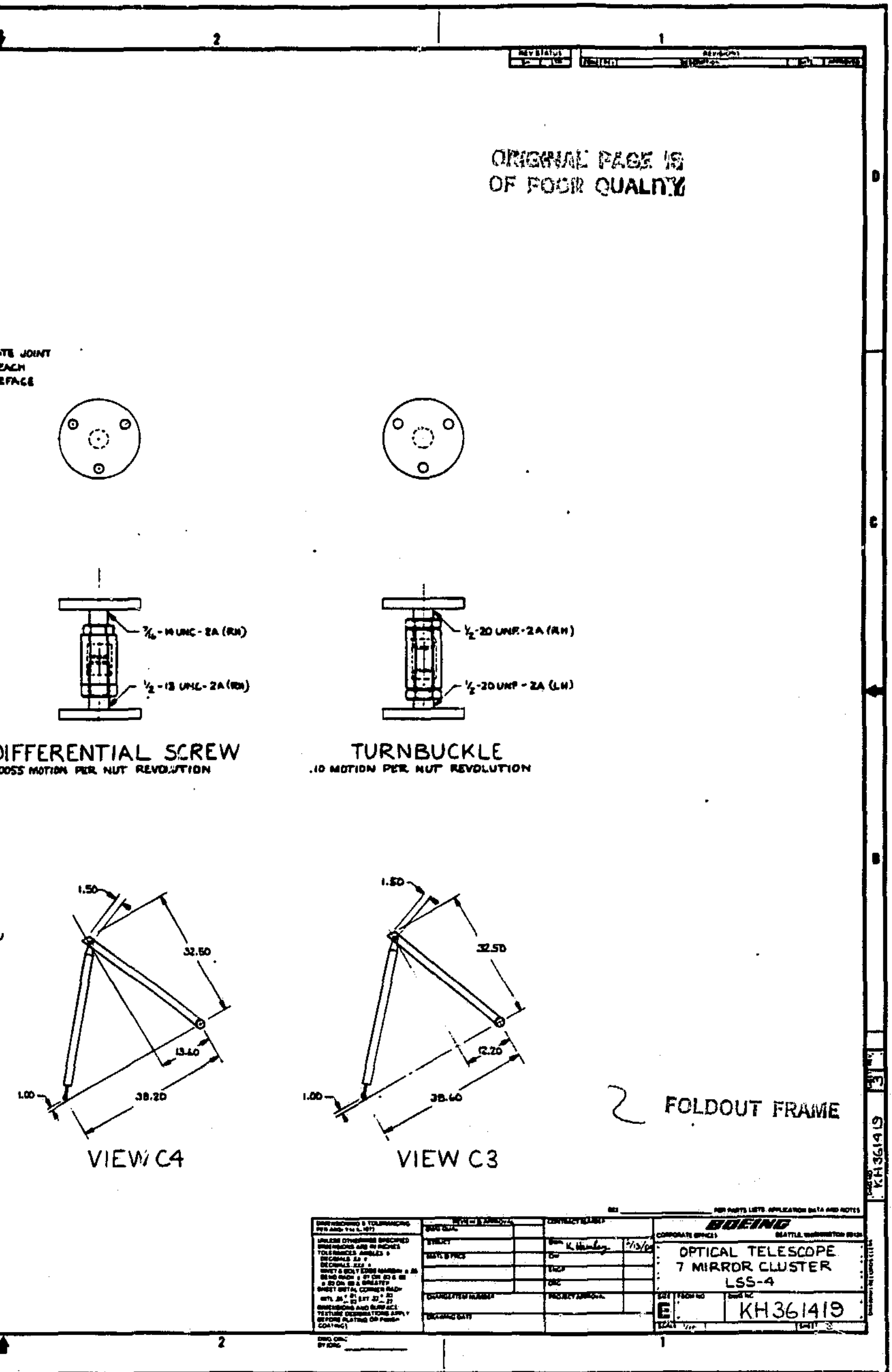
DIFFERENTIAL SCREW
.0055 MOTION PER NUT REVOLUTION



SIDE VIEW



VIEW C4


DIFFERENTIAL SCREW
.0055 MOTION PER NUT REVOLUTION
7/16 - 14 UNC - 2A (RH)
1/2 - 13 UNC - 2A (RH)
TURNBUCKLE
.10 MOTION PER NUT REVOLUTION
1/2 - 20 UNF - 2A (RH)
1/2 - 20 UNF - 2A (LH)
1.50
32.50
13.40
38.20
1.00
VIEW C4
1.50
32.50
12.20
38.60
1.00
VIEW C3
FOLDOUT FRAME
BOEING
OPTICAL TELESCOPE
7 MIRROR CLUSTER
LSS-4
E
KH361419

KH361413

APPENDIX B

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 1	
Review assembly procedure	480.0
Don suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
Obtain area lights	5.0
install lighting	10.0
turn on and adjust	4.0
Obtain CCTV equipment	5.0
Break	10.0
Mount CCTV	8.0
turn on and adjust	4.0
Prepare tool kit	5.0
Inspect berthing port	5.0
Activate RMS	5.0
Translate RMS to transfer tunnel	2.0
Secure RMS to transfer tunnel	1.0
Release transfer tunnel hold downs	1.0
Remove transfer tunnel from storage/orbiter bay	2.0
Translate transfer tunnel to berthing port	4.0
Berth transfer tunnel	2.0
Verify transfer tunnel berthed	5.0
Release RMS	1.0
Translate RMS to storage area/orbiter bay	2.0
Attach RMS to basic truss module	1.0
Release basic truss module hold downs	1.0
Remove basic truss module from storage/orbiter bay	3.0
Break	10.0
Deploy basic truss	25.0
Verify truss braces latched	12.0
Lunch	15.0
Verify truss braces latched	23.0
** SUBTOTAL **	
	686.0
* 2	
TEST TRUSS	0.0
Obtain vibration excitation equipment	15.0
Install vibration excitation equipment	4.0
Connect vibration excitation equipment	5.0
Test vibration excitation and data system	5.0
Stow tool kit	5.0
Enter air lock and pressurize	15.0
Doff suit	15.0
Conduct modal survey	240.0
** SUBTOTAL **	
	304.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 3	
ATTACH TRUSS	0.0
Don suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
Prepare tool kit	5.0
Align basic truss with transfer tunnel	10.0
Position truss on transfer tunnel	5.0
Attach top braces	2.0
Attach bottom braces	2.0
Attach tangent braces	4.0
Break	10.0
Verify braces secure	10.0
Release RMS	1.0
Stow RMS	5.0
** SUBTOTAL **	
	89.0
* 4	
INSTALL UTILITIES	0.0
Translate RMS to utilities package	2.0
Secure RMS to utilities package	1.0
Release utilities package hold downs	1.0
Translate utilities package to platform	2.0
Secure utilities package to platform	2.0
Release RMS	1.0
Prepare utilities package for assembly	5.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
Break	10.0
String and attach electrical and data lines	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
String and attach electrical and data lines	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
Lunch	15.0
String and attach electrical and data lines	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
String and attach electrical and data lines	10.0
Break	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
String and attach electrical and data lines	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
Break	10.0
String and attach electrical and data lines	10.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 4	
Remove utilities box	5.0
stow tool kit	5.0
Enter airlock and pressurize	15.0
Doff EVA suit	15.0
Don EVA suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
Prepare LSS-1 tool kit	5.0
Attach utilities box to platform	10.0
Break	10.0
String and attach electrical and data lines	10.0
Remove utilities box	5.0
Attach utilities box to platform	15.0
String and attach electrical and data lines	10.0
Connect electrical utility and data lines to SS	15.0
Break	10.0
Test lines	15.0
** SUBTOTAL **	
	419.0
* 5	
TEST TRUSS	0.0
Obtain instrumentation (accel., thermal, corner ref.	5.0
Install instrumentation on truss	20.0
Connect instrumentation to SS test subsystem	5.0
Lunch	15.0
Test instrumentation	15.0
Obtain laser measurement equipment	5.0
Install laser assembly on transfer tunnel	10.0
Connect laser to test subsystem	5.0
Test laser	5.0
Stow equipment containers	10.0
Break	10.0
Connect vibration excitation equipment	5.0
Test vibtration excitation equipment	5.0
Stow tool kit	5.0
Enter air lock and pressurize	15.0
Doff suit	15.0
Conduct flatness and thermal deformation tests	240.0
Conduct modal survey	240.0
** SUBTOTAL **	
	630.0
* 6	
INSTALL FLOOR	0.0
Don EVA suit	15.0
Pump down airlock	15.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 6	
Exit airlock	5.0
Prepare LSS tool kit	5.0
Obtain panel for platform floor	5.0
Install panel	8.0
Obtain panel for platform floor	5.0
Install panel	8.0
Break	10.0
Obtain panel for platform floor	5.0
Install panel	8.0
Obtain panel for platform floor	5.0
Install panel	8.0
Obtain payload support rail assembly	1.0
Install payload support rail #1 assembly	14.0
Break	10.0
Install payload support rail #2 assembly	16.0
Stow tool kit	5.0
Enter airlock and pressurize	15.0
Doff EVA suit	15.0
Conduct modal survey	240.0
** SUBTOTAL **	
	418.0
* 7	
INSTALL SOLAR SHIELD	0.0
Don EVA suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
Prepare tool kit	5.0
Activate RMS	5.0
Translate RMS to storage/orbiter bay	2.0
Attach RMS to solar shield package	1.0
Release solar shield holddowns	1.0
Remove solar shield from storage/orbiter bay	2.0
Translate solar shield to platform	4.0
Secure solar shield to platform	2.0
Release RMS	1.0
Stow RMS	5.0
Break	10.0
Obtain solar shield	5.0
Install solar shield R1	10.0
Obtain solar shield	5.0
Install solar shield R2	10.0
Obtain solar shield	5.0
Install solar shield R3	10.0
Obtain solar shield	5.0
Install solar shield R4	10.0
Break	10.0
Obtain solar shield	5.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 7	
Install solar shield R5	10.0
Obtain solar shield	5.0
Install solar shield R6	10.0
Obtain solar shield	5.0
Install solar shield R7	10.0
Lunch	15.0
Obtain solar shield	5.0
Install solar shield R8	10.0
Obtain solar shield	5.0
Install solar shield R9	10.0
Obtain solar shield	5.0
Install solar shield L1	10.0
Obtain solar shield	5.0
Break	10.0
Install solar shield L2	10.0
Obtain solar shield	5.0
Install solar shield L3	10.0
Obtain solar shield	5.0
Install solar shield L4	10.0
Break	10.0
Obtain solar shield	5.0
Install solar shield L5	10.0
Obtain solar shield	5.0
Install solar shield L6	10.0
Stow tool kit	5.0
Enter air lock and pressurize	15.0
Doff Suit	15.0
Don suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
Prepare tool kit	5.0
Obtain solar shield	5.0
Install solar shield L7	10.0
Break	10.0
Obtain solar shield	5.0
Install solar shield L8	10.0
Obtain solar shield	5.0
Install solar shield L9	10.0
Obtain botton solar shield	5.0
Install botton solar shield	5.0
Extend bottom solar shield	5.0
Secure solar shield	2.0
Obtain bottom solar shield	5.0
Install bottom solar shield	5.0
Break	10.0
Extend bottom solar shield	10.0
Activate RMS	5.0
Translate RMS to storage area	2.0
Attach RMS to extendable mast assembly	1.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 7	
Release extendable mast hold downs	1.0
Translate mast assembly into position	2.0
Align mast solar shield assembly	2.0
Attach ends of mast assembly to platform	10.0
Release RMS	1.0
Translate RMS to storage area	2.0
Attach RMS to extendable mast assembly	1.0
Release extendable mast hold downs	1.0
Translate mast assembly into position	2.0
Align mast assembly with platform	2.0
Attach ends of mast assembly to platform	10.0
Release RMS	1.0
Translate RMS to storage area	2.0
Lunch	15.0
Deploy R extendable mast and sunshield	10.0
Deploy L extendable mast and sunshield	10.0
Latch masts at peak	10.0
Secure sunshields at peak	10.0
Break	10.0
** SUBTOTAL **	
	630.0
* 8	
TEST HANGAR	0.0
Obtain instrumentation (accelerometers, reflectors)	15.0
Install instrumentation on hangar	5.0
Install instrumentation on hangar	25.0
Connect instrumentation to test subsystem	5.0
Break	10.0
Test instrumentation	15.0
Test laser	5.0
Stow equipment containers	5.0
Test vibration excitation equipment	15.0
Stow tool kit	5.0
Enter Airlock and pressurize	15.0
Doff EVA suit	15.0
Conduct flattness and thermal deformation tests	240.0
Conduct modal survey	240.0
** SUBTOTAL **	
	615.0
* 9	
REMOVE AND STOW TEST EQUIPMENT	0.0
Don EVA suit	15.0
Pump down airlock	15.0
Exit airlock	5.0
prepare tool kit	5.0

LSS-1 TIMELINE ANALYSIS

TASK	MIN
* 9	
Disconnect vibration excitation equipment	5.0
Remove vibration equipment from masts	20.0
Break	10.0
Stow vibration excitation equipment	30.0
Disconnect instrumentation from test subsystem	5.0
Remove instrumentation test cable	5.0
Stow instrumentation	10.0
Break	10.0
Disconnect laser meassurement equipment	5.0
Remove laser measurement equipment	30.0
Stow laser measurement equipment	15.0
Lunch	15.0
Stow laser measurement equipment	15.0
Remove accelerometers and reflectors	30.0
Stow tool kit	5.0
Enter air lock and pressurize	15.0
Doff EVA suit	15.0
Inspect platform and hangar	5.0
Turn off CCTV	1.0
Turn off lights	1.0
** SUBTOTAL **	
	287.0
** TOTAL **	
	4078.0

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 1	
START UP	0
Review assembly procedures	480
Don EVA suit	15
Pump down airlock	15
Activate platform lights	1
Activate remote CCTV	1
Exit airlock	5
Prepare LSS tool kit	5
** SUBTOTAL **	
	522
* 2	
ASSEMBLE CONSTRUCTION FIXTURE	0
Activate RMS	5
Translate RMS to construction fixture storage area	2
Secure RMS to construction fixture package	1
Release package hold downs	1
Translate construction fixture package to platform	2
Position package at platform hold downs	1
Secure package to hold downs	1
Release RMS	1
Break	10
Remove 2 # 1 rail segments	8
Latch rail segments together	4
Remove and attach 25 truss members	50
Break	10
Remove 2 # 1 rail segments	8
Latch rail segments together	4
Remove and attach 25 truss members	50
Lunch	15
Perform # 1 rail alignment	60
Break	10
Remove 2 # 2 rail segments	8
latch rail segments together	4
Remove and attach 25 rail segments	50
Break	10
Remove 2 # 2 rail segments	8
Latch rail segments together	4
Break	10
Remove and attach 8 truss members	16
Stow tool kit	5
Enter airlock and pressurize	15
Doff suit	15
Don suit	15
Pump down airlock	15
Exit airlock	5
Prepare toolkit	5
Remove and attach 17 truss members	34

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 2	
Break	10
Perform # 2 rail alignment	60
Translate RMS to storage area	2
Secure RMS to LSS-3 construction fixture motor	1
Release motor package hold downs	1
Translate motor package to platform	2
Position motor package	2
Attach motor package to platform	20
Release RMS	1
Release motor wiring from housing	2
String motor wiring to electrical,data bus	5
Break	10
Connect to bus	2
** SUBTOTAL **	
	580
* 3	
TEST CONSTRUCTION FIXTURE	0
Obtain insturmentation electrical lines	5
Install electrical lines	15
Obtain data lines	5
Connect electrical utility, and data lines to bus	5
Obtain instrumentation (accelerometers, reflectors)	5
Install instrumentation on fixture	20
lunch	15
Connect instrumentation to test subsystem	20
Obtain laser measurement equipment	5
Install laser	10
Test laser	5
Break	10
Connect laser to test subsystem	5
Obtain vibration excitation equipment	5
Install vibration excitation equipment	60
Break	10
Connect vibration excitation equipment	5
Test vibration excitation equipment	5
Stow equipment containers	10
Stow tool kit	5
Enter airlock and pressurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Disconnect vibration excitation equipment	5
Remove vibration excitation equipment from fixture	26

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 3	
Break	10
Disconnect instrumentation from the test subsystem	5
Remove instrumentation test cable	1
Stow instrumentation	15
Disconnect laser measurement cable	1
Remove laser measurement equipment	30
Break	10
Stow laser measurement equipment	10
** SUBTOTAL **	
	888
* 4	
ASSEMBLE TRUSS RING	0
Activate RMS	5
Translate RMS to MWR beam storage	2
Attach RMS to MWR beam package	1
Release MWR package hold downs	1
Translate beams to construction plaform	2
Prepare beams for assembly	5
Assemble 8 basic and 1 connecting beams and position	18
Lunch	15
Install 4 base members	8
Translate to peak	2
Install 4 peak members	8
Install 1 connecting member	2
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Install X braces	4
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam and position	16
Break	10
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Break	10
Install wiring	10
Install X braces	4
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 4	
Exit airlock	5
Prepare tool kit	5
Obtain beam parts	2
Assemble 7 basic and 1 connecting beams and position	16
Install 3 base members	6
Translate to peak	2
Break	10
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam and position	16
Break	10
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
install wiring	10
Break	10
Install X braces	4
Obtain beam parts	2
Assemble 7 basic and 1 connecting beams and position	16
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Lunch	15
Install wiring	10
Install X brace	4
Obtain beam parts	3

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 4	
Assemble 7 basic and 1 connecting beam and position	16
Install 3 base members	6
Break	10
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	2
Assemble 7 basic and 1 connecting beam and position	16
Install 3 base members	6
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Break	10
Install wiring	10
Install X brace	4
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam and position	16
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	2
Assemble 7 basic and 1 connecting beams and position	16
Break	10
Install 3 base members	6
Translate to peak	2

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 4	
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X brace	4
Lunch	15
** SUBTOTAL **	
	931
* 5	
TEST TRUSS	0
Obtain electrical lines	5
Install electrical lines	35
Obtain data lines	5
Break	10
Install data lines	35
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Connect electrical utility and data lines to SS	15
Break	10
Test lines	15
Obtain instrumentation (accelerometers, reflectors)	5
Install instrumentation on truss	20
Connect instrumentation on test subsystem	5
Test instrumentation	15
Break	10
Obtain laser measurement equipment	5
Install laser on transfer tunnel	10
Connect laser to test subsystem	5
Test laser	5
Stow equipment containers	10
Connect vibration excitation equipment	5
Test vibtration excitation equipment	5
Stow tool kit	5
Enter air lock and presssurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
** SUBTOTAL **	
	820

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 6	
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam	16
Break	10
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Break	10
Obtain beam parts	2
Assemble 7 basic and 1 connecting beams	16
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Lunch	15
Rotate ring	5
Install wiring	10
Install X brace	4
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam	16
Install 3 base members	6
Break	10
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	2
Assemble 7 basic and 1 connecting beams	16
Break	10
Install 3 base members	6
Translate to peak	2

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 6	
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Break	10
Install X brace	4
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam	16
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Break	10
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	2
Assemble 7 basic an 1 connecting beams	16
Install 3 base members	6
Lunch	15
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Obtain beam parts	2
Break	10
Assemble 7 basic and 1 connecting beams	16
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 6	
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Break	10
Install wiring	10
Install X brace	4
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Obtain beam parts	3
Assemble 7 basic and 1 connecting beam	16
Break	10
Install 3 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	3
Translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Rotate ring	5
Install wiring	10
Install X braces	4
Break	10
** SUBTOTAL **	
	840
* 7	
TEST TRUSS	0
Obtain electrical lines	5
Install electrical lines	35
Obtain data lines	5
Break	10
Install data lines	35
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Connect electrical utility and data lines to SS	15
Break	10
Test lines	15

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 7	
Obtain instrumentation (accelerometers, reflectors)	5
Install instrumentation on truss	20
Connect instrumentation on test subsystem	5
Test instrumentation	15
Break	10
Obtain laser measurement equipment	5
Install laser on transfer tunnel	10
Connect laser to test subsystem	5
Test laser	5
Stow equipment containers	10
Connect vibration excitation equipment	5
Test vibtration excitation equipment	5
Stow tool kit	5
Enter air lock and presssurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
** SUBTOTAL **	
	820
* 8	
COMPLETE TRUSS RING	0
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Obtain beam parts	2
Assemble 6 basic and 1 connecting beams	16
Break	10
Install 2 base members	6
Translate to peak	2
Install 4 peak members	8
Install 2 connecting members	4
translate back to base	2
Obtain corner reflectors and accelerometers	2
Mount corner reflectors and accelerometers	4
Install wiring	10
Break	10
Install X brace	4
** SUBTOTAL **	
	120
* 9	
TEST TRUSS	0
Obtain electrical lines	5
Install electrical lines	35
Obtain data lines	5

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 9	
Lunch	15
Install data lines	35
Connect electrical utility and data lines to SS	15
Break	10
Test lines	15
Obtain instrumentation (accelerometers, reflectors)	5
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Install instrumentation on truss	20
Break	10
Connect instrumentation on test subsystem	5
Test instrumentation	15
Obtain laser measurement equipment	5
Install laser	10
Connect laser to test subsystem	5
Test laser	5
Stow equipment containers	10
Break	10
Connect vibration excitation equipment	5
Test vibtration excitation equipment	5
Stow tool kit	5
Enter air lock and presssurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
** SUBTOTAL **	
	835
* 10	
Don EVA suit	15
Pressurize airlock	15
Exit airlock	5
Prepare tool kit	5
DEPLOY FEED SUPPORTS	0
Activate RMS	5
Translate RMS to feed support package	2
Secure RMS to feed support package	1
Release package hold downs	1
Translate feed support to construction area	2
Remove covers	5
Break	10
Deploy feed supports	10
Position feed support on truss	5

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 10	
Secure feed support to truss	5
Release RMS	1
Translate RMS to feed support package	2
Secure RMS to feed support package	1
Release package hold downs	1
Translate feed support to construction area	2
Remove covers	5
Deploy feed supports	10
Position feed support on truss	5
Secure feed support to truss	5
Release RMS	1
Translate RMS to feed truss package	2
Secure RMS to feed truss package	1
Release package hold downs	1
Translate feed truss to construction area	2
Break	10
Remove covers	5
Deploy feed truss	10
Position feed truss on feed supports	5
Secure feed support to truss	5
Release RMS	1
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Lunch	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Break	10
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Translate RMS to feed horn package	2

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 10	
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	10
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Lunch	15

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 10	
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Translate RMS to feed horn package	2
Secure RMS to feed horn package	1
Release package hold downs	1
Translate feed horn to construction area	2
Remove covers	5
Install feed horns	15
Break	10
Attach 4 cables to feed truss	10
Attach 2 cables to truss	10
Position other 2 cables	10
Tension 2 cables to position feed truss	10
attach 2 cables to truss	5
Break	10
** SUBTOTAL **	877

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 11	
TEST TRUSS	0
Obtain electrical lines	5
Install electrical lines	35
Obtain data lines	5
Lunch	15
Install data lines	35
Connect electrical utility and data lines to SS	15
Test lines	15
Obtain instrumentation (accelerometers, reflectors)	5
Install instrumentation on truss	20
Connect instrumentation on test subsystem	5
Test instrumentation	15
Break	10
Obtain laser measurement equipment	5
Install laser	10
Connect laser to test subsystem	5
Test laser	5
Stow equipment containers	10
Connect vibration excitation equipment	5
Test vibtration excitation equipment	5
Stow tool kit	5
Enter air lock and presssurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
** SUBTOTAL **	
	740
* 12	
INSTALL MEMBRANE	0
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Translate RMS to membrane package	2
Secure RMS to membrane package	1
Release membrane package holddowns	1
Translate membrane package to truss	2
Remove membrane package covers	10
Attach fittings to truss	10
Break	10
Deploy membrane	180
Attach membrane tensioning cables	180
Stow tool kit	5
Enter airlock and pressurize	15
Doff EVA suit	15
Don EVA suit	15
pressurize airlock	15

LSS-3 TIMELINE ANALYSIS

TASK	MIN
* 12	
Exit airlock	5
Prepare tool kit	5
** SUBTOTAL **	
	511
* 13	
TEST	0
Obtain electrical lines	5
Install electrical lines	35
Break	10
Obtain data lines	5
Install data lines	35
Connect electrical utility and data lines to SS	15
Lunch	15
Test lines	15
Obtain instrumentation (accelerometers, reflectors)	5
Install instrumentation on truss	20
Break	10
Connect instrumentation on test subsystem	5
Test instrumentation	15
Obtain laser measurement equipment	5
Install laser	10
Connect laser to test subsystem	5
Test laser	5
Break	10
Stow equipment containers	10
Connect vibration excitation equipment	5
Test vibtration excitation equipment	5
Stow tool kit	5
Enter air lock and presssurize	15
Doff suit	15
Conduct flatness and thermal deformation tests	240
Conduct modal survey	240
Don EVA suit	15
Pump down airlock	15
Exit airlock	5
Prepare tool kit	5
Remove laser	5
Stow laser	5
Remove instrumentation	5
Stow instrumentation	5
Break	10
Stow tool kit and equipment	15
Inspect platform to insure equipment stowed	10
Enter airlock and pressurize	15
Dofff EVA suit	15
Inspect platform with CCTV	5
Turn off CCTV	5

LSS-3 TIMELINE ANALYSIS

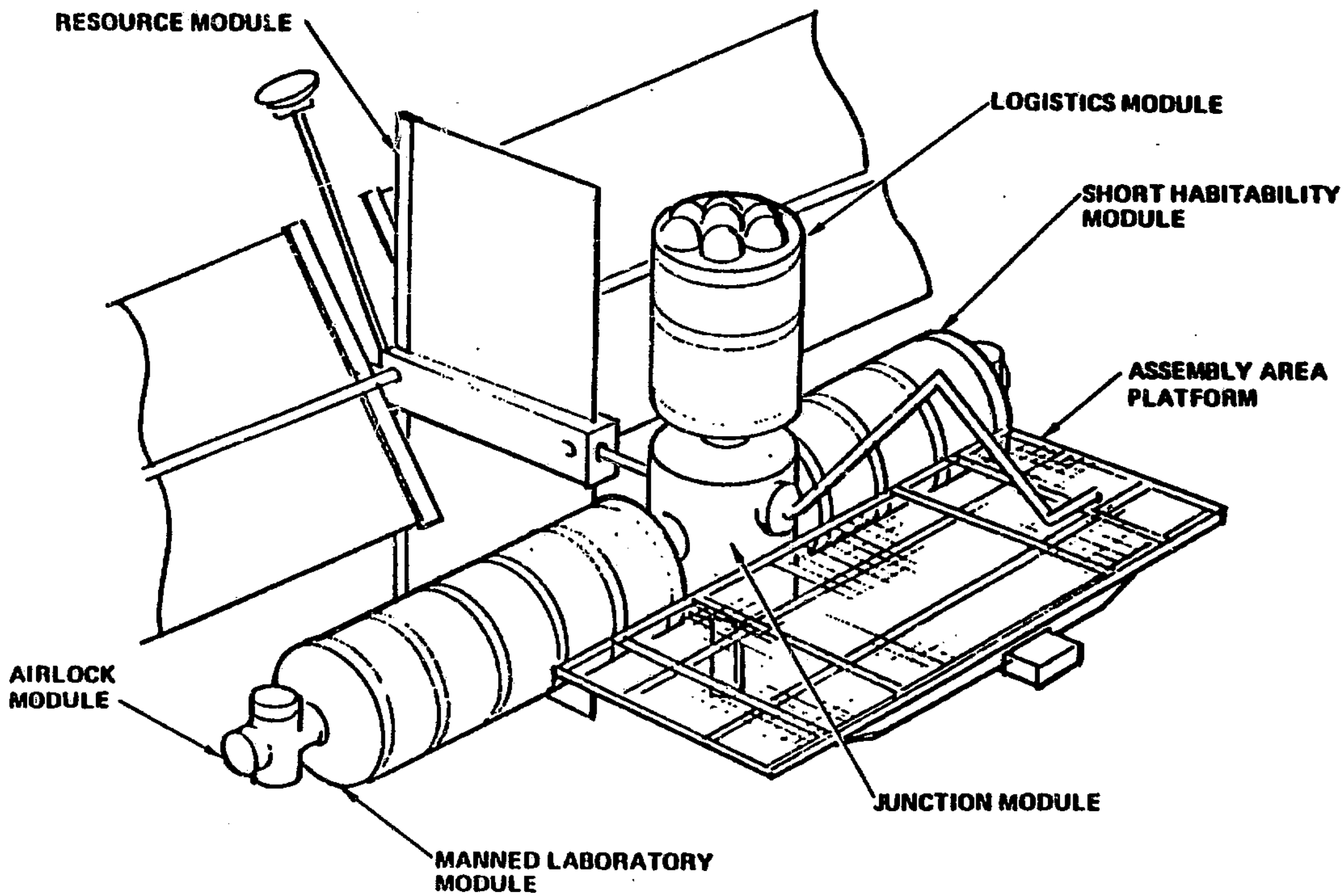
TASK	MIN
* 13	
Turn off lights	1
** SUBTOTAL **	896
** TOTAL **	9380

APPENDIX C

Program Management
Division
TRW Space &
Technology Group

Flight-4 Configuration (5 Crew)

TDM-181



Available Resources - TRW

BOEING

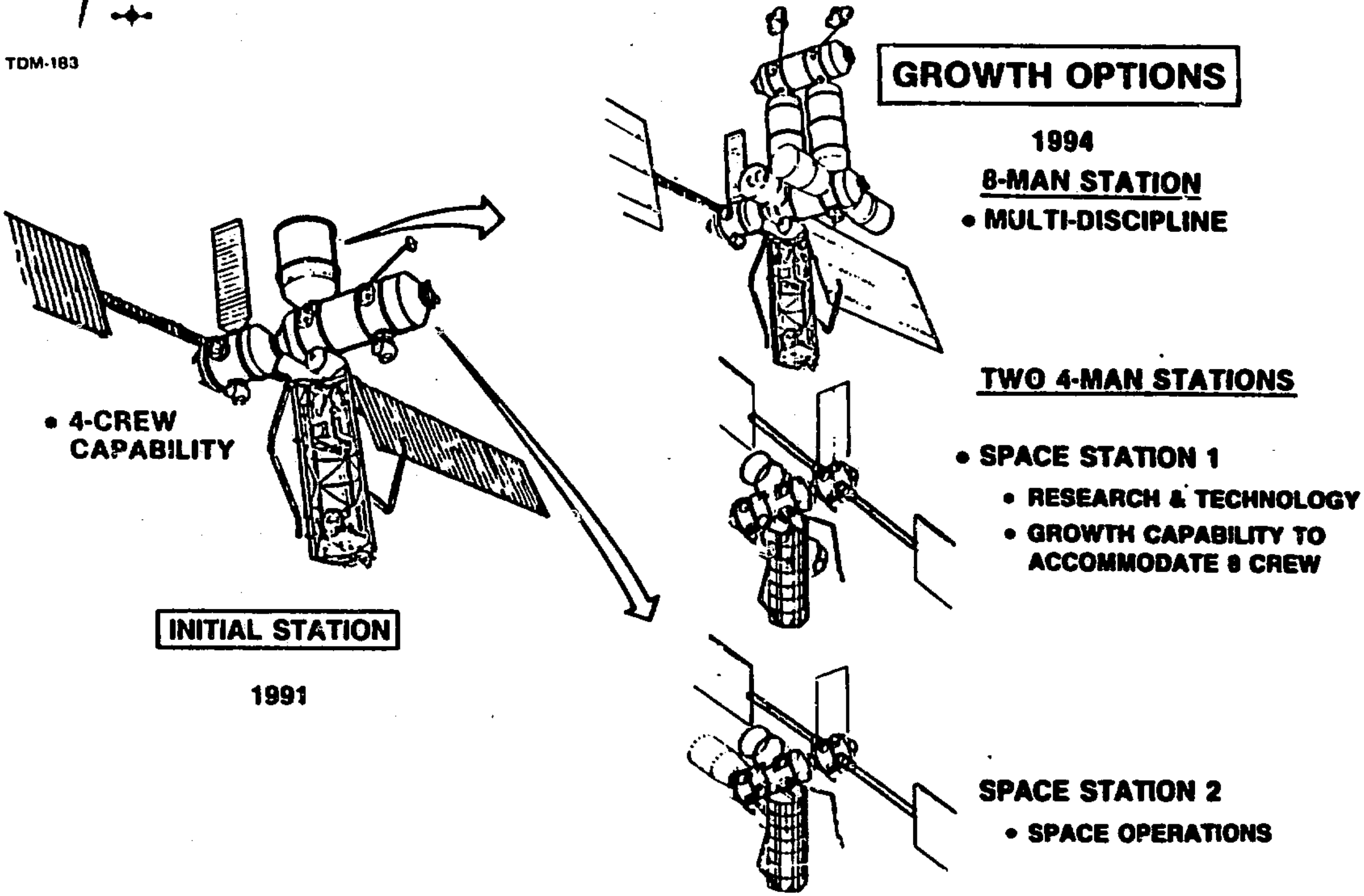
TDM-182

- 5 crewmembers
- 30 KW power
- 4 berthing/docking ports
- Platform
    - RMS
- TRWX2014 precision structure assembly 1990

SPACE STATION

ALTERNATE SPACE STATION ARCHITECTURE OPTIONS . . .

TDM-183



Shuttle Integration & Satellite Systems Division

Rockwell International

Available Resources - Rockwell International

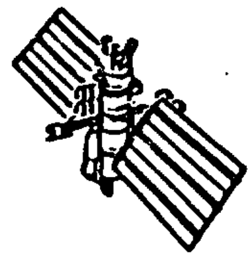
BOEING

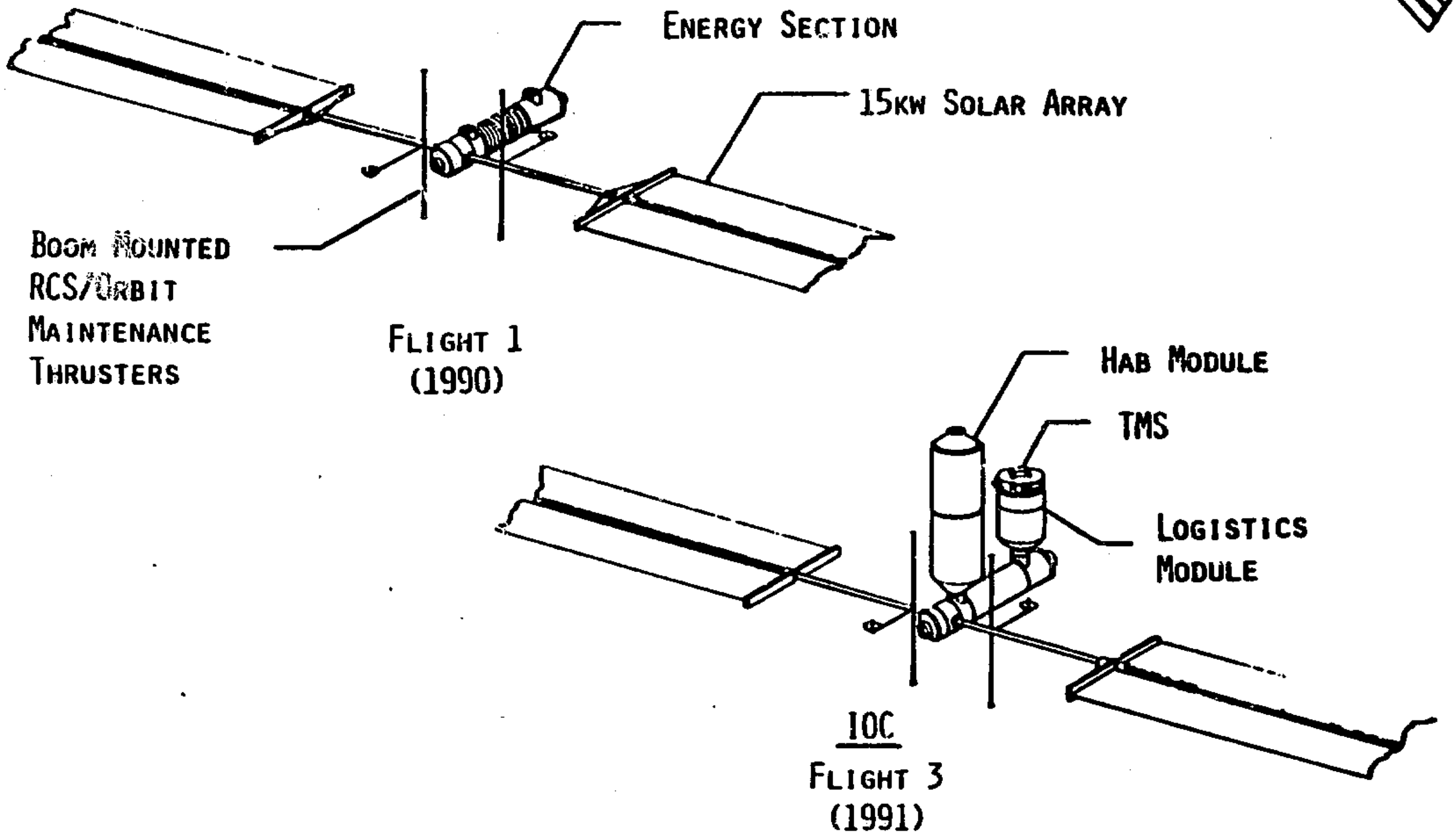
TDM-184

- 4 crewmembers
- 23.5 KW power
- 5 berthing/docking ports
- Payload service assembly
  - Electrical power
  - Thermal
  - Environmental control
    - Ventillation
    - Pressurization
  - Intercom
  - RMS
- Scenario 6 assemble large space structure 1993

Early Configuration

TDM-185 Modular 14′ Dia.





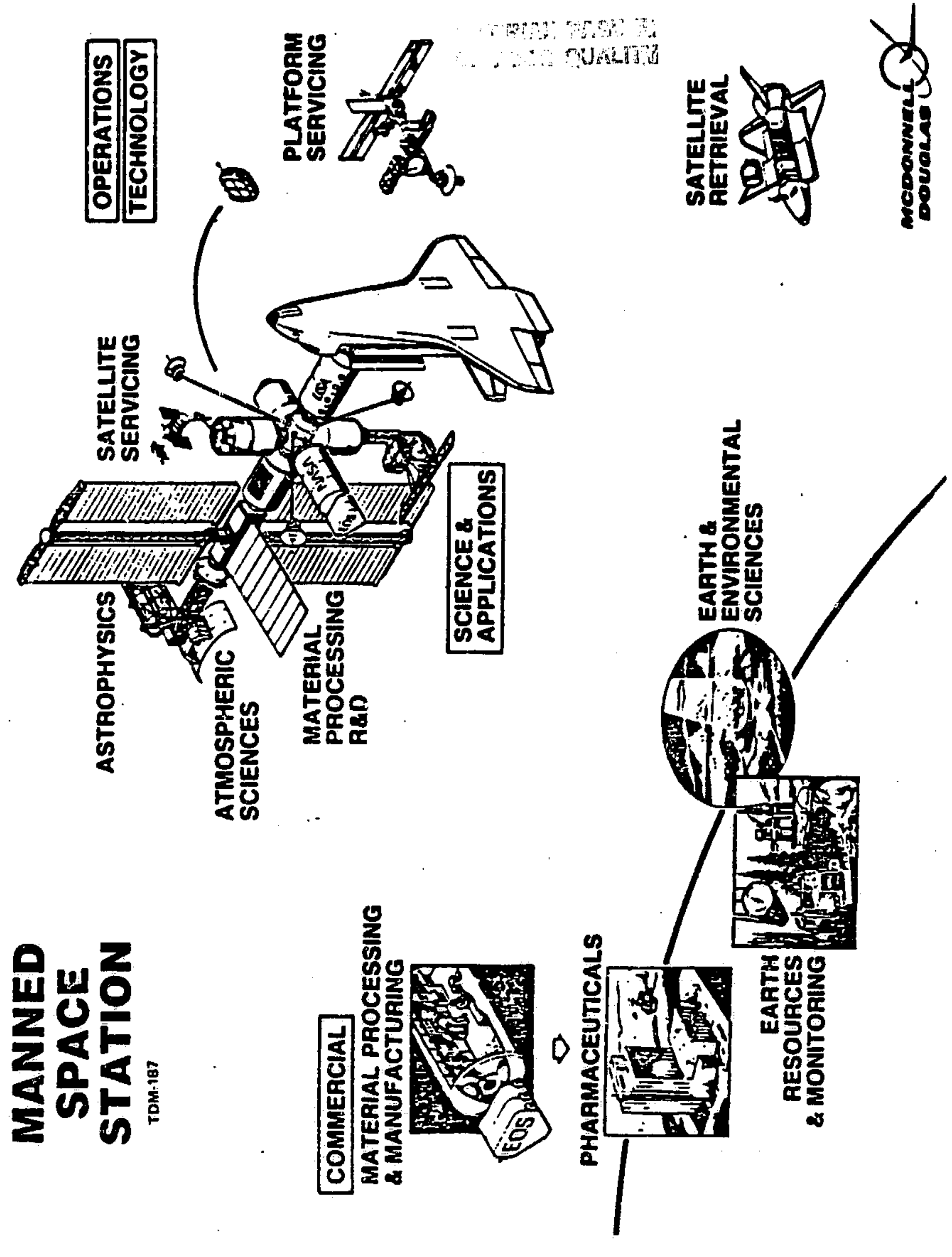
MARTIN MARIETTA

Available Resources - Martin Marietta

BOEING

TDM-186

- 4 crewmembers
- 33 KW power
- 3 berthing/docking ports
- Hangar
    - Communications
    - RMS
    - OTV
- MMCX 2022 large structures technology 1992


MANNED SPACE STATION
TDM-187
COMMERCIAL
MATERIAL PROCESSING & MANUFACTURING
PHARMACEUTICALS
EARTH RESOURCES & MONITORING
ASTROPHYSICS
ATMOSPHERIC SCIENCES
MATERIAL PROCESSING R&D
SATELLITE SERVICING
SCIENCE & APPLICATIONS
EARTH & ENVIRONMENTAL SCIENCES
OPERATIONS
TECHNOLOGY
PLATFORM SERVICING
SATELLITE RETRIEVAL
MCDONNELL DOUGLAS

Available Resources - McDonnell Douglas

BOEING

TDM-188

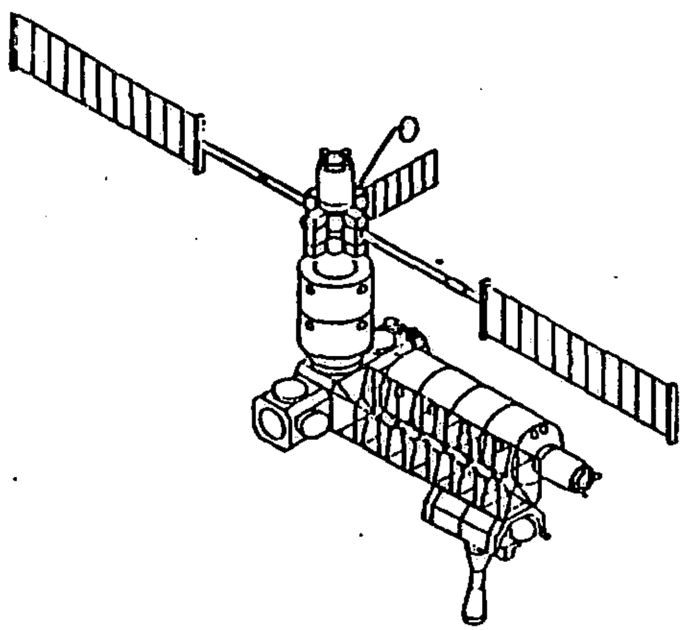
- 3 crewmembers
- 25 KW power
- 5 berthing/docking ports
- Payload support module
    - 14 unpressurized ports
    - OMV
    - RMS
- TGN 005 LSS construction 1994

LMSC-D889718

SPACE STATION PROGRAMS

SPACE STATION MISSION ACCOMODATION
PHASE 3 OCT 1991

TDM-189



MISSION ACCOMODATION CAPABILITY	(STUDY SCENARIO NO)
• EARTH OBSERVATION FACILITY	(5)
• OCEAN OBSERVATORY LABORATORY	(11)
• SATELLITE SERVICING (MINIMUM)	(14)
• HUMAN RESEARCH LAB	(1)
• SPACE ENVIRONMENT FACILITY	(4)
• SPACE OBSERVATION LAB	(10)

STATION CAPABILITY ADDITION

- CENTER STRUCTURE
- HABITABILITY & LIFE SCIENCES MODULE (REGENERATIVE ECLSS)
- 3 MEN (FOR TOTAL OF 6 MEN)
- CONSUMABLES

Lockheed

Available Resources - Lockheed

BOEING

TDM-190

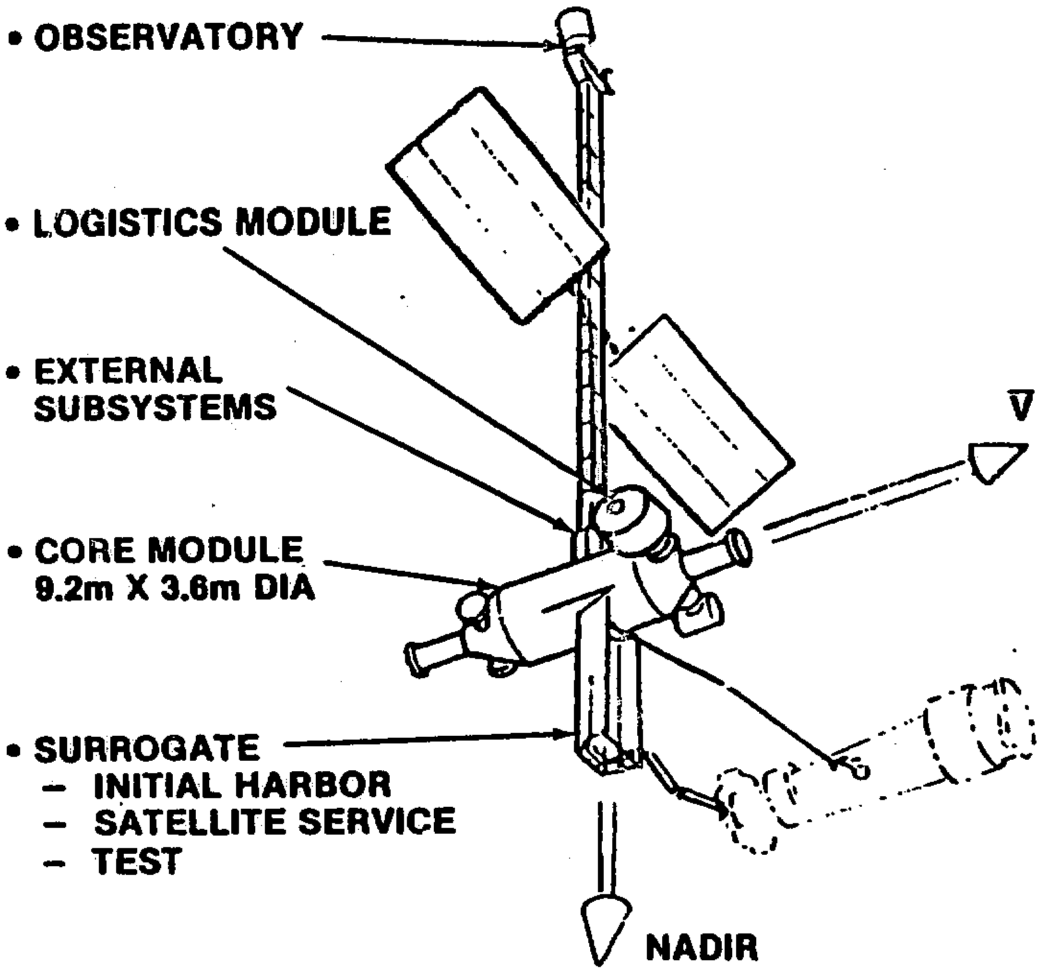
- 3 crewmembers
- 13 KW power
- 2 berthing/docking ports
- Center structure
  - Communications
  - Data
  - Instrumentation
  - Closed circuit TV
  - EVA service support
  - Sunshades
- RMS
- Scenario 15 LSS assembly 1994

SPACE STATION

INITIAL SPACE STATION AT 28.5° INCLIN

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

TDM-191



- CREW SIZE = 3
- POWER = 22 kW
- MASS = 22,000 kg
- COST = $4.28 B
- TYPICAL MISSIONS
  - ASTRONOMY
  - LIFE SCIENCES
  - POV & TMS TURNAROUND
  - SATELLITE SERVICE
  - R&D

Available Resources - Grumman

BOEING

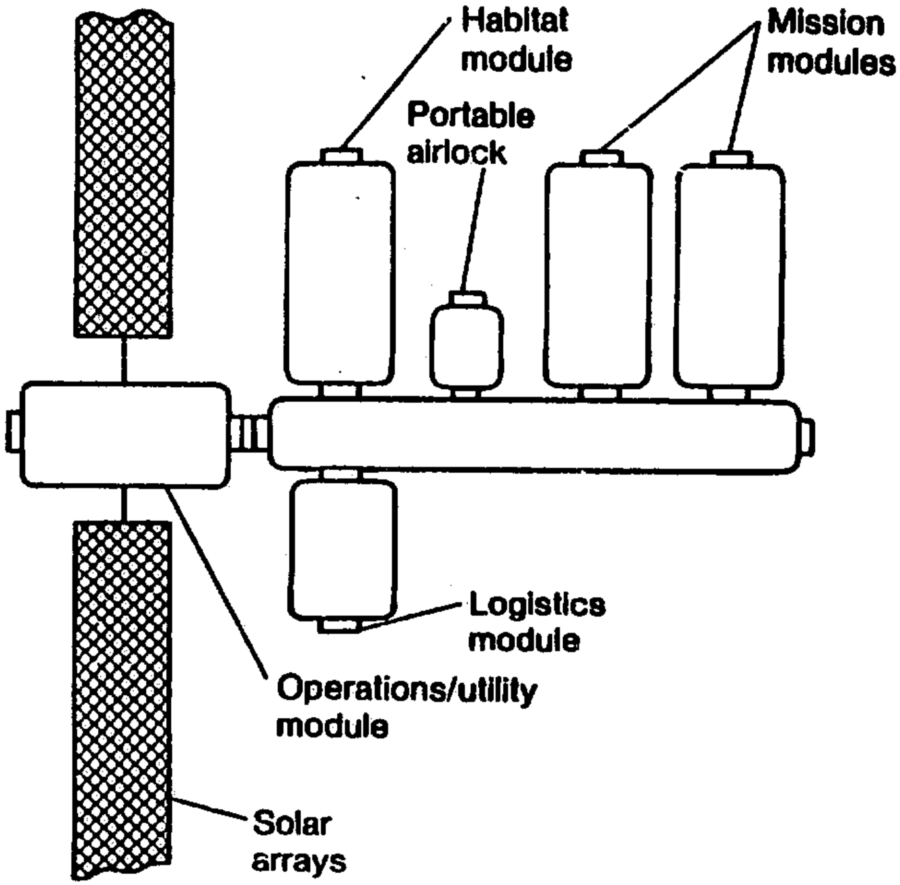
TDM-182

- 3 crewmembers
- 22 KW power
- 4 berthing/docking ports
- Surrogate bay platform
  - Lights
  - Power
  - Cooling
  - Data
  - Video
  - RMS
  - MMU
  - Tools and parts storage
- Large space structures 1992

GENERAL DYNAMICS
Convair Division

EARLY ARCHITECTURE
1990

TDM-193

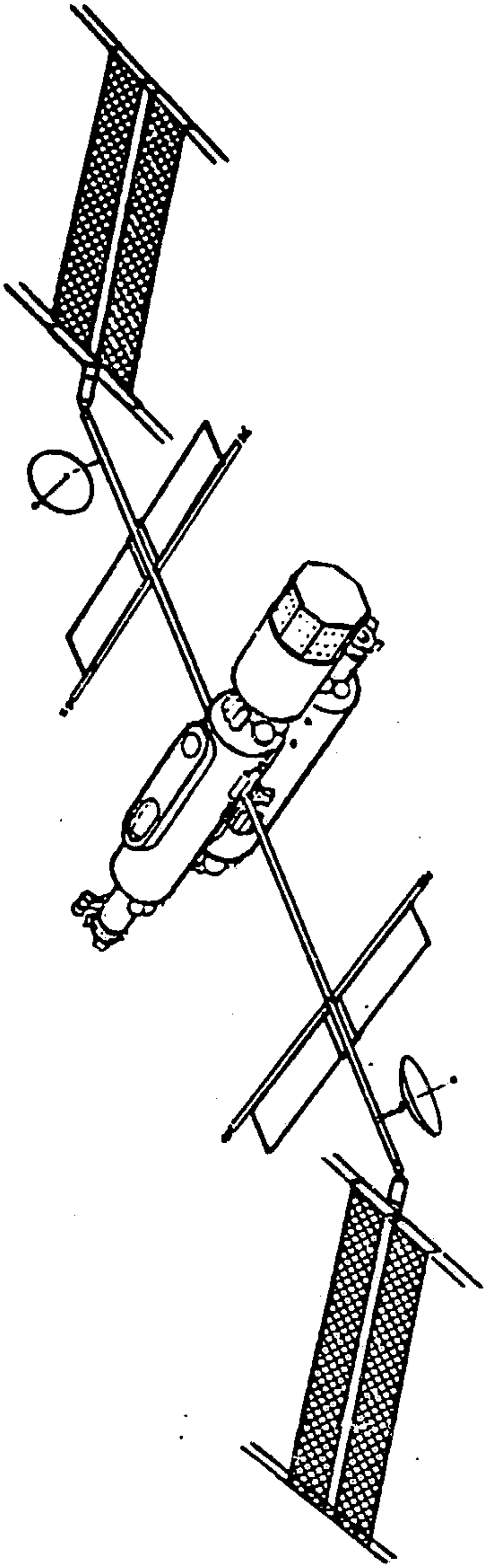


Available Resources - General Dynamics

BOEING

TDM-194

- 5 crewmembers
- 40 KW power
- 6 berthing/docking ports
- Maintenance dock
  - Electrical interconnects
  - Fluid lines
  - Lighting
  - Parts storage
  - Tool storage
  - Handling device
    - RMS
    - OMV
  - Remote TV
- GDC2007 large structures technology 2000



Available Resources - Boeing

BOEING

TDM-198

- 4 crewmembers
- 25 KW power
- 5 berthing/docking ports
- Platform
    - Support fixtures
    - Instrumentation
    - Data systems
    - Utilities
    - Handling and auxiliary equipment
    - Small tools
- BACX2037 construction and storage facility 1991

National Aeronautics and Space Administration

TDM-197

1991 SPACE STATION CONCEPT