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FINAL REPORT
REFURBISHMENT COST STUDY OF THE THERMAL PROTECTION SYSTEM OF A SPACE SHUTTLE VEHICLE

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SUMMARY

This report documents the phase I study results, which are definitions and and planning activities for phase II. Phase II will consist of performing various maintenance tasks to establish test data on refurbishment costs and to develop efficient refurbishment techniques. During phase I, design and cost details associated with ablative, metallic and nonablative nonmetallic types of thermal protection systems (TPS) and associated attachment techniques were identified, evaluated and characterized. In particular phase I consisted of defining primary load carrying structural arrangements, defining suitable TPS attachment techniques, generating operational labor cost estimates, evaluating design and cost uncertainties, and designing TPS component parts for a full-scale mockup and formulating a detailed experimental test plan.

In our examination and definition of primary and support structure for the various TPS concepts, indications are that structure components have little, if any, effect on scheduled TPS maintenance when the externally removable panel concept is employed. This assumes that the deflections experienced by the primary and support structure under repeated loading conditions are always within design limits and surface continuity is maintained. Any adverse loading conditions which would tend to distort the structure could complicate panel removal by binding mechanical fasteners. This would be unscheduled maintenance, the analysis of which is unpredictable in a paper type study. The arrangement of primary and support structure does not seem to dictate the TPS type and attachment method. Properly designed, the primary and support structure can accommodate a variety of approaches so that replaceability and/or interchangeability of panels can be accomplished with nominal effects on the refurbishment cycle.

Certain TPS attachment methods evolved as prime candidates for space shuttle application. These include multiple mechanical fasteners and pi-straps for ablative heat shields, a key/keyway concept for the nonablative, nonmetallic heat shields, and flush fasteners and pi-straps for metallic heat shields. The most critical design aspect concerning feasibility and related maintenance of heat shield attachment is joints and seals between adjacent panels. Incompatibilities exist. On the one hand, gaps between panels must be provided to allow for the normal expansion and contraction of the panels under various environmental extremes. Yet these same gaps have to be minimized, if not eliminated, to prevent the inflow of hot boundary layer gases and water. Gaps are caused by a variety of conditions the most critical of which are attributable to cryo tank shrinkage, primary structure thermal gradients, body deflection during booster separation, panel expansion during entry and manufacturing tolerances.

The problem is not as acute with some type of heat shields as with others. In the case of ablative heat shields, silastic type seals provide sufficient flexibility to resolve the problem. The same problem is solved with metallic heat shields by overlapping panel joints. However, in the case of the HCF heat shield the problem is more critical due to the expansion and contraction characteristics of the material. In this instance the goal of the designer is to provide a joint and/or seal which is compatible with the anticipated use life of the basic heat shield material (i.e., 100 flights) so as to minimize refurbishment. Silastic seals, in this case, have limited application because of their reusability aspects. Overlapping the joints with other high strength temperature metals or ceramics in combination with various stepped geometry is a possible solution.

The results of phase I clearly indicate that maintenance labor costs are primarily sensitive to the type and method of attachment of the particular TPS being considered. Depending on the concept employed and projected use life of the construction materials, variations in labor costs of two orders of magnitude can be realized for a representative space shuttle flight program (i.e., 445 flights over 10 years). Probably the most significant factor affecting refurbishment labor costs is panel size. Indications are that labor costs decrease as panel size increases whereas elapsed time requirements increase as panel size increases. For removal and replacement of the ablative and HCF heat shield systems, there appears to be little cost advantage in refurbishment of panels greater than 20 square feet. In the case of metallic heat shield systems the break even point seems to be between 40 and 60 square feet. The degree of uncertainty in these cost estimates lies in the exact tradeoffs involved between the number of men and the quantity of support equipment needed to handle and install a panel as the panel increases in size. Since no spacecraft built has employed a significantly large panel (i.e., greater than 20 by 20 inches) maintenance data is limited if not nonexistent.

Uncertainties exist concerning fastener installation and removal, the latter appearing to be the most critical. In the case of an ablative or HCF heat shield system, fastener removal involves first locating the fastener and secondly removing either the used or conditioned insulating material down to a depth which exposes the mechanical fastener, allowing its subsequent removal. Fastener location may or may not be a serious problem. If the technique of using small pilot holes in the insulating material proves to be a workable scheme, removal will be relatively straightforward. However, if after exposure to a thermal environment these holes become obscure due to the products of ablation or fusing of the coatings, complications could arise which would involve time consuming and costly refurbishment techniques. Depending on the number of fasteners used this could make a particular attachment concept noncompetitive. Unfortunately, there is not sufficient data available to assess its severity. In the case of metallic fasteners the problem also exists but with potentially less severity. In this instance the problem consists of coatings flowing into the attach points causing fasteners to freeze up, making removal more difficult.

Another critical problem area involves the adequacy of the maintenance operation to make panel repairs while the panel is still attached to the vehicle. This may involve nothing more than reconditioning surface scratches to complete material replacement. The ability of the maintenance crew to inspect the damaged part, assess the degree of repair necessary and then to make the repair hinges on the location of the repair on the vehicle and the tools and equipment needed.

These latter items could range from only light hand tools to complicated jig fixtures. The advantages of repair in place is that it eliminates or minimizes time-consuming removal operations of a complete panel assembly which, of course, is a goal in achieving low operating costs.

In those instances where accurate cost estimation was difficult, or where technical or practical feasibility of a concept was questionable, detailed experiment plans were developed to resolve uncertainties. These plans call for fabrication and experimental testing of component parts of selected TPS for a full-scale mockup at NASA-LRC during phase II. Included in these plans are component part quantities, number of personnel, personnel skills, experiment procedures, measurement and equipment requirements, schedules, and costs.

The most efficient method of resolving key problems is through experimental examination of specific refurbishment tasks on actual or simulated hardware. The test program outlined in Task 5 is aimed towards examining those concepts which exhibit desirable individual characteristics insofar as minimizing refurbishment activities associated with future space shuttle maintenance and those concepts which when combined in an experimental program cover the full spectra of anticipated refurbishment problems.

To accomplish this fabrication and assembly, activities will be closely monitored and controlled through cost-effective administrative control systems. TPS panels fabricated for mockup use need not be flight quality, minimizing quality controls. The key to a successful test program lies in the manner in which the data is obtained, data accuracy, and data presentation methods. For these reasons a field tested video tape recording system, used by MDAC on related programs, provides the best method of measuring human performance. A significant factor effecting TPS reuse/refurbishment is its physical change after exposure to ground and flight environments. Thus, a certain amount of testing is desirable to create a realistic maintenance environment. As a minimum this environmental testing should include entry temperature simulation. Timely initiation and completion of the phase II effort will greatly enhance the overall aspects of TPS design and cost predictions for future space shuttle activities.

INTRODUCTION

One of the most significant factors affecting design and cost aspects of thermal protection systems for space shuttle application is reuse and/or refurbishment. The economic feasibility of a manned space shuttle hinges on the ability to reuse a vehicle from 50 to 100 times with minimum refurbishment. Therefore, the designer's goal is to minimize refurbishment and increase reusable life of various components. These requirements, and the costs involved in current vehicle development, demand that new techniques be developed for application of potentially high performance materials.

Three basic overall cost elements of a typical space shuttle vehicle are those associated with research, development, test, and evaluation (RDT&E); investment; and operational phases. Past experience has shown that in each phase one of the most critical cost drivers is the vehicle thermal-structural system. It is significant that the combined thermal-structural system of the vehicle contributes over 20% of total program costs and is thus an area where the achievement of cost goals is imperative. A sufficient amount of knowledge has been accumulated so that RDT&E and investment costs can be predicted with a high degree of confidence. However, additional operational cost data are necessary, particularly in the area of recertification, before total system cost can be realistically predicted.

Within the operational activity, the labor costs associated with inspection and scheduled and unscheduled maintenance (i.e., repair and replacement) represent areas where cost predictions are limited. The manhours involved in inspection, repair and replacement, of course, depend on the particular thermal-structural arrangement being considered. Based on the traffic rates considered, the refurbishment cycle may or may not effect vehicle turnaround time.

Thus, the success of any highly reusable system depends in large part on achievement of low operating costs. A key challenge to this achievement is the development of thermal protection systems requiring easily performed, routine inspection and a minimum level of unscheduled repair and replacement. Economical development of these desirable characteristics in a thermal protection system will occur only if those refurbishment activities to achieve low-cost goals are identified and related to appropriate system design features before the designs are committed to production. This is the intent of the study results described herein.

Specifically, the purpose of this study was to identify costs associated with inspection, repair, and replacement of components of typical thermal protection systems for space shuttle orbiter application (phase I) and to develop efficient techniques for performing these operations (phase II). This report deals with the results of phase I only since phase II is not funded to date.

In particular, the following tasks were accomplished:

Define primary load carrying structural arrangements in terms of the type of contruction used and material application (task 1).

Define suitable attachment techniques for various types of heat shields and primary structure (task 2).

Provide detail operational cost estimates for the refurbishment cycle associated with the thermal protection system configurations selected (task 3).

Evaluate refurbishment activities to determine critical cost drivers and status of design feasibility (task 4).

Design heat shield panels and attachment components for a full-scale mockup and formulate a detailed experimental test plan for obtaining valid cost data and determining efficient refurbishment procedures (task 5).

This document is the final report of phase I of A Refurbishment Cost Study of the Thermal Protection System of a Space Shuttle Vehicle performed for NASA-LRC by the McDonnell Douglas Astronautics Company - East (MDAC-East), under contract number NAS 1-10093. Phase I of the study was performed over an eight-month period beginning in June 1970. A summary of results is contained in NASA CR-111833.

Mr. D. W. Haas, study manager, was responsible for overall technical direction of the study. In support of the study manager were other members of the McDonnell Douglas engineering staff, including Mr. V. M. Gerler, Mr. E. J. Carroll, Mr. J. Komeshak, Mr. H. S. Zahn, and Mr. J. K. Lehman.

Mr. C. W. Stroud, of the Materials Division, Langley Research Center, Hampton, Va., was the technical monitor for the study.

CANDIDATE HEAT SHIELD SYSTEMS

To achieve more visibility and understanding of refurbishment problems (i.e., techniques for performing specific operations, and attendant costs) in the initial design and subsequent recertification of thermal protection systems (TPS) for an orbiter space shuttle application, general TPS characteristics of a representative space shuttle configuration (in terms of exposed areas and unit weight estimates), a representative thermal structural requirement definition, and specific heat shield concepts are reviewed herein.

Orbiter Space Shuttle Configuration

The general arrangement and basic geometric data which effect a representative orbiter space shuttle configuration TPS design are presented in figure 1. The specific configuration cited is a fixed-wing reusable vehicle being considered by MDAC during the NASA phase B space shuttle study. This configuration accommodates a crew of two with a payload capability of up to 50 000 pounds to and from orbit.

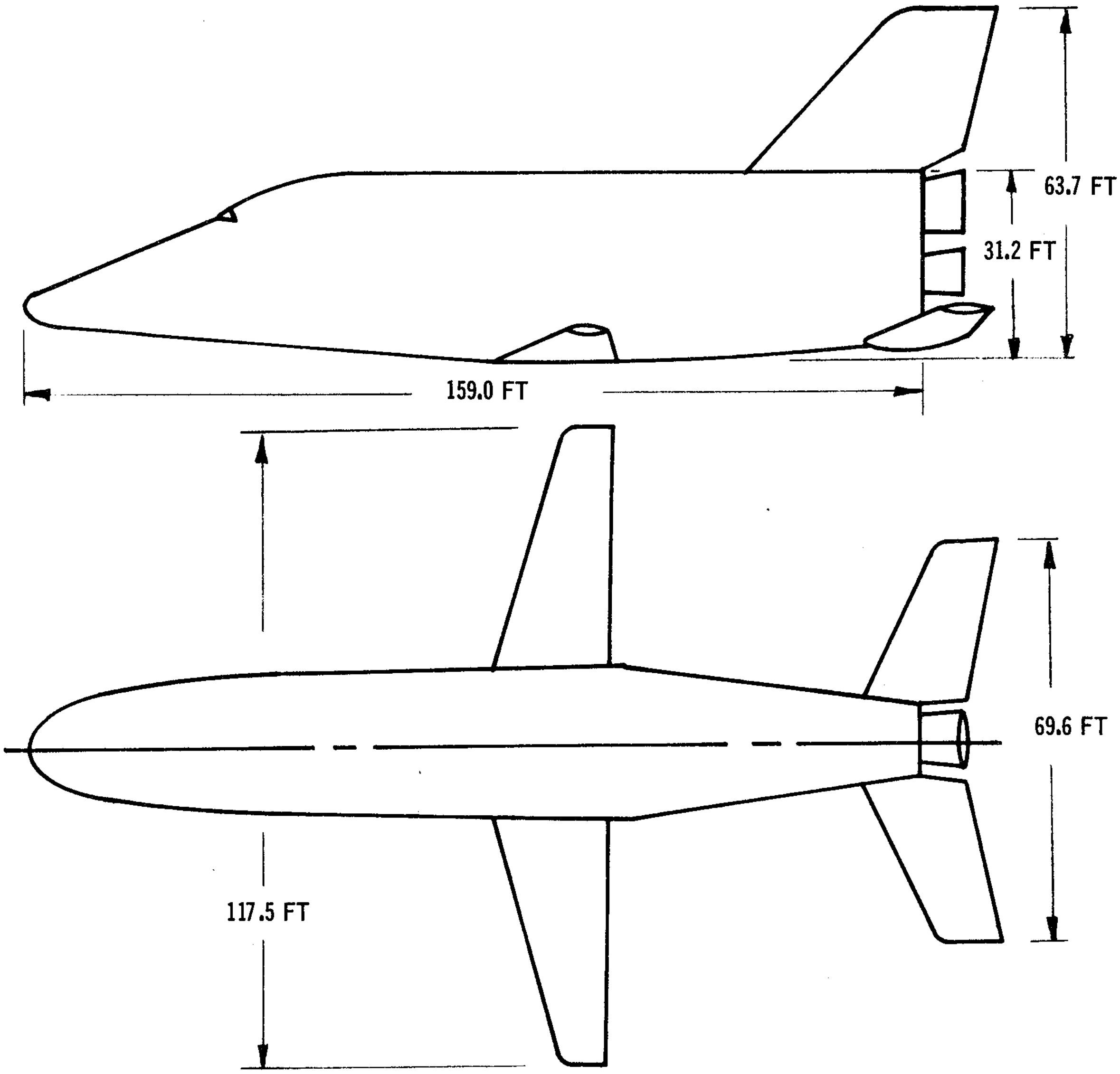
The total wetted area of the vehicle is estimated at 19 575 square feet which includes the fuselage, wing, and horizontal and vertical tail surfaces. Of this area, approximately 52% requires some form of reusable/refurbishable thermal protection system to protect the primary structure and internal subsystems. In the remaining 48% of the vehicle, temperatures are sufficiently low to permit the primary structure to act as its own heat sink or the primary structure is covered by some component, such as cargo doors, where TPS is not required. In these vehicle areas the structure is considered totally reusable. Of that portion of the vehicle requiring some type of heat shield system only 5% (nose tip, chines, and leading edges) represents extremely high surface heating areas in which special design considerations must be taken.

The estimated total vehicle dry weight is 184 000 pounds, 13% of which is attributable to TPS and 38% to primary structure. The remaining 49% is distributed between all other vehicle subsystems. Taking 13% of the vehicle's total dry weight and 52% of the vehicle's wetted area yields an average TPS unit weight of 2.4 lb/ft^2. Similarily, 38% of the vehicle's total dry weight and 100% of the vehicle's wetted area results in a primary structure unit weight of 3.6 lb/ft^2. Therefore, the total thermal-structural system unit weight is roughly 6.0 lb/ft^2. These unit weight estimates vary depending on the type of heat shield system used and its location on the vehicle. The intent is to give relative values to better understand problems.

Various heat shield systems/attachment techniques discussed in subsequent sections are not necessarily based on identical unit weights. Thus, a particular concept which shows a low refurbishment cost potential may not represent the minimum weight design or vice versa. Tradeoffs involving weight and cost must be made in the case of the final TPS selection for a particular vehicle configuration. Such tradeoffs were considered beyond the scope of the current study.

Thermal-Structural Requirements

The type of TPS employed is dictated by natural and induced environments to which it is exposed during various phases of mission flight. Magnitudes, rates, and period of exposure to these environments on various components are of critical importance in TPS design.



Body	
Wetted area	13 457 ft^2
Ml volume	79 000 ft^3
Wing	
Wetted area	2858 ft^2
Theo area	1970 ft^2
Horizontal tail	
Wetted area	1500 ft^2
Theo area	1000 ft^2
Vertical tail	
Wetted area	1760 ft^2
Theo area	880 ft^2

FIGURE 1 ORBITER GENERAL ARRANGEMENT

Natural environments include rain, dust, wind, meteoroids, etc, which may require, in certain instances, that additional protective devices (e.g., coatings) be applied to the basic heat shield system. Reusable/refurbishable aspects of these protective devices are significant factors in vehicle recertification and, as such, were analyzed under inspection and repair task analyses (task 3). Induced environments include aerodynamic heating, pressures, acoustics, etc, which result from vehicle configuration aerodynamic design and the selected flightpath from launch to touchdown (including emergencies). Each of these environmental conditions lends itself to detail analytical and experimental study.

Maximum temperatures specify material and thus the type of heat shield system to be used in the TPS. The class of metal materials with moderate temperature capabilities, represented by stainless steel and titanium, are restricted to about 900°F. Materials referred to as superalloys have potential usefulness up to 2000°F. Between 2000° and 3000°F it is necessary to use refractory metals, with melting points above 4000°F and the ability to retain their strength at very high temperatures. Ablative and nonmetallic, nonablative materials (e.g., HCF and carbon/carbon) become competitive above 2500°F but are most effective in the temperature regime above 3100°F. Figure 2 shows the temperature distribution over a representative space shuttle configuration which indicates that over 75% of the vehicle's surface experiences temperatures below 2000°F.

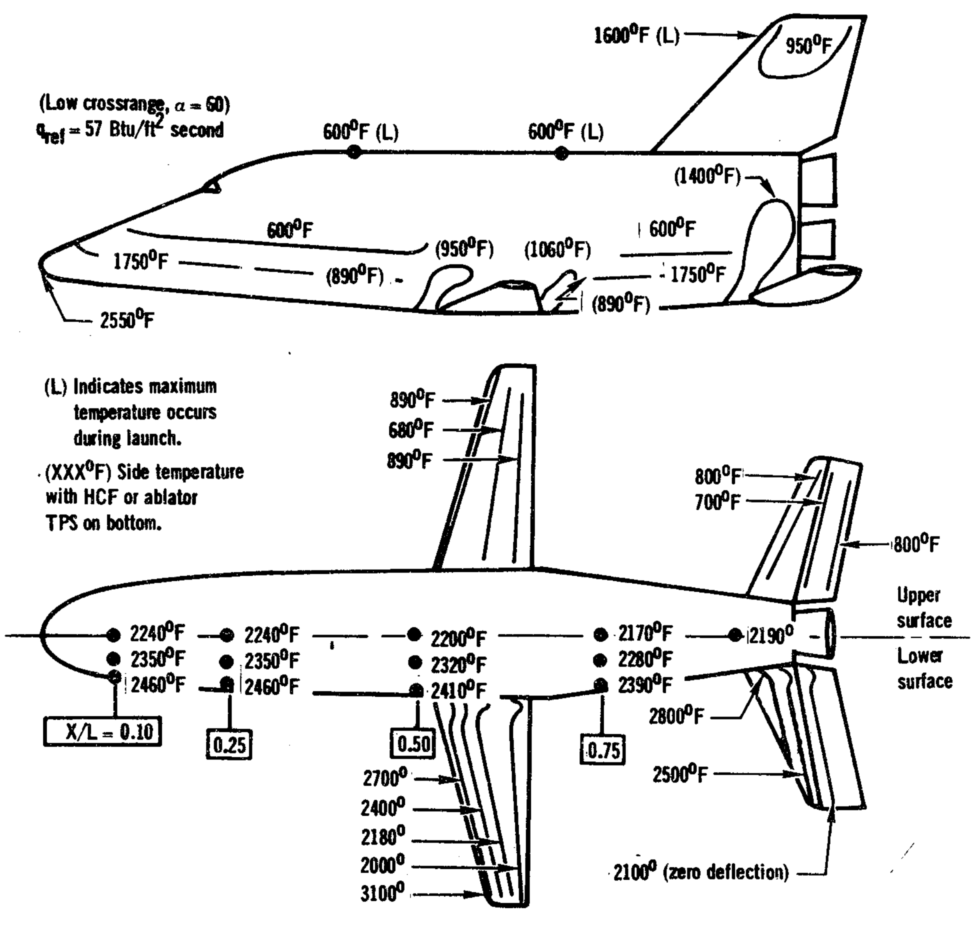


FIGURE 2 ORBITER DESIGN TEMPERATURES

Differential pressure conditions experienced by the TPS, in general, size the heat shield panels and are used to determine spacing requirements for mechanical fasteners. During various phases of flight, positive and negative pressures are experienced. For the most part, positive pressures size the panels while negative pressures determine fastener spacing. A representative pressure versus temperature profile for high and low crossrange orbiters is shown in figure 3. These data show that a peak limit pressure of 1.75 lbf/in^2 occurs at 200°F. For the purposes of this study, design (ultimate) pressures are limit pressures increased by a 1.4 safety factor. This safety factor with the peak pressure shown in figure 3 yields a design pressure condition of 2.45 lbf/in^2 for sizing the panels. The critical loading condition for determining attachment spacing is a limit pressure of 1 lbf/in^2 acting outward on the panel. This condition could occur during ascent if entrapped air is not allowed to vent rapidly.

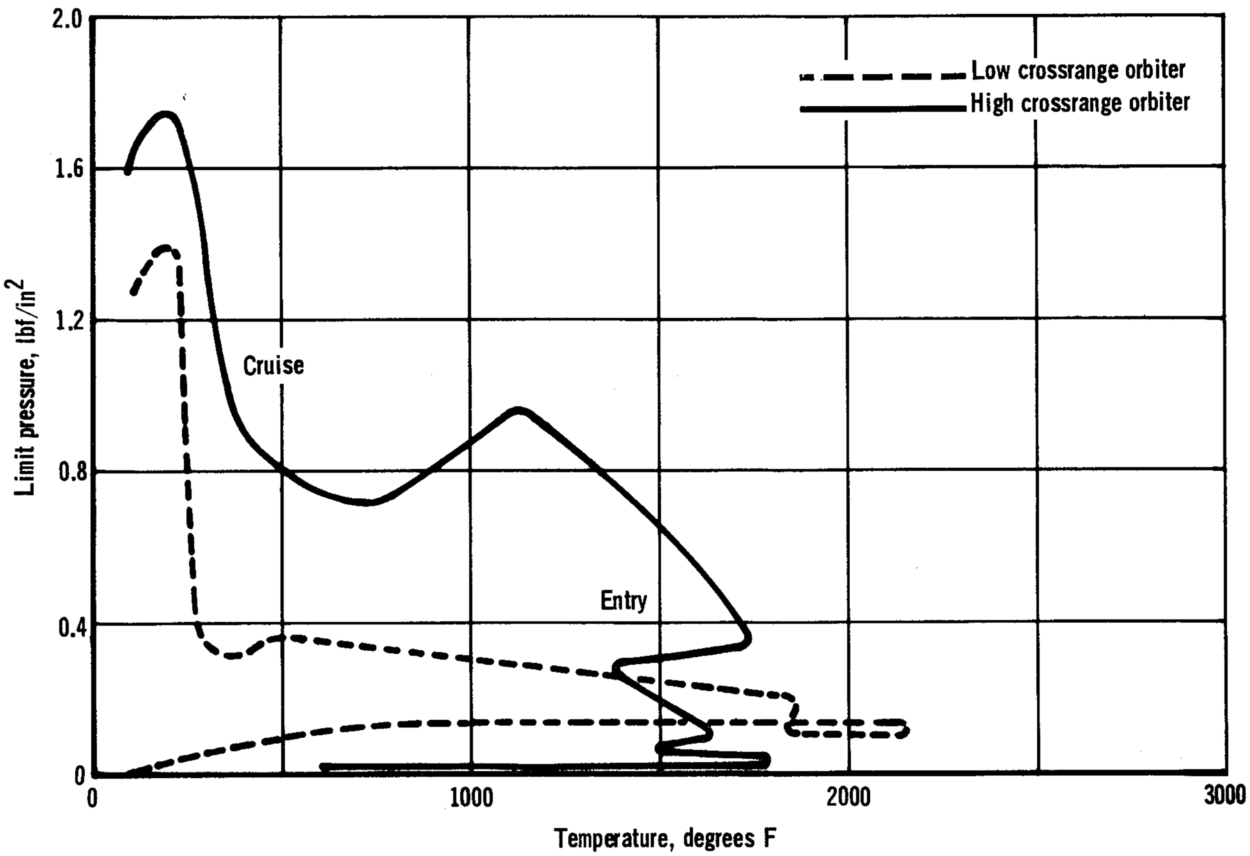


FIGURE 3 REPRESENTATIVE PRESSURE/TEMPERATURE PROFILE

The predominant source of external panel vibratory excitation is random acoustic pressure. During lift-off, the acoustic environment results from rocket noise and is maximum near the aft portion of the booster. Panel excitation during ascent is due to turbulence in the boundary layer which becomes maximum at approximately the same time as peak differential pressures. To account for this phenomena in panel sizing, an additional factor of 1.2 is applied to the pressure condition of 2.45 lbf/in^2 quoted previously to give an ultimate design pressure of 3.0 lbf/in^2 which was used in this study.

Types of Heat Shield Systems

During this study three basic TPS were considered including ablative heat shields, metallic heat shields, and nonablative-nonmetallic heat shields. Each type may be used with passive insulation, active cooling, or combinations thereof. Active cooling system options vary from exterior surface transpiration cooling to direct protection of primary structure using coolant distribution tubes. The active cooling system approach was not considered in this study. In subsequent paragraphs of this section, characteristics of each basic heat shield type are discussed.

Studies conducted to date indicate that the externally removable heat shield panel concept for a space shuttle vehicle TPS is the most efficient means of achieving near optimum system reusability/refurbishability. The panel concept offers minimum weight (primarily due to structural-temperature allowables) and shorter vehicle recertification turnaround times, since the whole vehicle (including internal systems) need not be involved in the refurbishment cycle.

Ablative heat shield. - The ablative TPS is characterized by nonmetallic materials which, when heated, undergo a thermochemical or thermophysical phase transition. Advantages of an ablative system are many, as it combines heat sink and radiative capabilities and mass transfer in absorbing heat, and good insulating qualities, especially for low density heat shields. Tradeoffs in insulating value and mass transfer heat absorption allow more uniform shield thickness distribution over the vehicle perimeter. In some cases, temperature and heat flux tolerance allow as much reradiation as do presently practical radiative systems. Ablators are state-of-the-art and allow a temperature overshoot capability not offered by metallic heat shields. Current disadvantages of an ablative system are limited reuse capability and time-consuming refurbishment.

Various classes of materials have been used or proposed (depending on the application) for ablative systems, including silica/silica fiber composites; mixed inorganic or organic composites with silica, nylon and carbon fiber reinforced resins (phenolics, epoxies, and silicones); and carbon/graphite based materials. High or low density composites (10 to 150 lb/ft^3) for charring and noncharring systems have been considered. Low density elastomer ablators use gas blowing agents or additives (microballoons) to achieve low density. Studies conducted for space shuttle vehicles have indicated that low density (10 to 35 lb/ft^3), low thermal conductivity (0.05 to 0.10 Btu/hr-ft-°F), and relatively high surface temperature (3000° to 4000°F) materials are well suited for the application. In this study, only the elastomer type ablation material was considered for refurbishment analysis.

One of the major advantages of ablators using a silicone resin base is applicability to a variety of formulations and processing techniques. Compression, vacuum bag, and injection molding techniques have been used to fabricate ablative structures of various complexities. By compression technique, the material is loaded uniformly into a metal mold and pressed at a relatively low pressure ($\simeq$ 100 lbf/in^2).

A widely used fabrication method consists of loading the basic resin system into the cells of a honeycomb, generally a fiberglass/phenolic matrix which may or may not be bonded first to a substrate. Loading is accomplished by trowel fill/vacuum bag or vacuum filling (pulsing), depending on material viscosity. The trowel-fill/vacuum bag fabrication technique was considered as the baseline for the refurbishment analysis of this study.

Another application technique for elastomer materials is spraying. Airless and air atomized equipment have been used for this purpose. Ablative material may be sprayed directly on primary structures and cured, or sprayed on panels and attached by fasteners/adhesives. Spray applied ablators have been used in numerous aircraft and missile applications and, depending on panel use and location on the vehicle, may be applied in densities from 15 to 60 lb/ft^3. Elevated temperatures are usually required to effect a proper cure but a few room temperature curing resins are available for certain critical design applications where only room temperature cures may be tolerated.

The ablator is usually attached to the substructure by a bonding agent and/or mechanical fasteners. Bond material selection becomes quite complex and, as expected, becomes a function of mission, vehicle configuration, and mechanical and thermal stresses. The bond must have elongation to maintain its integrity when subjected to stresses resulting from the differential thermal expansion between the ablator material and the substructure. At lower temperatures, the bond shear modulus must be relatively low in order to prevent excessive stress development in the ablator or the substructure. The bond must have sufficient strength at high temperature to maintain the heat shield integrity during those portions of entry when the backface temperature reaches peak values. If the bond does not have adequate strength at high temperature, system weight is increased because additional ablator is required to limit the backface (bondline) temperature to be compatible with bond properties.

Bonding materials are generally classified by rigidity considerations. If the bond does not deform, it is considered rigid. A bond which can accommodate small tensile and compressive deformation, but which can absorb shear deformation, is considered semirigid. Elastomer materials are generally classified as flexible bonds.

Cure temperature is quite important. When the ablator is attached to the substructure at elevated temperatures, the zero stress condition of the resulting composite is at values higher than at room temperature.

In some cases the designer will use mechanical fastener techniques to enhance bond performance. When this is done, care must be exercised so that the fastener has the proper strength when it must perform during entry. For example, if the bond is inadequate at the higher bondline temperatures, the mechanical fastener must still be intact.

Heat shield refurbishment requires removal of used ablator and replacement with new material. For a panel design, this may be accomplished by removing used panels and substituting new ones. The used panels can then be refurbished or discarded, thereby minimizing vehicle turnaround time. Direct application to the vehicle skin would require that the used ablator be removed directly from the primary structure and new ablator applied. This type of refurbishment may increase vehicle turnaround time since the whole vehicle may be involved in the refurbishment cycle.

In either case, the elastomer type of ablator is sufficiently soft that refurbishment can be accomplished by a variety of techniques. This ablator can easily be cut with a knife, or other sharp edge, layer-by-layer down to the substrate. It can be skived, abraded, or scraped using tools of intermediate hardness between the soft ablator and the substructure, thereby avoiding possible substrate damage. The char formed on elastomerics is soft and powdery; over this, a thin layer of silica forms. The char is easily removed by scraping or abrading and brushing before removing the virgin material.

Techniques for removing elastomers include use of chemical reagents. Silicone rubber can be made to revert to a semiliquid state by reaction with amines. The resulting softened mass could be scraped off and washed down with solvents leaving a clean substrate.

The techniques mentioned above are clearly more effective and efficient than those used for removing rigid bonds. Rigid bonds, of such hardness to warrant grinding techniques or abrading cycles of much longer duration, result in higher cost and present a constant hazard of substructure damage, e.g., gouging, requiring time-consuming and costly repair.

Elastomer ablator refurbishment does not necessarily require complete removal of the used ablator and its attachment to the substructure. One approach to refurbishment is to originally provide a thickness of ablator ample for several flights. After the first flight, only the charred or spent ablator is removed, a relatively simple task. This imposes an initial weight penalty. Another approach is to refurbish the ablator simply by removing the charred or spent ablator down to the virgin material. New ablator would then be applied over the virgin material by spraying or brushing on an amount of new material equal to the charred or removed material. This method requires no new bond as the coating material readily bonds to the virgin material. Curing is performed on the vehicle. Ablator thickness is measured by pins imbedded in the ablator at specified intervals and attained by sanding the surface to the required height. If the specific material application requires elevated temperature curing, ablator panel removal is necessary.

Metallic heat shield. - The use of metallic radiative panels supported off a cool structural shell with a layer of insulation between is a feasible TPS concept over major portions of the shuttle vehicle and is limited in its applicability only by elevated temperature strength and oxidation characteristics of the metal. Systems which use the radiation concept accommodate the imposed heat load by emitting radiant energy back to the atmosphere from a high temperature surface. Metals are intrinsically durable materials and therefore are capable of extensive reuse. However, metallic materials have oxidation or strength limitations which are subject to the synergistic time-temperature-pressure and stress effects.

The most likely candidates for metallic radiative heat shields on the shuttle include titanium, nickel and cobalt base superalloys, TD nickel-chrome (TD NiCr), and coated columbium alloys.

Selecting the upper use temperature limit for a metallic material involves evaluation of factors such as creep strength, metallurgical stability, rate of oxidation, life of the oxidation protective coating, and effect of oxidation protective coatings on the mechanical properties of base materials.

A significant portion of TPS panels and structure components for the shuttle could be fabricated from titanium and superalloys with the ratio of quantities of these materials dependent on the established critical temperature limit for titanium alloys. The generally accepted temperature limit for long time exposure of titanium alloys is ≃ 900°F. However, current analyses show that maximum loading occurs at low temperatures with only very minor loads and short exposure times at maximum temperature. On this basis, the titanium TPS panels could be designed by low temperature loading and the critical maximum temperature established by high temperature creep or metallurgical stability limits of the alloy. This could mean 200° to 300°F increase in the upper temperature limit of titanium alloys (i.e., 1200°F max) and a substantial weight savings over use of superalloys in this same temperature range.

Large surface areas of the shuttle TPS will be subjected to temperatures in the 1200° to 1800°F range. Conventional nickel and cobalt base superalloys are the most efficient and economical materials for this application. Superalloys have been used extensively on spacecraft developed over the past 10 years. Applications include both radiative heat shields and hot primary structure.

The shuttle TPS requires an efficient material for the 1800° to 2200°F temperature range. Above 1800°F conventional superalloys are not structurally efficient materials. Below 2200°F, coated columbium is not weight efficient. TD NiCr alloy is the most promising candidate to fill this temperature range. TD NiCr is a relatively new material and very little information is available regarding its use in a thin gage reusable heat shield application. Thin sheet properties must be established and the mechanical properties characterized after cyclic time-temperature-pressure-stress exposure.

The major advantage of the TD NiCr and superalloys over the columbium alloys is that they do not require oxidation protective coating. Major disadvantages include a lower temperature limit and a high thermal expansion coefficient.

Oxidation is of major concern when dealing with columbium alloys. Temperature limitations are determined by the ability of a coating to retard oxidation. At present, coatings have been developed which will permit an upper limit temperature of about 2500°F for 100 cycles. Major advantages of coated columbium alloys are temperature resistance, availability, fabricability, and prior use history. Currently MDAC is under contract to NASA-Lewis (contract no. NAS 3-14307) and NASA-MSFC (contract no. NAS 8-26121) to investigate the fused slurry coating process of columbium and the nature of columbium coating repairs, respectively.

Fabrication techniques for producing metallic heat shields vary depending upon type of construction and the particular material application. Designs vary greatly and include corrugation and honeycomb sandwich construction, single and double skin beaded panels, and rib stiffened panels. Recent study results indicate that some materials are more amenable to certain types of construction than others. Major fabrication considerations include such items as weldability, formability, machineability, and heat treatment.

Fabrication with titanium is state-of-the-art; superalloys are reasonably ductile and may be formed and joined by existing proven methods and oxidation resistance is acceptable; TD NiCr has directional properties which complicate formability and low strength welds due to thoria agglomeration; although readily fabricable, the oxidation protective coating on columbium alloys necessitates additional processing and poses handling difficulties. In addition to the above considerations, thin gage (0.005 to 0.010 in.) joining needs to be fully characterized for all of these metals.

Nonmetallic, nonablative heat shield. - Those materials which are characteristic of nonmetallic, nonablative heat shields include hardened compacted fibers, referred to by MDAC as HCF, and oxidation inhibited carbon/carbon.

HCF material is characterized by a layer of rigidized inorganic fibers which combines functions of a high temperature reradiative surface and an efficient insulation. MDAC is under contract to NASA-MSC (contract no. NAS9-11221) to characterize such a material for space shuttle application.

HCF is a promising candidate for reusable space shuttle applications because of its potential weight savings, availability, and temperature overshoot capability. Also, being chemically inert in air at high temperatures, the material has a good potential for many reuses. Due to mechanical weakness, these ceramic materials must be bonded or otherwise attached to a structural substrate. The development of suitable reusable coatings is probably the most critical problem which must be solved before this type of material can be successfully used as external insulation on the space shuttle.

Those materials considered most likely candidates are from 12 to 15 lb/ft^3. These materials are relatively soft, extremely porous, and have inherently low emittance values. Those classes of materials used to produce HCF are identified by chemical composition of the fibers; aluminosilicate, silica, aluminosilicate-chromia, mullite, and zirconia. These HCF are potentially useful for 100 shuttle flights in the range of 2000° to 3000°F depending on type.

In this study, only mullite HCF was considered because of its thermal stability, relatively high strength after extended exposure to 2500°F, relatively low thermal expansion coefficient, low thermal conductivity comparable to other HCF, temperature overshoot capability, and capability for adjustment of stress-strain properties. The HCF is formed by a vacuum felting procedure, cured at elevated temperature, machined to specific dimensions, and then coated for handling resistance, liquid waterproofing, and a high emittance. Coating requires elevated temperature firing.

For application as a TPS, coated HCF is generally bonded to support panels when the shield stands off from the structure, or bonded directly to primary structure surfaces when these surfaces follow the vehicle moldline contours. Adhesive bonding is used since HCF material does not support mechanical fasteners. Both elastomer and rigid adhesives have been considered; however, the rigid types tend to add to any strain incompatibility problem and are not as easy to process as elastomers.

HCF system refurbishment is similar in many respects to that of the elastomer ablator except there is no char layer to complicate removal. HCF material is removed to the bond line or plugs are cored out to reach fasteners attaching the support panel to the primary structure. In either case HCF material is soft enough for refurbishment to be accomplished by a variety of hand or light tooling operations.

MDAC-East is under contract to NASA-MSC (contract no. NAS9-11223) to develop and screen carbon/carbon materials for space shuttle application. These oxidation inhibited, fiber reinforced, carbonaceous materials offer good potential for a reusable, reasonable cost, high-temperature resistant TPS. The strength-to-weight ratio of these materials at high temperatures is unsurpassed and oxidation protection from 3000° to 4000°F appears acceptable. On the other hand, coatings for refractory metals are limited to about 3000°F.

Most preliminary designs consider carbon materials for leading edge applications but it may be possible to use them also for basic heat shield panels. Reinforcement in the carbonaceous material system is based on either carbon or graphite fibers, usually in the form of cloth. Most of our work has been with carbon cloth and parts have been fabricated using standard reinforced plastic laminating processes.

These materials can be inhibited to oxidation by in-depth additives or by coatings on the surface. Surface coatings offer better protection. Coatings are applied on all exposed surfaces to protect surfaces from oxidation at high temperature. Oxidation inhibitors are also placed between layers of fibers but these are not as effective as coatings in preventing oxidation.

Reinforcement in the carbonaceous composite is usually based on carbon or graphite cloth (or fibers). The fibers can be in a woven three-dimensional matrix. In either case, a temporary phenolic binder binds the carbon fibers together. In the two-dimensional cloth, or fibers, a high pressure (300 to 1000 lbf/in^2) is applied during curing. This technique is the same as is used in making glass reinforced plastics. In the three-dimensional composites, resin is introduced without pressure. Composites are then cured and postcured using a standard phenolic plastic cure cycle. After curing, the parts are placed in an argon atmosphere and pyrolyzed to 2000°F in an 80-hour cycle.

The initial cost of a leading edge or panel is not determined, since materials are still under development. Except for the pyrolysis cycle and the coating application process, costs should be similar to those of reinforced plastics.

No coating repair procedures have been established; however, flame or plasma spraying of coatings has been suggested. Some of the repair procedures applicable to coated refractory metals may be useful to repair coatings on carbon/carbon.

Insulation materials. - All candidate TPS require internal insulation. As temperatures are far above the limits tolerable to humans and sensitive components, it is necessary to thermally isolate the TPS from the internal shell or pressure vessel. Although the amount of insulation varies from system to system, it is virtually impossible to eliminate the requirement without excessive increases in TPS weight.

There are two applicable basic varieties of thermal insulation. The first is the load bearing or structural material which is necessarily a relatively dense substance with inferior insulating capabilities. Its usefulness is limited to those systems where load bearing ability is essential (i.e., support junctions). Typical members of this class of insulators are CS-1000, foamed silicon carbide, and Min-K-2000 (Johns Manville Co.).

The second insulating material, which is very useful in the design of minimum weight structures for space shuttle application, is the fibrous material characterized by low strength, low density, and low thermal conductivity. Although this material must be well supported, it provides the best insulating capability with minimum complexity. Insulators typical of this class include Q-Felt, Micro-Fibers, and Dynaflex.

Selection of a particular material is based on weight, limiting service temperature, and imposed loads.

TASK 1 - PRIMARY STRUCTURE ARRANGEMENTS DEFINITION

Arrangements of orbiter primary structural components to which TPS are attached are defined herein. In accomplishing this task, extensive use was made of those structural concepts developed by MDAC in its continuing research and development activities during NASA phase A and current phase B shuttle studies. To supplement this activity, a review of space shuttle phase A studies conducted by other contractors was performed to identify representative structural arrangements (references 1 through 11). Two orbiter structural arrangements representing integral and nonintegral tank concepts are described in detail.

Design Considerations

Adequate vehicle primary structure definition is of the utmost importance in early design stages since the primary structure provides load carrying capabilities and support for the TPS. Major factors considered in the primary structure components arrangement which affect TPS design include:

Distance from heat shield panels to primary structure

Temperature drop required from the outer body surface to the primary structure

Requirements for purge on the launch pad or for postflight cooling.

The first factor affects internal clearances for access to attach heat shield panels and, in some cases, may dictate completely external fastening. The temperature drop requirement influences the insulation design and, in order to minimize conductive heat shorts, will affect attachment complexity. Heat shorts are most serious where heat shield panels are attached directly to primary structure, and the design of the insulating spacers between elements of support structure is difficult. The third factor requires consideration of adequate flow passages between the thermal protection elements and the propellant tank primary structure (integral tanks). All of these factors were considered in selecting representative primary structures. In accomplishing this task, design criteria and guidelines consistent with space shuttle phase B objectives were adhered to.

Candidate Structural Arrangements

Typical examples of primary structural arrangements are shown in figure 4. For the purposes of this study we have chosen to categorize these structures according to endoskeletal, exoskeletal, and combination arrangements.

Endoskeletal applies to those arrangements where primary structural elements are at some significant distance inside of the outer body contour. Furthermore, structural shape requirements are dominated by factors other than vehicle external configuration. An example of this is shown in figure 4(a). This sketch shows a section of a siamesed dual-lobe tank which contains the propellants for the orbiter stage of the boosted flight and carries major body shear, axial loads, and bending moments. Frames and stiffening members are outside the tank skin.

Exoskeletal structures are those whose elements follow closely the outer moldline of the vehicle. An example is shown in figure 4(b). In this case, stiffening members are internal and frames are outside the tank skin.

A combination endo and exoskeletal structure is shown in figure 4(c). The lower surface body shape departs significantly from the cylindrical tank structure and is located some distance away. Above the maximum half-breadth, however, the tank shell structure serves as a heat sink type TPS. Compatible with this approach, the stiffening members and frames are inside the skin.

A semimonocoque unpressurized shell structure is shown in figure 4(d) An example of exoskeletal structure, this particular structure consists of internal stiffening and internal frames and is a candidate approach for the body nose region.

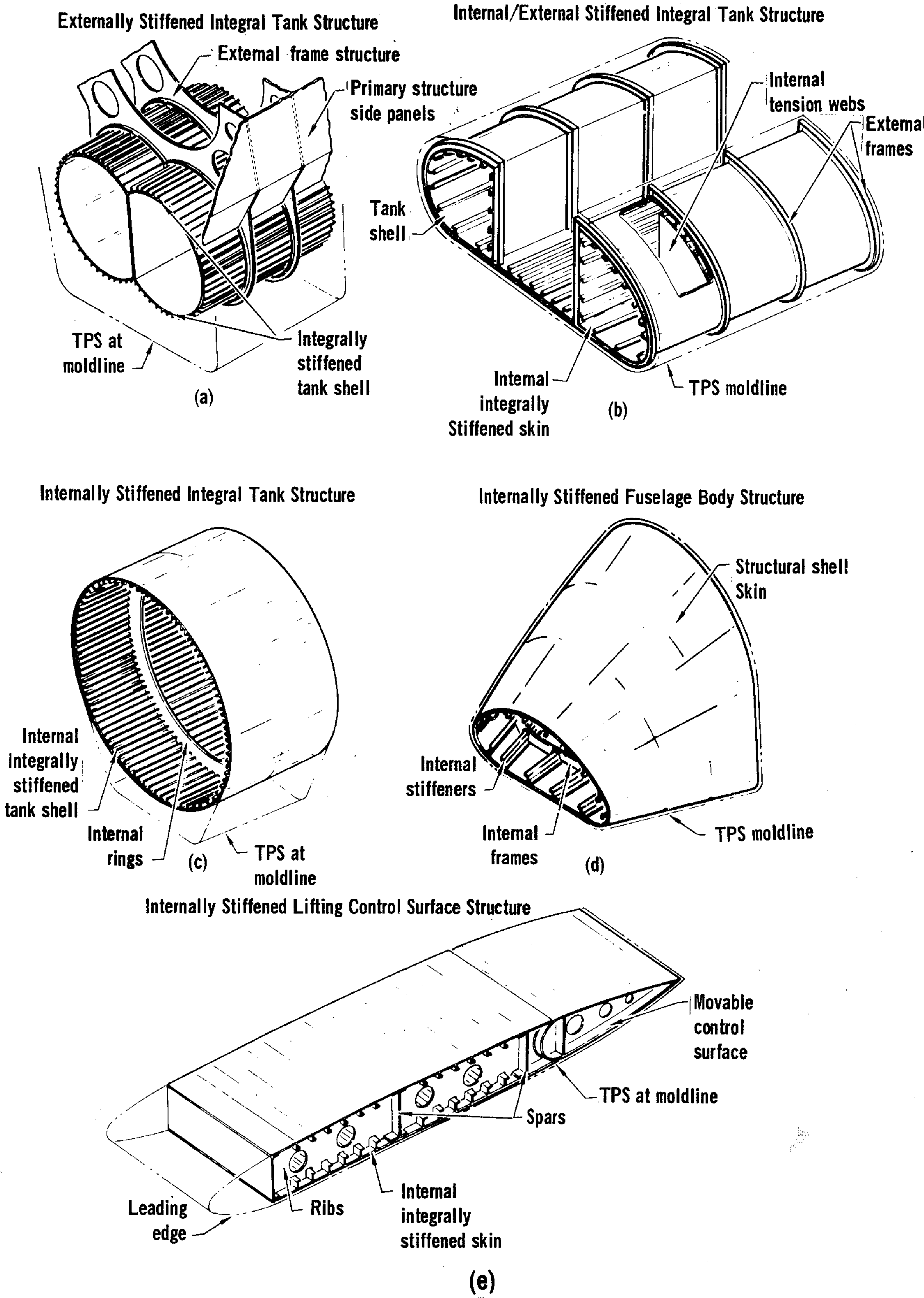


FIGURE 4 PRIMARY STRUCTURE CONCEPTS

Another example of exoskeletal structure is shown in figure 4(e). This section is a part of a tail surface consisting of an internally stiffened spar structure.

Applicability of these structural arrangements to specific space shuttle concepts is presented in table 1. Capsule primary structure descriptions are given for various orbiter vehicle sections investigated by several contractors during phase A space shuttle studies. Those vehicle sections considered are shown in figure 5 and include the forward body or nose region, payload doors, upper fuselage, lower fuselage, and aerodynamic surfaces. Structure classification of an exoskeletal or endoskeletal concept, hot (reradiative) or cold (thermally protected), and the particular material considered for construction are also given.

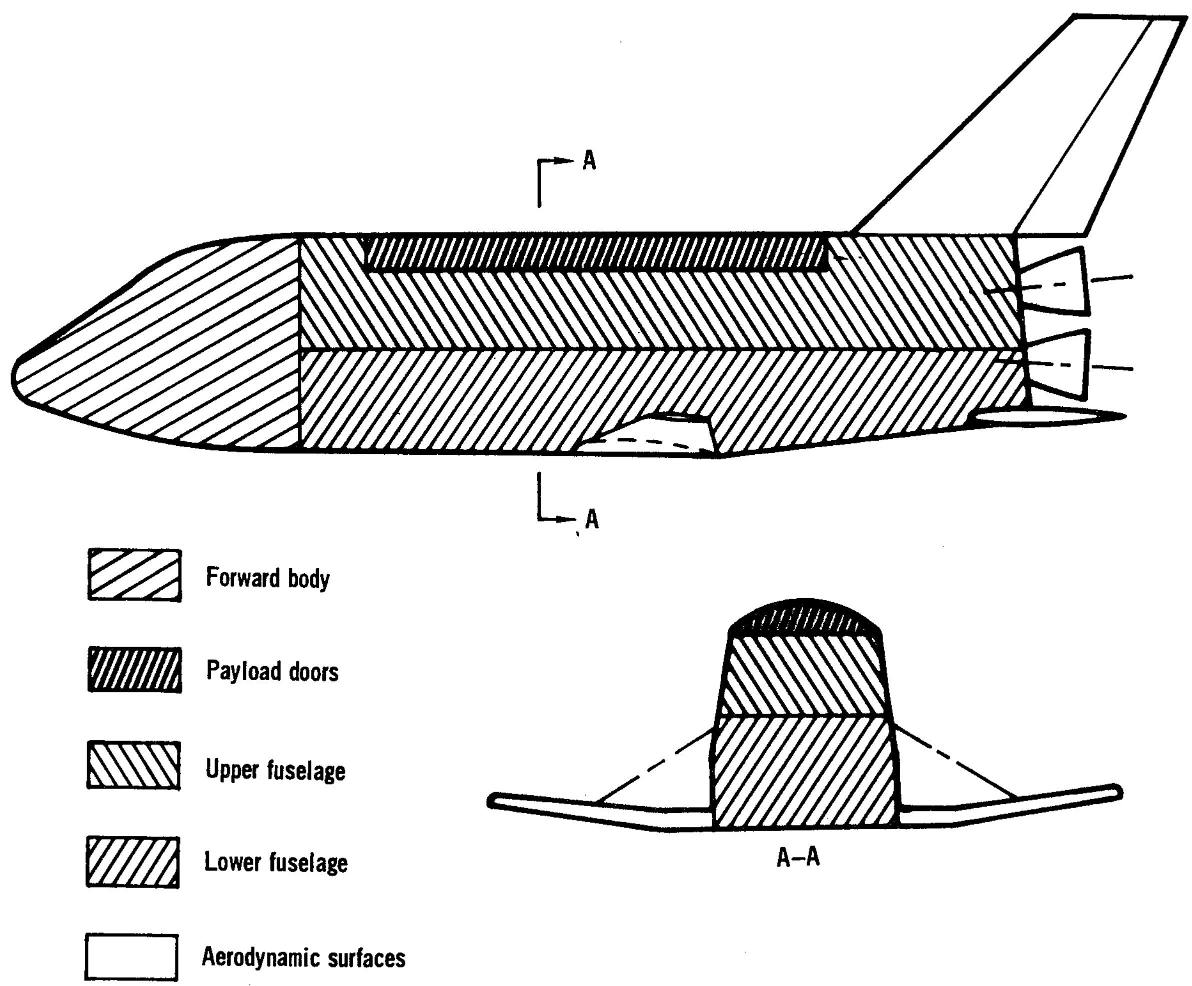


FIGURE 5 ORBITER SECTIONAL ARRANGEMENT

TABLE 1 SPACE SHUTTLE PHASE A ORBITER PRIMARY STRUCTURE REVIEW

BODY SECTION	CONTRACTOR	STRUCTURAL CONCEPT	STRUCTURE LOCATION RELATIVE TO MOLD LINE		STRUCTURE ENVIRONMENT		RECOMMENDED MATERIALS
			EXOSKELETAL	ENDOSKELETAL	HOT	COLD	
Fwd Body	GDC	Semimonocoque thermo protected shell	√			√	Aluminum
	LMSC	Corrugated panel/frame/longeron with interchangeable heat shield panels (LI-15, metallic, ablative)	√			√	Aluminum
	MDC	Upper section: semimonocoque external shell construction	√		√		Rene 41 Titanium L-605
		Lower section: semimonocoque thermo protected shell		√		√	
	MMC	Shell/stringer/frame with active cooling	√			√	Aluminum
	NAR	Upper section: semimonocoque external shell			√		Titanium
		Lower section: semimonocoque thermo protected shell	√			√	
Payload Doors	CDC	Semimonocoque external shell	√		√		Titanium
	MDC	Semimonocoque external shell	√		√		Titanium
Upper Fuselage	GDC	Semimonocoque thermo protected shell with integral tanks positioned fore & aft of the payload bay	√			√	Aluminum Titanium
	LMSC	Corrugated panels/frame/longeron with nonintegral tanks & interchangeable heat shield panels (LI-15, metallic, ablative)	√			√	Aluminum
	MDC	Semimonocoque external shell	√		√		Titanium
	MMC	Shell/stringer/frame with active cooling	√			√	Aluminum Titanium
	NAR	Semimonocoque external shell construction with nonintegral tanks positioned fore and aft of payload bay	√		√		Titanium
Lower Fuselage	GDC	Semimonocoque thermo protected shell with integral tanks positioned fore & aft of the payload bay	√	√		√	Aluminum Titanium
	LMSC	Corrugated panels/frame/longeron with nonintegral tanks & interchangeable heat shield panels (LI-15, metallic, ablative)	√			√	Aluminum
	MDC	Externally stiffened integral tank with heat shield post support stand-offs		√		√	Aluminum
	MMC	Shell/stringer/frame with active cooling	√			√	Aluminum Titanium
	NAR	Semimonocoque thermo protected external shell construction with nonintegral tanks positioned fore & aft of the payload bay	√			√	Titanium
Aero-dynamic Surfaces	GDC	Spar box beam with rib & stringer stiffened skins (swing wings - thermo protected stabilizers)	√			√	Titanium stabilizer
	MDC	Spar box beam with hot skins and/or thermo protected skins	√		√	√	Titanium
	MMC	Fin-webbed spars and ribs covered with mechanically fastened panels	√		√		Titanium
	NAR	Spar box beam with hot skins and/or thermo protected skins	√		√	√	Titanium

Phase A Contractors	Final Report
GDC - General Dynamics Corporation	GDC-DCB69-04
LMSC - Lockheed Missiles & Space Company	LMSC-A959837
MDC - McDonnell Douglas Corporation	MDC-E-0056 MDC-E-0120
MMC - Martin Marietta Corporation	MCR-69-36
NAR - North American Rockwell	SD69-573-4

In general, the primary structure proposed by most contractors is best described as an exoskeletal concept in which the structural elements closely follow the outer moldline of the vehicle. The upper structure is, in most cases, considered a hot structure while the lower surface is cold.

In the hot structure approach, where the skin of the primary structure also serves as a heat sink, titanium is the most likely candidate material since expected surface temperatures are below 800°F. Titanium alloys possess good structural efficiencies from high (900°F) through cryogenic temperatures. These alloys are more expensive than aluminum but their application is increasing since they are lightweight and corrosion resistant. The 6Al-4V alloys are widely used, having good characteristics in annealed and heat treated conditions. These alloys can be formed, machined, and welded. They have good strength to 750°F, and acceptable impact strength and notch toughness at cryogenic temperatures. The 5Al-2.5 Sn alloy has moderate strength and is easily welded. This alloy can be used to 900°F for extended periods. New grade alloys are being developed for improved ductibility and notch toughness.

For the cold structure approach, wherein the primary structure is thermally protected, aluminum is the most likely candidate material for construction. Aluminum alloys are the most widely used materials in primary structures. These alloys must not be operated at temperatures above 250°F for extended periods of time. Although strength and stiffness of these alloys are not high compared to some other materials, efficiency parameters are competitive. The aluminums are inexpensive, easily formed and machined, and are readily available.

Structural concepts described in table 1 indicate that several types of construction are available to the designer. In some cases primary bending loads are carried in heavy members or longerons running lengthwise down the vehicle. These members are supported at intervals by rings of a stiffness adequate to prevent general instability failure of the structure. For this type of structure the primary function of the skin is to transfer pressure loads to longerons and rings and to support shear loads.

Primary bending loads can also be carried in a semimonocoque type structure. In this case the heavy members are eliminated and the skin is stiffened to carry the compressive loads in addition to pressure and shear. As in the previous case, stiff rings at appropriate intervals prevent general collapse of the structure. Among various design techniques available to generate these structures, sandwich, stiffened-skin, and corrugation-skin concepts are perhaps most widely used in current spacecraft conceptual design.

Since these structures are only conceptual, trade studies involving various options such as integral versus nonintegral propellant tanks, common versus separate bulkheads, structural versus nonstructural payload doors, and conventional versus composite materials, are required before the structure is committed to hardware. For this reason various available alternatives are discussed as they affect heat shield attachment.

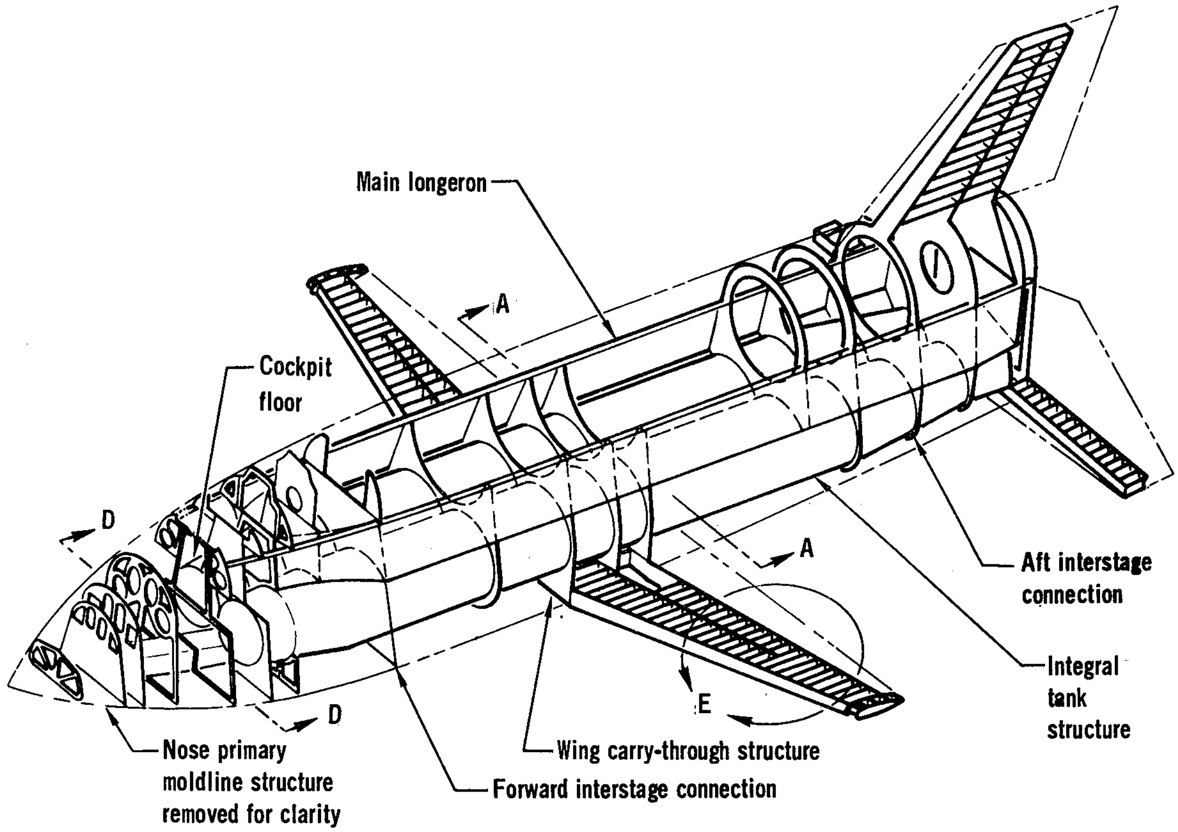
The conclusion from data in table 1 is that primary structural concepts, proposed by different contractors, favor the integral propellant tank approach for the orbiter design. Basic differences are primarily in number, location, and size of various structural components such as rings, frames, and longerons. Even in these instances differences are not large enough to force a decision between one concept over another at this time.

Representative Structural Arrangements

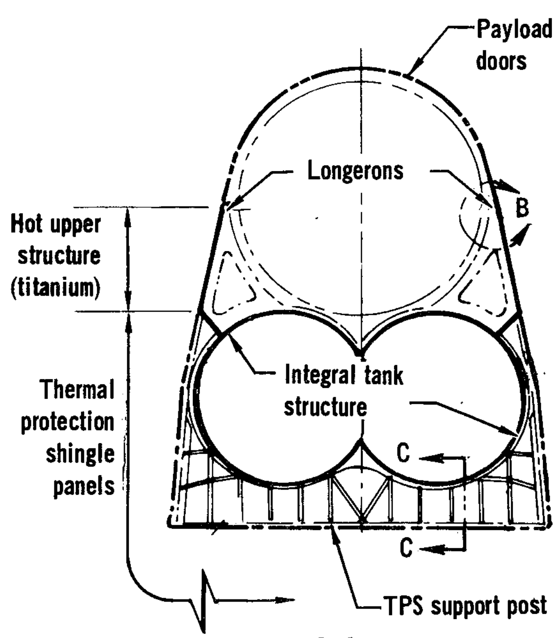
Primary structural components of two orbiter vehicles are described herein. While the descriptions are for two specific vehicles the discussion is generally applicable to all vehicles investigated in phase A shuttle studies. The purpose is to give a visual as well as narrative description of the interface between the primary structure and the TPS support structure, as far as it affects basic installation and refurbishment cycles of various heat shield concepts. Heat shield support structure of course, depends on location and size of various primary structural components such as rings, frames, skins, and longerons. Physical characteristics of these components for a typical space shuttle application are defined for integral and nonintegral propellant tank approaches. Minimum weight considerations favor integral tanks; however, tank simplicity, replaceability, and maintenance considerations suggest nonintegral tanks. The intent of this study was not to select one concept over the other but merely to show how each leads to different, and in some cases similar, structural design concepts.

Integral tank design. - A candidate orbiter vehicle configuration being considered by MDAC during the phase B shuttle study is a fixed-wing reusable vehicle accommodating a crew of two, with payload capability up to 50 000 pounds. This vehicle accommodates a deployable payload canister 15 feet in diameter by 60 feet. The payload can be deployed directly from the payload bay through a large opening covered by a single door on the upper fuselage area. The general arrangement and geometry of the vehicle are shown in figure 6(a).

The primary body structure of this vehicle is made up of upper longerons adjacent to the payload bay, and the propellant tank structure below the payload and joined by the fuselage side skin panels as shown in figure 6(b). Two integrally stiffened cylindrical tank shells are joined by a common keel web in a double-bubble arrangement. The side panels are single skin stiffened by corrugations and supported by frames spaced at approximately 20 inch intervals. Ellipsoidal domes form the end closure bulkheads. The tank shells are comprised of 2219 aluminum skins with integral longitudinal and circumferential stiffeners. Aluminum was chosen for the tank structure because of its excellent formability, weldability, and strength down to cryogenic temperatures. Longitudinal and circumferential stiffeners are outside the shell, presenting a smooth inner wall for insulation attachment. This arrangement provides accessibility for insulation inspection and maintenance. The integral stiffened tank shell carries a combination of overall body bending, shear, and axial load in addition to



(a)



A–A
(b)

FIGURE 6 INTEGRAL TANK ORBITER PRIMARY STRUCTURE ARRANGEMENT
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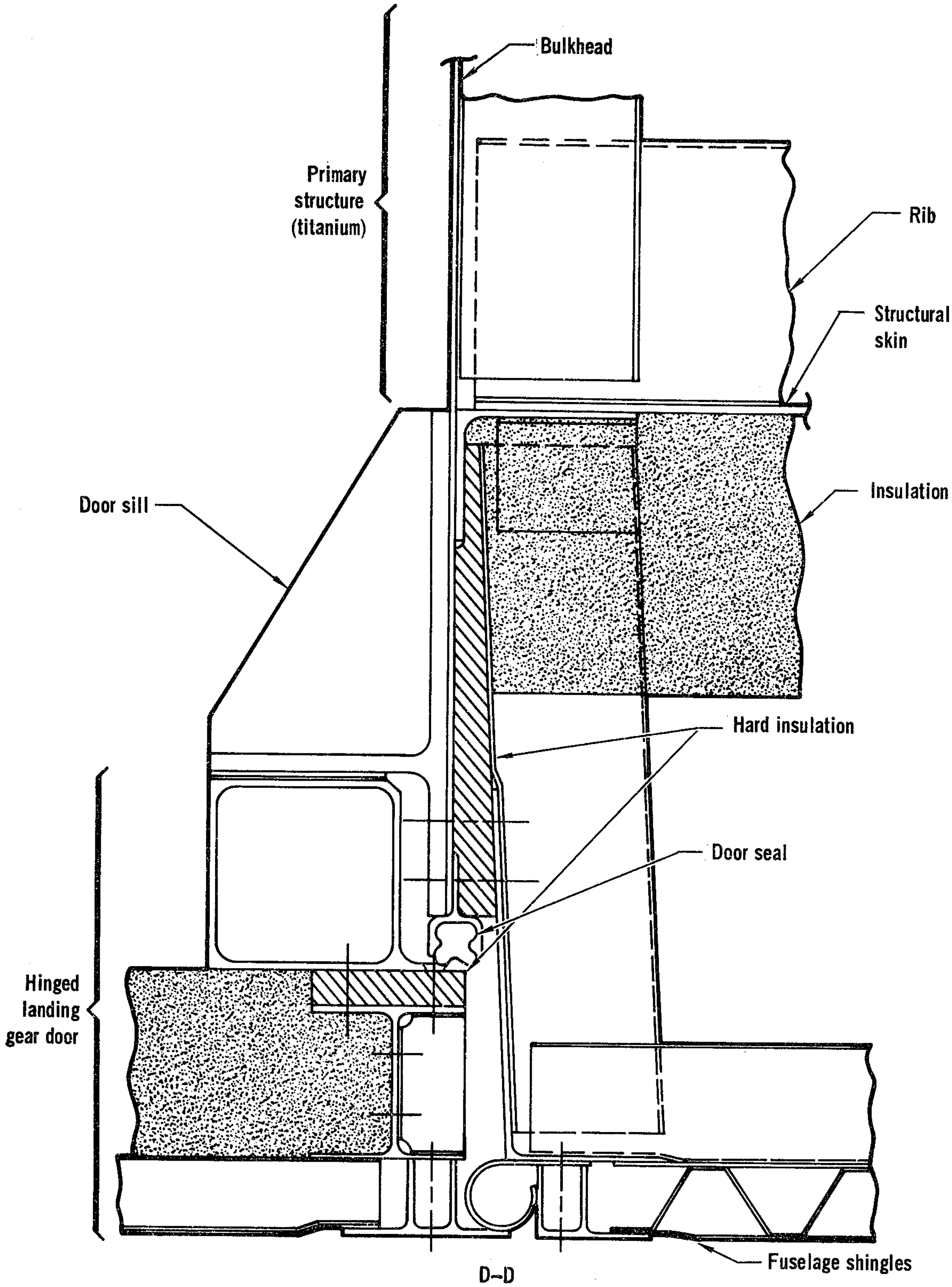

(c)

FIGURE 6 CONTINUED
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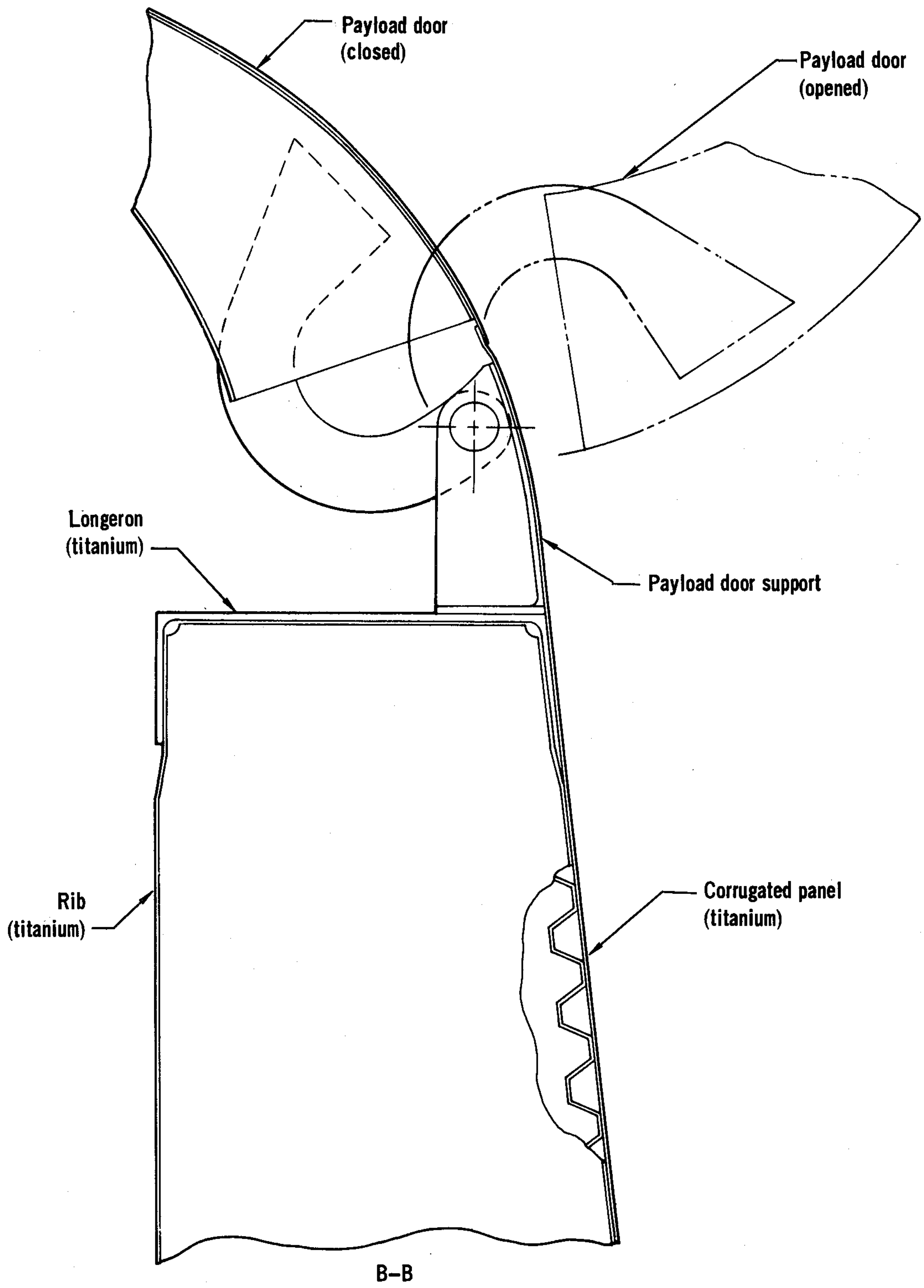

(d)

FIGURE 6 CONTINUED
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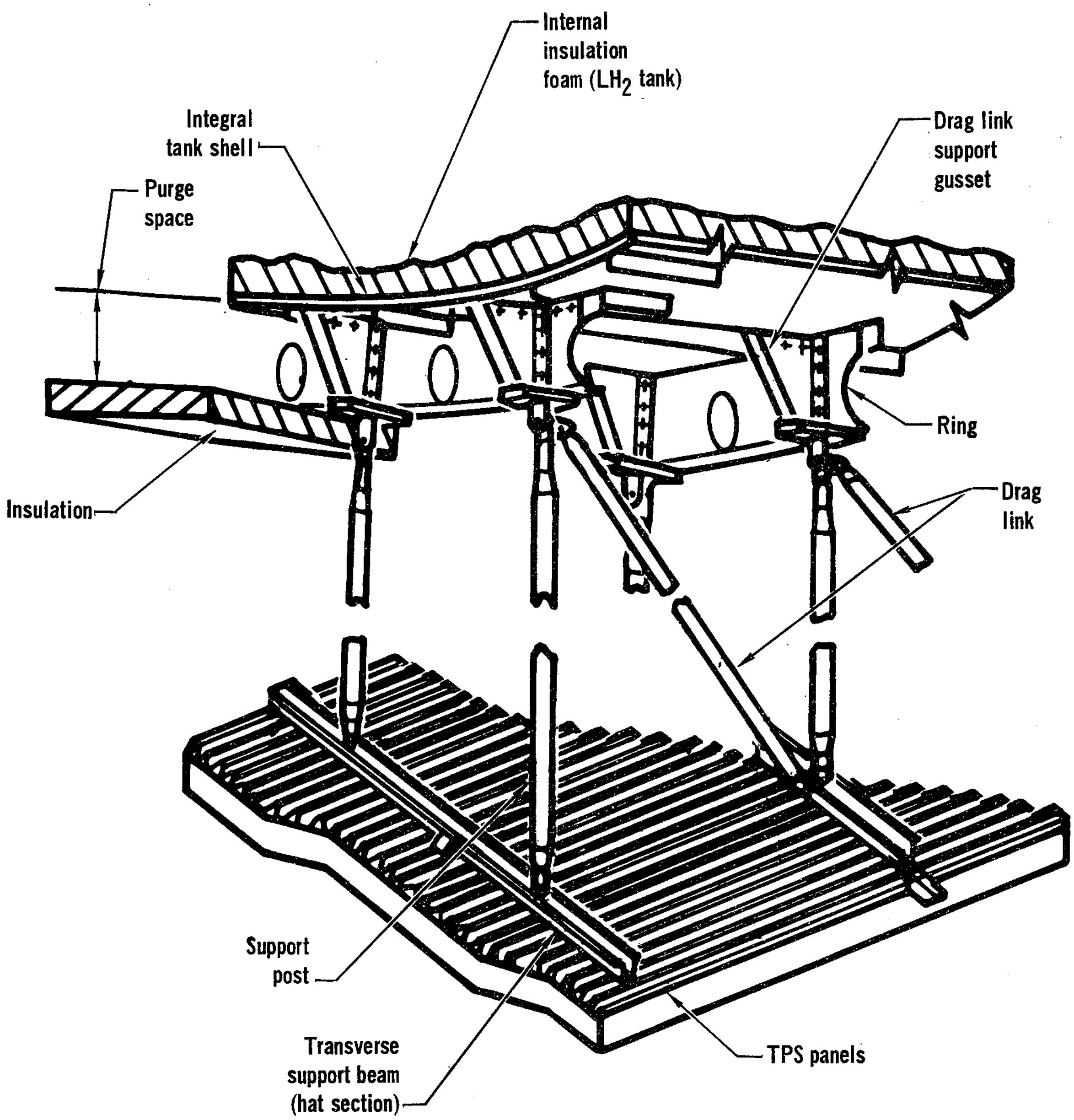

(e)

FIGURE 6 CONTINUED
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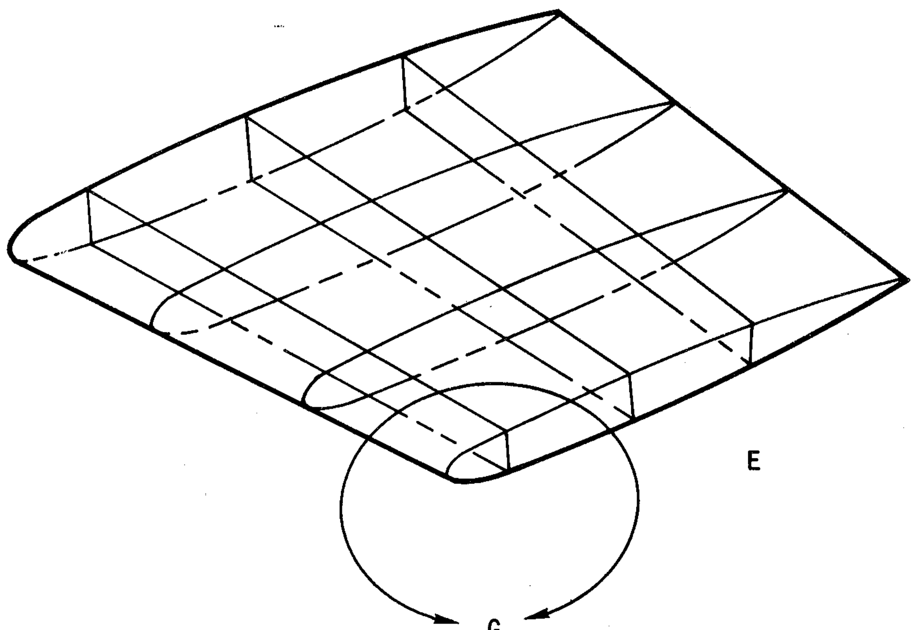
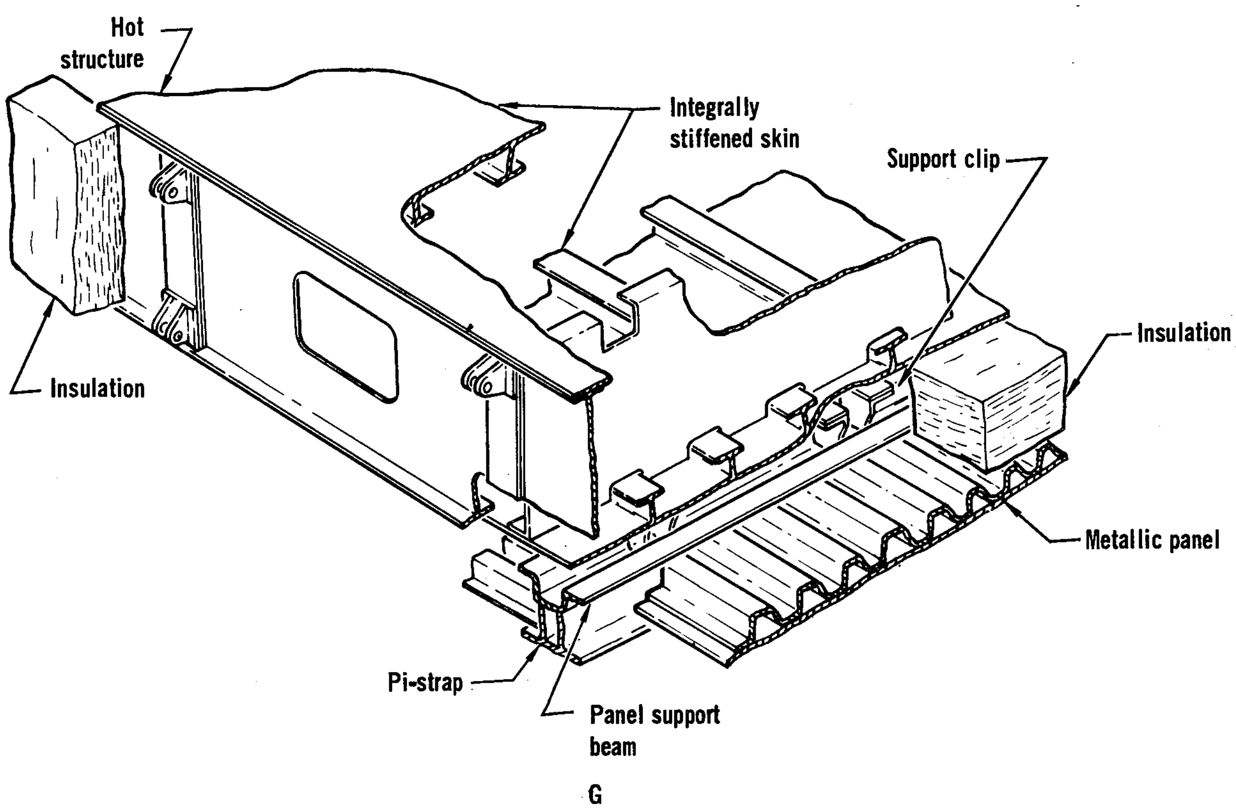


(f)



(g)

FIGURE 6 CONCLUDED

internal tank pressure and hydrostatic pressures due to vehicle accelerations. Titanium rings, stiffened by intercostals, are mechanically attached to the integral circumferential rings. These rings help to stabilize the tank shell and distribute TPS truss support loads into the primary tank shell structure.

Forward body: The primary structural shell is composed of longitudinally stiffened titanium skins, and frames. TPS shingles protect the primary load carrying structure on the lower fuselage and on some portions of the upper fuselage. In regions of lower heating on the sides and top of the forward body, the titanium primary structure is exposed to entry heating.

The forward body/landing gear door interface is shown in figure 6(c). The cutout in the primary structure is enclosed on two sides by bulkheads that are outward to form a closure wall in the area between TPS panels and the primary structure, whereas intercostals provide the other two walls. The hinged door is supported by a sill attached to the extended bulkhead. Although the landing gear bay is not pressurized an elastomer seal restricts direct air passage into the bay area. A looped spring seal obviates the thermal expansion gap between the landing gear door and the TPS panels.

Payload doors: Payload doors are composed of single-faced titanium corrugations which act as hot structure. Primary loads are beamed around the payload doors so that they carry local airloads only. The side fuselage/payload door interface is shown in figure 6(d).

Upper fuselage: The upper fuselage structure consists of single-faced corrugated panels supported by ribs and main longerons, as shown in figure 6(d). The titanium longerons are adjacent to the payload bay with titanium ribs providing the structural shear tie between the upper fuselage and propellant tanks. Single-skin corrugated titanium panels are supported by the longeron and the 20 inch spaced ribs. Titanium was selected for the upper fuselage structure due to its high strength and stiffness efficiencies. Since temperatures during entry in this area are below 800°F, no insulation is used to protect the primary structure. However, a thin insulation blanket attached to the panels restricts the internal area temperature. As shown, the electromechanical actuated payload door is supported by the longerons with hinge support fittings on one side and locking mechanisms on the opposite side for securing the door closed.

Lower fuselage: Heat shield panels on the lower fuselage are attached to beams supported off the tank shell stiffening rings by struts spaced at approximately 24 inches across the fuselage, as shown in figure 6(e). The support structure consists of hat section beams and links to support the beams. Panels are supported by the beams and held in place by pi-straps. Beams are attached to the primary structure by support posts and drag links.

Aerodynamic surfaces: The wing is divided into three major sections: leading edge, primary box beam structure, and trailing edge flaps, as shown in figure 6(f and g). The primary structure is of a conventional box beam construction, employing spars, ribs, and internally stiffened skins. The all-titanium wing box is a two-cell compartment using an intermediate spar, with rib spacing of approximately 20 inches. The lower surface of the box is protected from entry heating by radiative heat shield panels while the upper surfaces, due to lower temperature environment, require no additional thermal protection. The carbon/carbon composite leading edge supports itself and is attached to the wing box forward spar.

Nonintegral tank design. - An example of a nonintegral tank configuration is shown in figure 7. In this concept, propellant tanks do not support overall body bending and shear loads. The tanks are within and supported by the outer primary load-carrying structure. A primary difference between integral tank and nonintegral tank configurations is that the structural skin of the nonintegral concept either forms or closely follows the moldline, whereas for the integral concept, it follows the shape of the tank. Therefore, TPS panels for the non-integral tank are attached to structural skins using shallow standoff brackets, where generally for the integral tanks, the panels are supported by truss members attached to the tank's external stiffening members.

For the nonintegral tank the tank walls resist internal pressure plus hydrostatic pressures from vehicle accelerations. These inertia loads are distributed to the primary structure through a series of supports. The design of these supports must comply with differential expansions and contraction between the tankage and primary structure. This deformation is due to tank shrinkage during fueling, tank growth during pressurization and outer structural shell growth during entry. A feasible support concept with longitudinal and lateral load reactions is also shown in figure 7. The support fittings at the forward end react to vertical, lateral, and longitudinal loads whereas tension bars carry lateral and vertical loads at the aft end. Spherical bearings at attach points allow transverse freedom of movement when deformation takes place between the primary structure and the nonintegral tank.

TASK 2 - HEAT SHIELD ATTACHMENT TECHNIQUES DEFINITION

Provision for easy panel installation and removal is an integral part of previously described heat shield system design. Attachment methods must provide panel support and a load path for aerodynamic and panel inertia loads to the primary structure. During this study representative attachment techniques associated with ablative, metallic, and nonmetallic-nonablative type heat shields were reviewed and identified for subsequent refurbishment cost analyses.

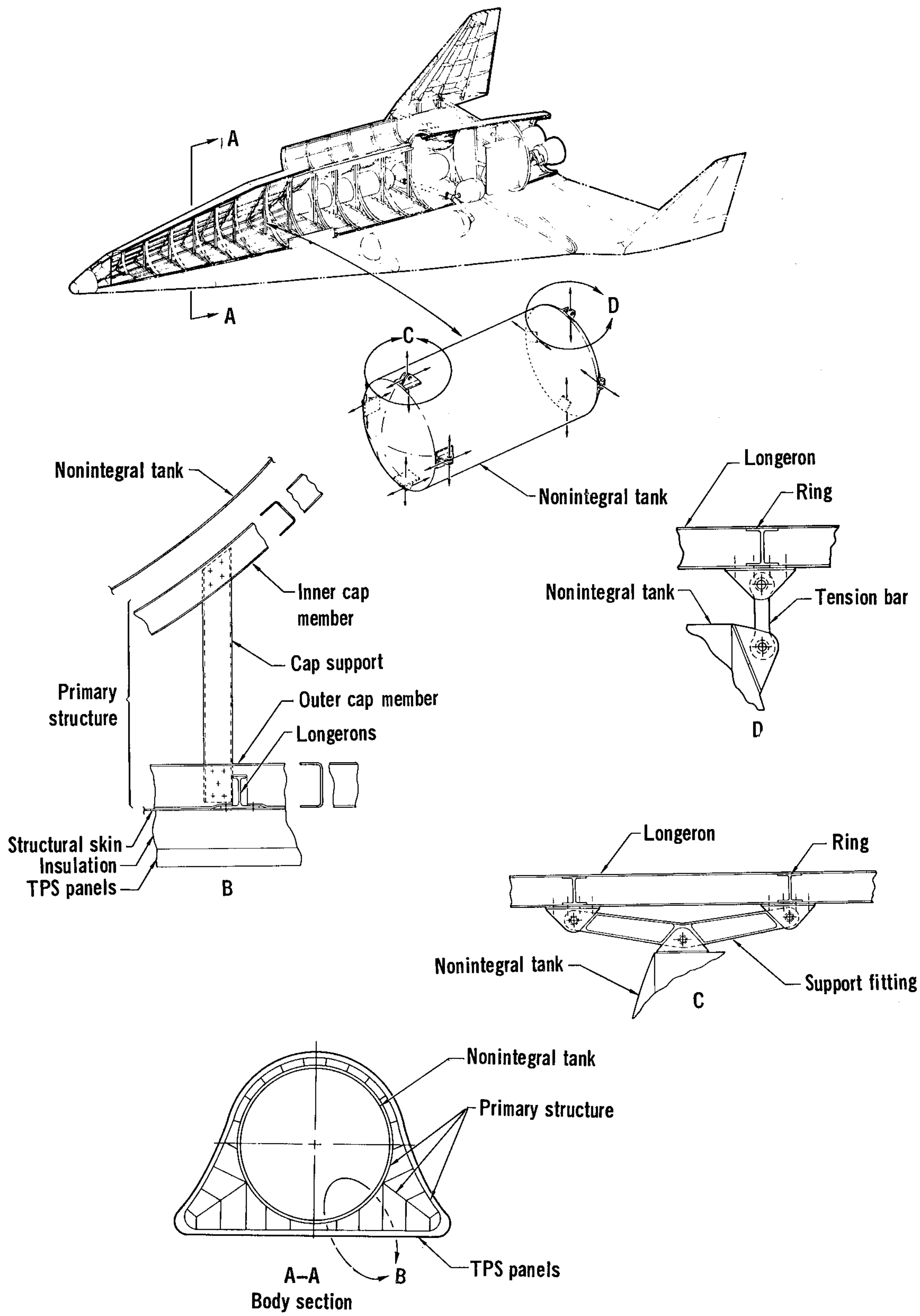


FIGURE 7 NONINTEGRAL TANK ORBITER PRIMARY STRUCTURE ARRANGEMENT

Design Considerations

In specifying an attachment technique for a particular kind of heat shield system, certain thermal-structural factors must be considered early in the conceptual stages to ensure an adequate design approach. Major attachment methods selection factors which effect TPS design include:

Heat shield system type

Expected loads and temperature

Applicable material behavior characteristics

Heat shield system size, shape, and cross-sectional geometry

Heat shield system location relative to primary supporting structure

Attachment method ability to maintain surface continuity (i.e., smooth aerodynamic surface)

Expansion and contraction characteristics with temperature extremes

Requirements for access to primary structure, insulation, and internal subsystems

Attachment locations such as panel joints or other surface discontinuities relative to areas subject to boundary layer gas inflow

Easy heat shield system installation and removal.

The attachment technique used (i.e., adhesive bond, mechanical fastener, or combinations thereof) is primarily a function of heat shield system type, whereas attachment location and size are dictated in part by positions of primary structure components such as rings, frames, longerons, and skins.

Magnitudes, rates, and periods of exposure to thermal/structural loads are of critical importance in heat shield attachment design. These load levels are functions of heat shield system and primary load carrying structure interface environments.

Material selection for various attachment concepts requires consideration of a number of criteria such as material temperature use limits; projected mechanical, metallurgical, and chemical properties which reflect the allowables for the time period considered, fabrication characteristics which denote manufacturing feasibility; and material strength-to-weight efficiencies for desired temperature ranges.

The particular type of attachment used, in addition to being a function of the heat shield system, is dictated by panel substrate size, shape, and cross-sectional geometry. Panel sizing is a direct function of imposed loads and material used in construction whereas shape is related to aerodynamic requirements. Analytic trade studies have shown that certain materials lend themselves more readily to specific construction techniques (i.e., panel cross-section) than do others. In areas of relatively sharp curvature, panel size could be limited by fabrication or purely geometric constraints. In addition, the overall size of available material stock might require splicing in order to fabricate panels of the desired size. Tooling, facilities, and general handling requirements may also influence panel sizes.

Primary structure proximity to the heat shield system may effect attachment type and location. Heat shields which are far from the primary structure may be more amenable to internal fastening and subsequent quicker refurbishment activities.

Panels tend to undergo bending distortions due to temperature extremes, producing edge rotations which could lead to surface gaps and possible interruption of a smooth aerodynamic surface. Therefore, it is advisable to attach the panel so that bending is suppressed without inducing large thermal stresses.

To prevent gaps at joints, panels are not rigidly attached to support framing members. This precludes overstressing the heat shield, attachments, and possibly supporting members. One method is to attach the panel in oversized holes so that it is free to expand and contract without restraint in the plane of the panel.

Requirements for access to primary structure, insulation, and internal subsystems may necessitate either internal or external attachment. Ablative and HCF type heat shields are more amenable to internal fastening whereas metallic heat shields lend themselves more readily to external fastening.

Self-adjusting, flexible gaskets between adjacent heat shield panels close gaps caused by panel contraction or deformation in a cold environment, precluding high enthalpy gas flow between panels during vehicle entry. Gaskets used to prevent the gap formation must be flexible enough that large in-plane compressive forces in the panels are not developed when the panels are at elevated temperatures, since such forces may buckle the panels. The attachments must withstand these forces and maintain surface continuity.

To minimize vehicle recertification time, attachment methods must permit easy heat shield panel installation and removal. Therefore, attachment design concepts must be as simple, reliable, and predictable as possible.

Basic Heat Shield Attachment Techniques

Once the primary structure and type of heat system are defined for various vehicle locations, a suitable attachment between the two systems must be provided. Since the primary structure and type of heat shield system may vary significantly from one location on the vehicle to another, attachment methods must be relatively simple to accomplish smooth transition. Therefore, the design goal is commonality.

Inherent and critical in the refurbishment concept is an attachment method which allows easy access to internal subsystems so as to minimize removal, repair, and inspection times of various components. Attachment techniques vary from proven adhesive/bolt-on approaches to unproven unique designs such as loop-and-pile, perforated interface, elastomer pillars, and mystic tape no. 7000.

In this study every attempt was made to analyze in detail only those attachment techniques which are amenable to near future space shuttle application. To make the TPS refurbishment cost results applicable to space shuttle designs, a close working relationship was maintained between the activities of this study and MDAC's effort on the space shuttle phase B study. This effort was supplemented by a literature review of various concepts proposed by other companies in the industry (references 12 through 34).

From investigations, certain concepts evolved as prime candidates for space shuttle application. Descriptions of those concepts which were analyzed in detail during the cost estimate study task are presented in the following paragraphs. Although a specific structure is shown for each attachment concept, this does not restrict the attachment concept from being used on other applicable primary structural approaches.

In narrowing down the field of candidate attachment methods to be analyzed, certain guidelines or constraints were adhered to. Each concept chosen for analysis has one or more of the following attributes:

Simplicity

Accessibility

Reliability

State-of-the-art

Interchangeability

Easy replacement, inspection, and repair.

<u>Ablative heat shield attachment concepts</u>. - Ablative heat shield attachment techniques lend themselves readily to adhesive bonding, mechanical fasteners, or combinations thereof. The simplest and most direct approach involves bonding the ablator to the structural skin of the vehicle or to an intermediate panel substrate. In the latter case the panel substrate is mechanically fastened to the primary structure through secondary supports. Elastomer ablators are too weak to be attached directly with mechanical fasteners.

In the following paragraphs representative attachment concepts are described. These include:

Concept 1 - bonded attach

Concept 2 - mechanical fastener attach

Concept 3 - pi-strap attach

Concepts 4a and 4b - multiple mechanical fastener attach

Concept 5 - key/keyway attach.

Concept 1 - bonded attach: The most direct and widely used method for attaching an ablative heat shield is direct bonding the resin filled honeycomb matrix to the vehicle primary structural skin, as shown in figure 8. This concept was used successfully on Gemini and Apollo. However, direct application to the vehicle skin requires used ablator to be removed from the primary structure and new ablator applied. This type of refurbishment may increase vehicle turnaround times since the whole vehicle may be involved in the refurbishment cycle.

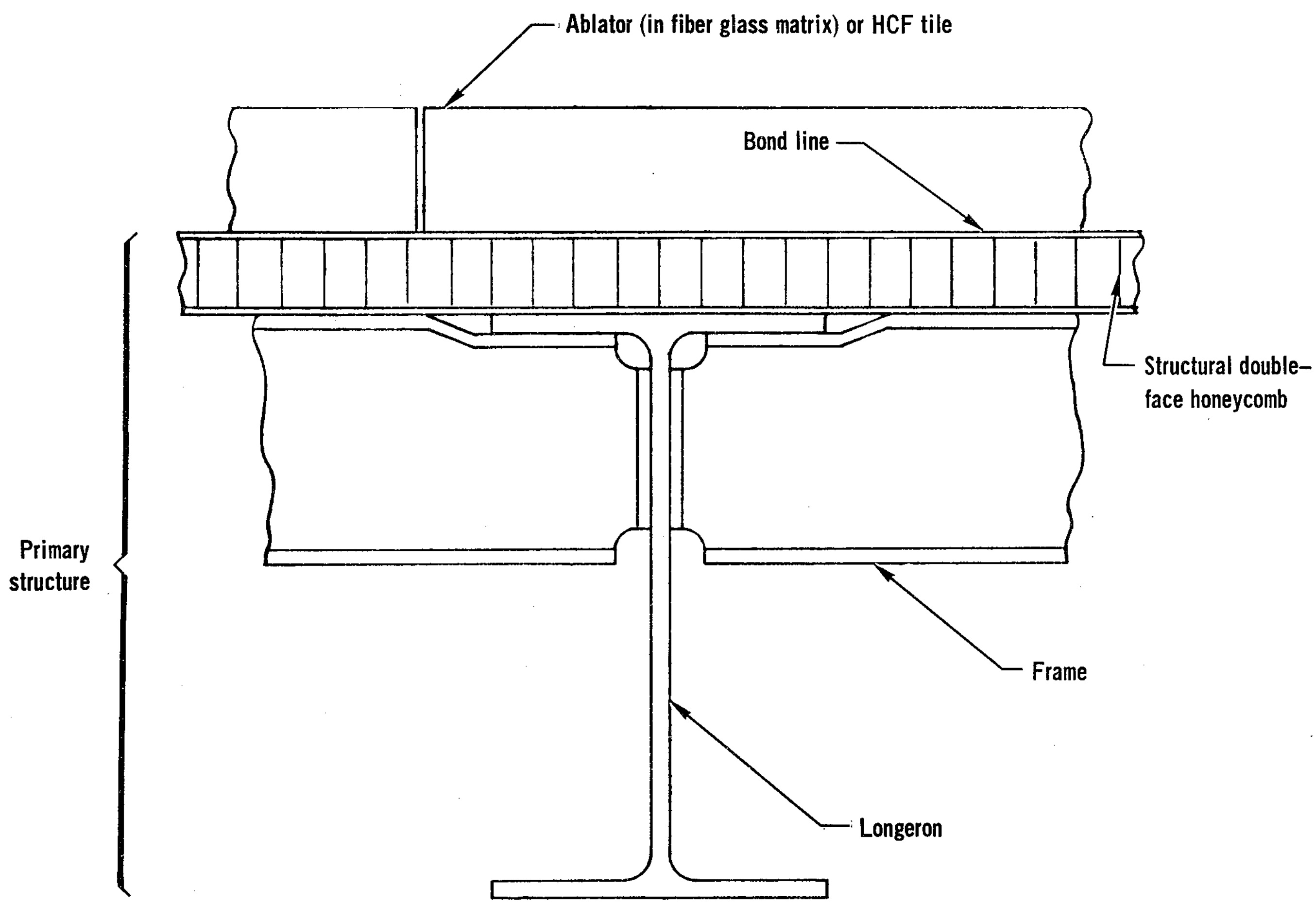


FIGURE 8 BONDED CONCEPT

One advantage of an elastomer ablator is that it can be easily cut with a knife, or other sharp edge, layer by layer down to the metallic substrate. Methods for releasing the bond include use of chemical reagents. Silicone rubber is changed to semiliquid by reaction with amines. The resulting softened mass can be scraped off and washed down with solvents, leaving a clean substrate. This technique is clearly more effective and efficient than those used to remove rigid bonds. Rigid bonds, hard enough to warrant grinding or abrading cycles of much longer duration, increase costs and present a hazard to the substructure, e.g., gouging, which would require time-consuming, costly repair.

Concept 2 - mechanical fastener attach: A typical mechanical fastener attach concept is shown in figure 9. The TPS panel consists of the ablator (silicon/fiber glass honeycomb matrix) bonded to a double-faced fiber glass honeycomb substrate. The composite panel is attached, by mechanical fasteners (screws, bolts, etc) every 10 inches on two edges only to transverse panel support beams while the other two edges rest on sills between the beams. Transverse panel support beams are attached to bulkheads of the primary structure. Analyses indicate that minimum weight is obtained for panel lengths of approximately 20 inches along unfastened edges. Additional fasteners may be provided for redundancy if desired. Panel size and bolt hole spacing analyses for each concept are presented later in this report.

Holes through the panel, to match the attach pattern in the support beam, allow access for installing and removing the mechanical fasteners. Following panel installation, these holes are filled by bonding in a premachined ablative plug with a high temperature silicone adhesive. If surface mismatch between plug and panel is < 0.030 inches no surface blending is required. Small holes in the center of these plugs are used for locating same and subsequently drilling out the plug, allowing access to mechanical fasteners and panel removal during refurbishment. Panels are not rigidly attached to the support framing members. This precludes overstressing the heat shield, attachments, and possibly supporting members. This is done by attaching the panel in oversized holes so that it is free to expand and contract without restraint in the plane of the panel.

Gaskets are provided between adjacent heat shield panels to prevent the inflow of water and hot boundary layer gases into panel joints. These gaskets must not only seal the joints but be sufficiently flexible to allow for the normal contraction and expansion of the panels under various environmental extremes. For this application various state-of-the-art silicone elastomeric type materials are available which possess adequate thermal and ablation characteristics. Examples of two commercially available products are General Electric's TBS-757 and Dow Corning's DC 93-044. In addition several variations of MDAC-East foamed silicone ablative materials, namely S-6, F-34 and S-20 could be used for this application.

To date, most gasket materials have been fabricated by either molding or extrusion methods in the density range from 35 to 45 lb/ft^3. Lower density materials (i.e., 15 lb/ft^3) are achievable but not necessarily commensurate with gasket flexibility, compression and tensile requirements. Currently these type gaskets have no reuse life capability and as such would be limited to the application of ablator heat shields only. Gasket configuration depends on the panel interface and is thus subject to detail design. Several approaches to the problem for ablative type heat shields are shown in figure 10. The general problem of gaps for all type heat shield systems is discussed in the section titled <u>Heat Shield Panel Interface</u>, page 49.

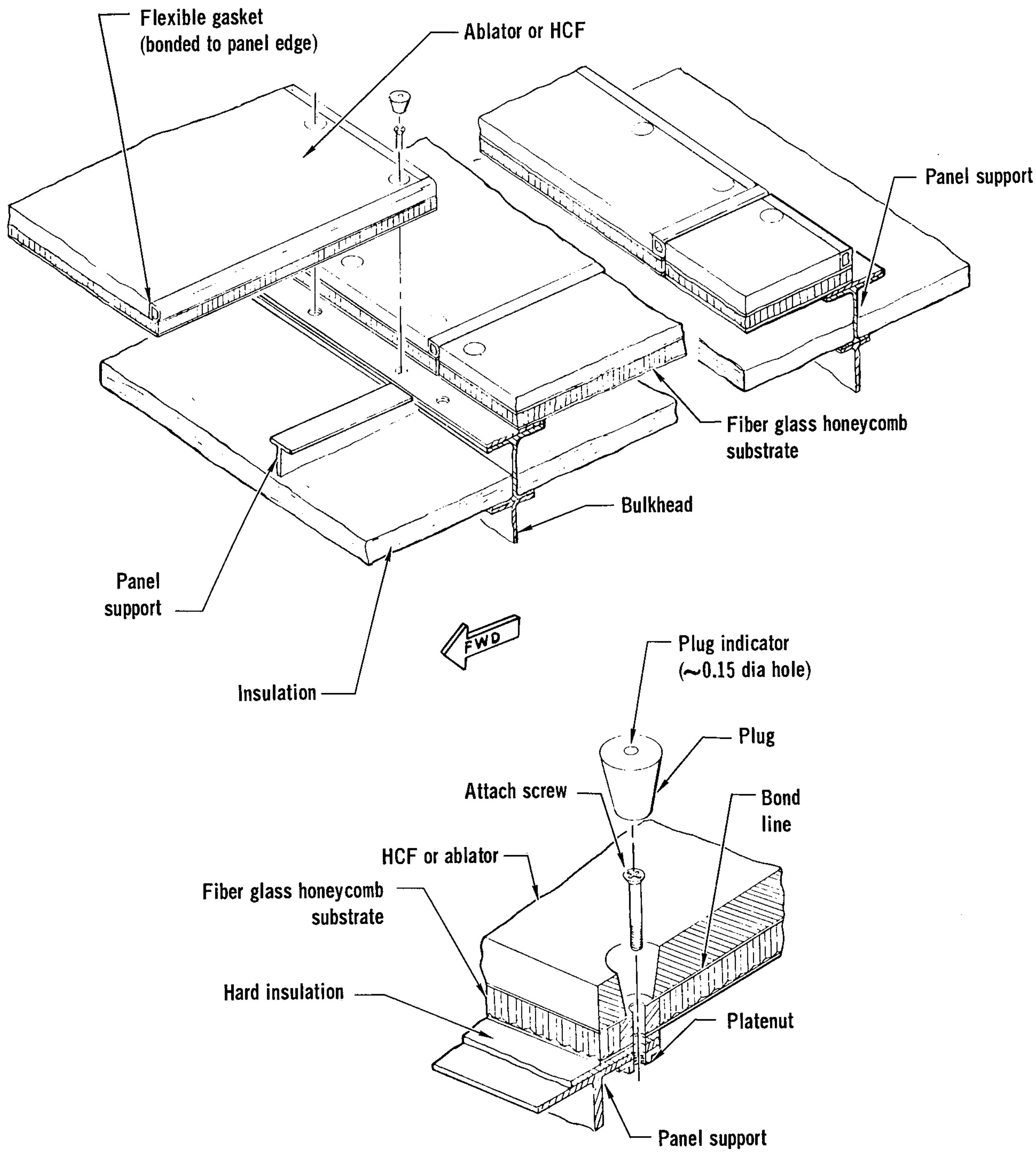


FIGURE 9 MECHANICAL FASTENER ATTACH CONCEPT

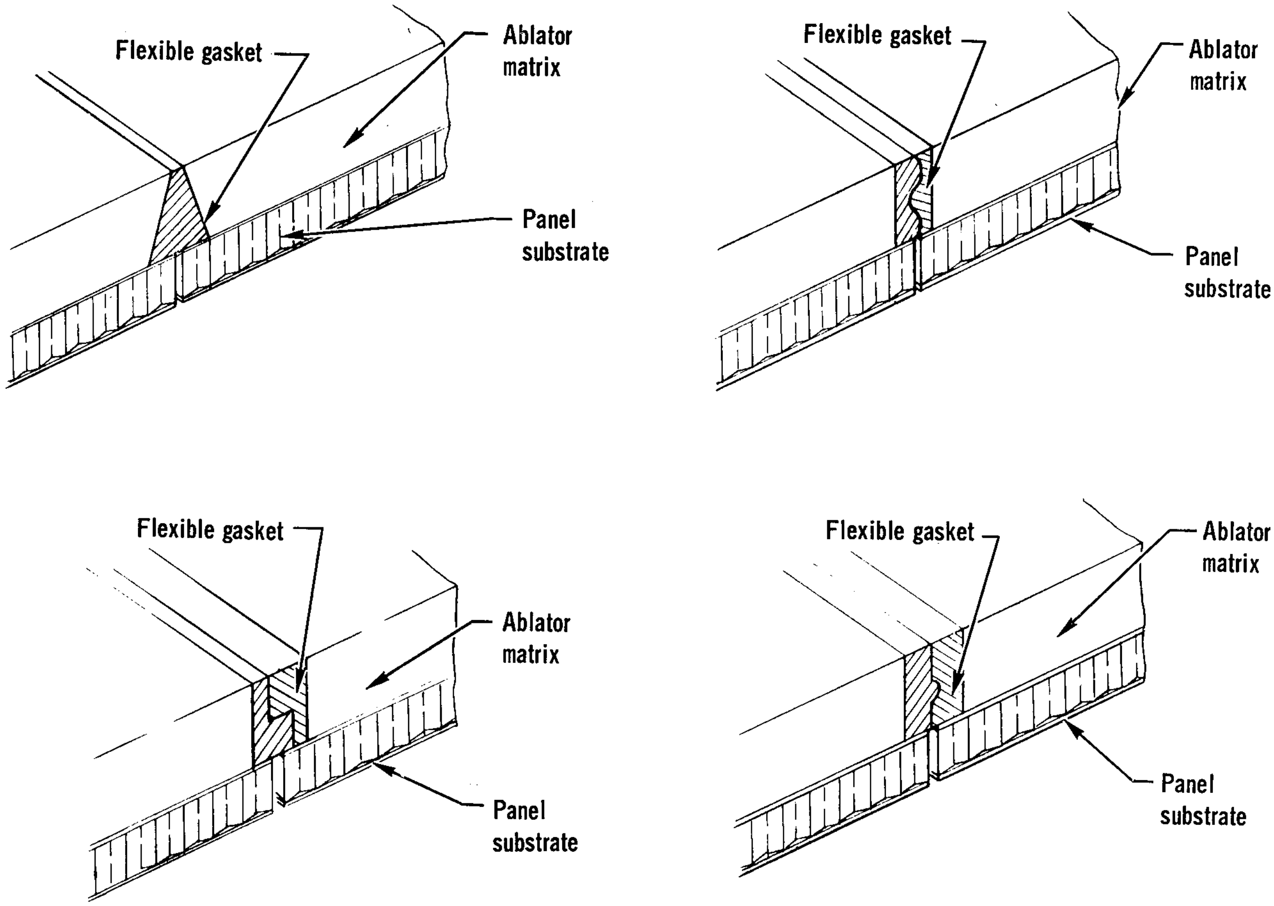


FIGURE 10 PERIPHERAL JOINT DESIGN CONCEPTS

Concept 3 - pi-strap attach: Another way to mechanically fasten an ablative panel is with a pi-strap as shown in figure 11. In this concept the panel is supported along a lip machined along two opposite edges of the panel. With the panel resting on a support beam, as shown, a strap is positioned over the lip and firmly attached to the panel support beam. Sills support the other two edges with gaskets between panel interfaces as in concept 2. Pi-straps could be provided along all four edges if desired. The pi-strap is formed by bonding a fiber glass honeycomb matrix to a metal extrusion and filling the honeycomb cells with the ablator compound (similar to primary panel construction). Pi-straps, which are not restricted to matching panel lengths, are attached by mechanical fasteners as in concept 2.

Concept 3 has several advantages over concept 1. Although hole spacing in both concepts is similar, the pi-strap concept requires half as many fasteners since it secures two adjacent panels edges. The gap between the pi-strap and adjacent panels is less of a problem since the in-flow of hot gases to the primary support is less likely due to overlapping.

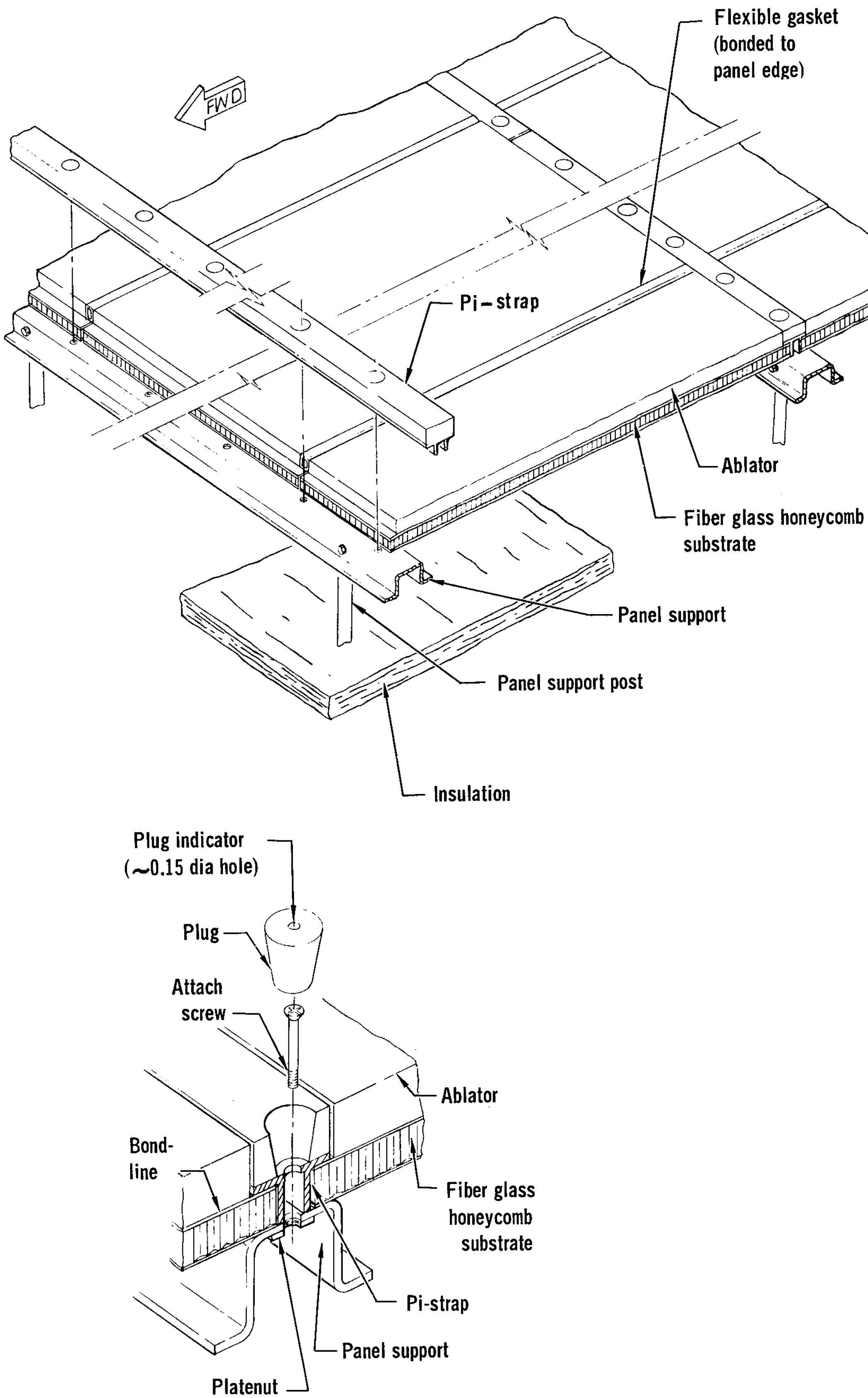


FIGURE 11 PI-STRAP CONCEPT

Concepts 4a and 4b - multiple mechanical fasteners: Two approaches whereby the panel substrate, used for supporting the ablator, is immediately reusable are shown in figures 12 and 13. In these two approaches the ablator matrix is not bonded to the panel substrate. Instead, many mechanical fasteners are used. However, a thin face sheet of fiber glass is bonded to the ablator matrix to support the mechanical fasteners since the ablator material will not withstand the imposed fastener loads.

Mechanical fasteners are metal studs which in concept 4a (figure 12) are attached intermittently to the opposite face of the ablator matrix/single face sheet composite. These studs are inserted into solid fiber glass plugs, imbedded in the panel substrate, to which nuts are attached. The required spacing of these studs was determined by analysis to be on 7-inch centers in a grid pattern. Once the ablator composite is attached to the panel substrate, the panel is mounted to the supporting structure in a manner similar to that of concept 3. Although the ablative cover must be attached to the panel substrate before the substrate is attached to the vehicle, the concept does allow for quick panel refurbishment without time-consuming bond removal.

The same principal of attachment is used in concept 4b (figure 13). In this concept the ablator is attached to the panel substrate after the substrate is secured to the primary structure. The panel substrate is attached to the primary structure by flush head screws. Predrilled holes are provided in the ablator matrix/single face sheet composite. Through these holes the ablator composite is attached to metal plugs imbedded in the panel substrate. Bolt heads are encased in the ablator and bear against the ablator composite face sheet. After installation the holes are filled with premachined plugs which are bonded in place similar to the aforementioned concepts. A slight gap or washer is provided between the bottom end of the ablator plug and head end of the bolt for easy access to the bolt head during refurbishment. The biggest advantage of this concept is that the panel substrate is directly reusable and need not be removed from the vehicle during the refurbishment cycle. However, during refurbishment the plugs will have to be removed before access can be gained to the mounting bolts for subsequent ablator removal. The quantity of attachment points required to maintain thermal-structural continuity between the ablator and panel substrate will determine the real refurbishment advantages of this concept. From a design aspect, additional ablator thickness may be required to limit the temperature environment on the fastener. In this regard, the concept is not applicable in those areas of the vehicle where ablator thickness requirements are equal to or below the exposed bolt head depth.

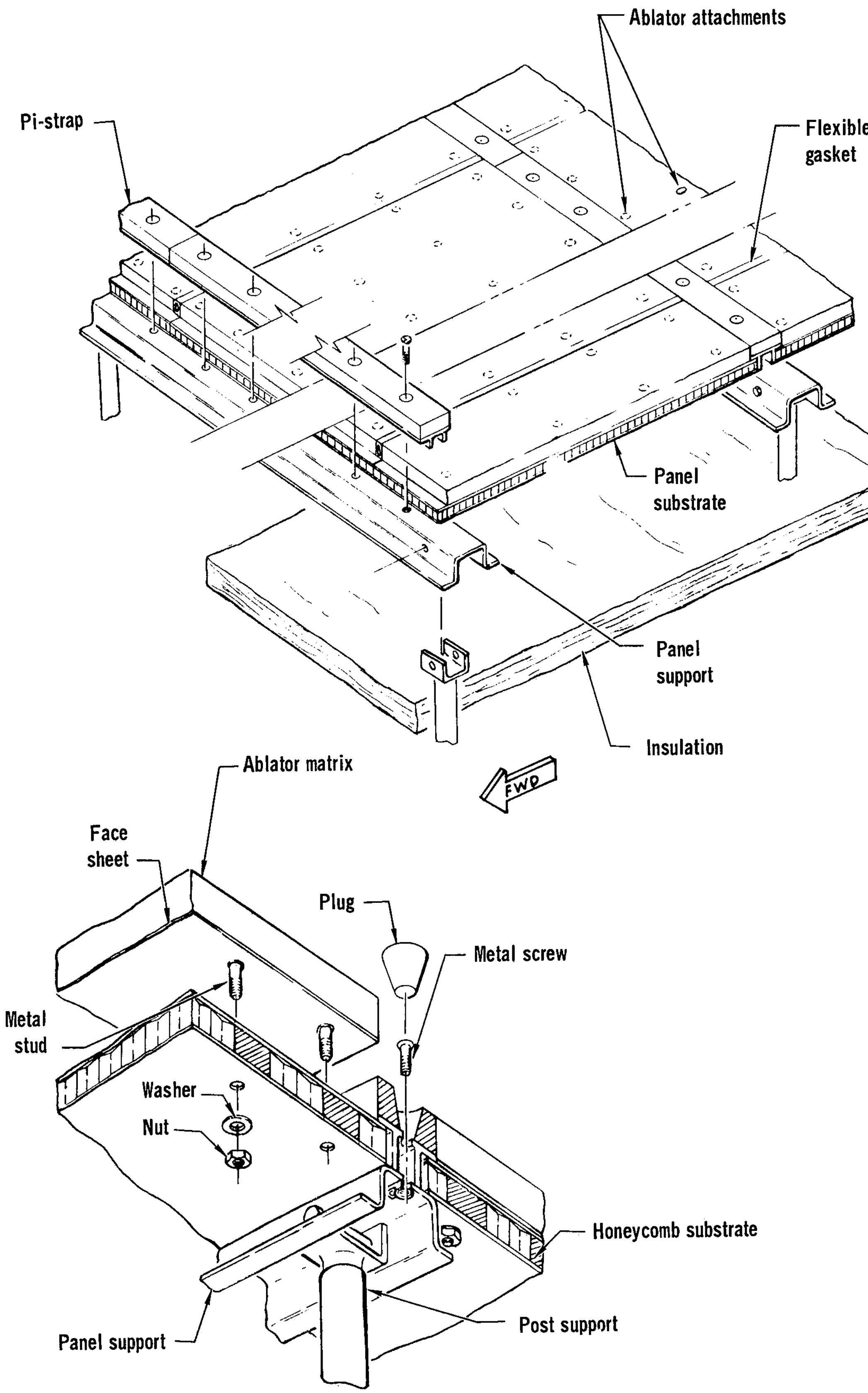


FIGURE 12 MULTIPLE MECHANICAL FASTENERS (4A)

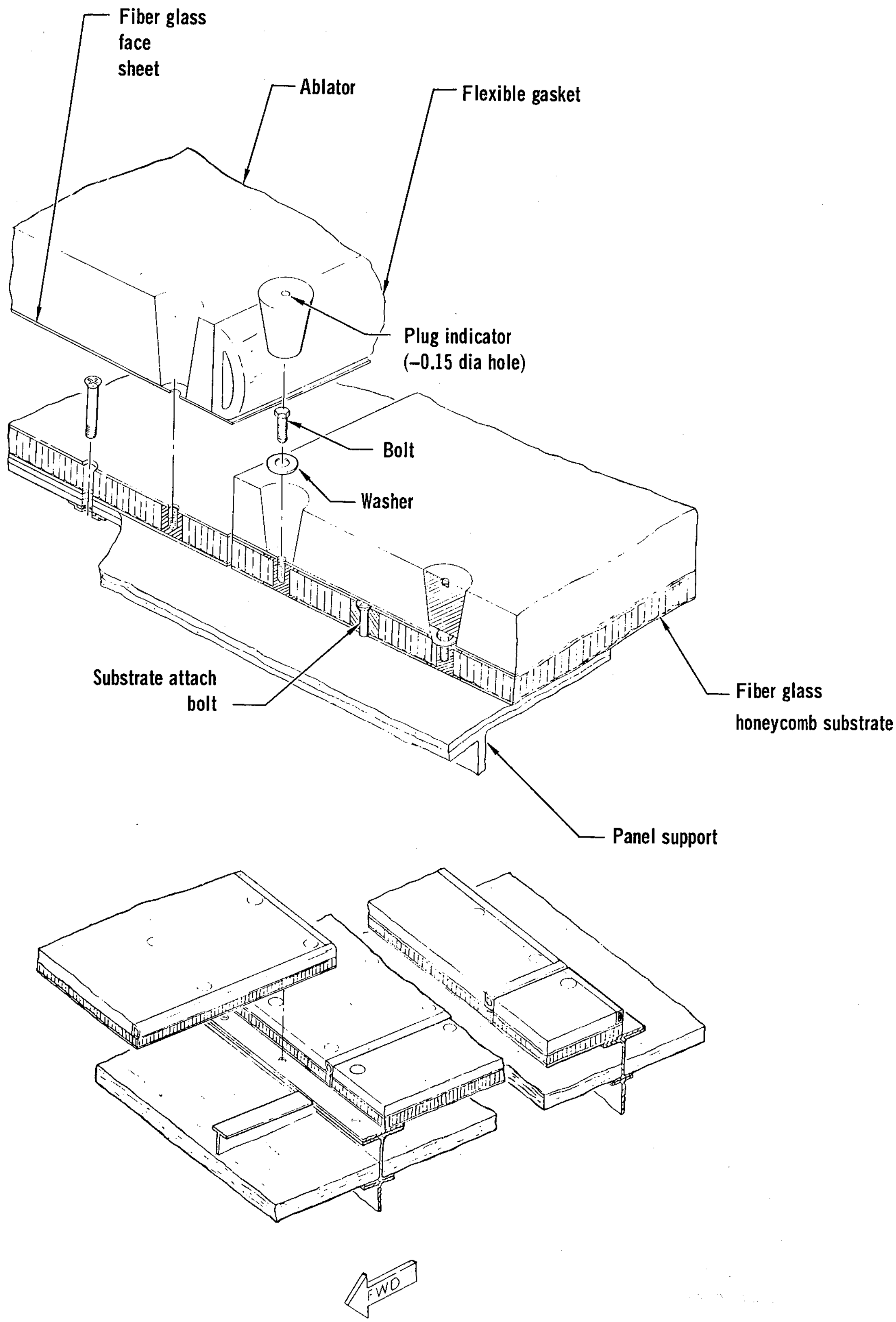


FIGURE 13 MULTIPLE MECHANICAL FASTENERS (4B)

Concept 5 - key/keyway attach: For the key/keyway attach concept, the panel is supported and attached along two opposite edges by a key/keyway joint as shown in figure 14. The keyway or female part consists of two split wedge-shaped rails bonded or mechanically fastened to the panel substrate at opposite ends of the panel. The key, male part, which also serves as the panel support sill is attached to the primary structure and spaced to mate the panel split keyways. Intermittent notches are machined into the key and the keyways allowing the panel to drop over the key, after which the panel is moved along the key ≈ 0.75 inch to achieve a mechanically attached assembly. Sills support the other two panel edges, similar to concept 2. The key/keyway joint must allow the panels to contract and expand under a thermal environment, yet be sufficiently restrained to minimize dynamic response to an acoustic environment.

A longitudinal pi-strap (concept 3) is positioned after every third or fourth panel. This not only controls longitudinal gaps between panels but allows removing selected panels without removing a series of panels starting at the end of a row. Gaps between intermittent panels are controlled by flexible gaskets as in previously discussed concepts.

Metallic heat shield attachment concept. - Unlike ablative heat shields, metallic heat shields rely primarily on the use of some sort of mechanical fastener. The fastener head is generally exposed to the environment; subsequently, its reuse capability is more limited. Direct accessibility to the fastener, however, is an attractive feature from a refurbishment point of view. For these concepts conventional high speed aircraft design experience was heavily relied on. The following concepts are discussed:

Concepts 6a and 6b - flush fastener attach

Concepts 7a and 7b - pi-strap attach concept.

Concepts 6a and 6b - flush fastener attach: The flush fastener panel attach concept, 6a, attaches two TPS panel edges to support beams with flush fasteners spaced 10 inches apart. In concept 6b, shown in figure 15, the panel is attached by three rows of flush fasteners using an intermediate beam between the outer two edge support members. Thus, except for the middle support the concepts are identical. Two panel edges are unsupported except for adjacent panel interlocking edge members, as illustrated. A sill extends beyond the panel skin edge to facilitate wedging the adjacent panel between the sill and external skin. These edge members allow for transverse thermal expansion.

End caps, consisting of a Z section and a right angle, are welded to the single-faced corrugated stiffened panel. Bushings are welded between the skin and end caps, surrounding the attach holes, to prevent the skin from deforming when attach screws are installed. The Z section is also used as a sill by having it extend beyond the skin edge. This allows the adjacent panel skin to overlap the sill and thereby restrict any direct air flow into the vehicles interior area. All sills and overlaps are dimensioned to allow the panel to be dropped into position and then shifted in two directions to achieve proper overlapping.

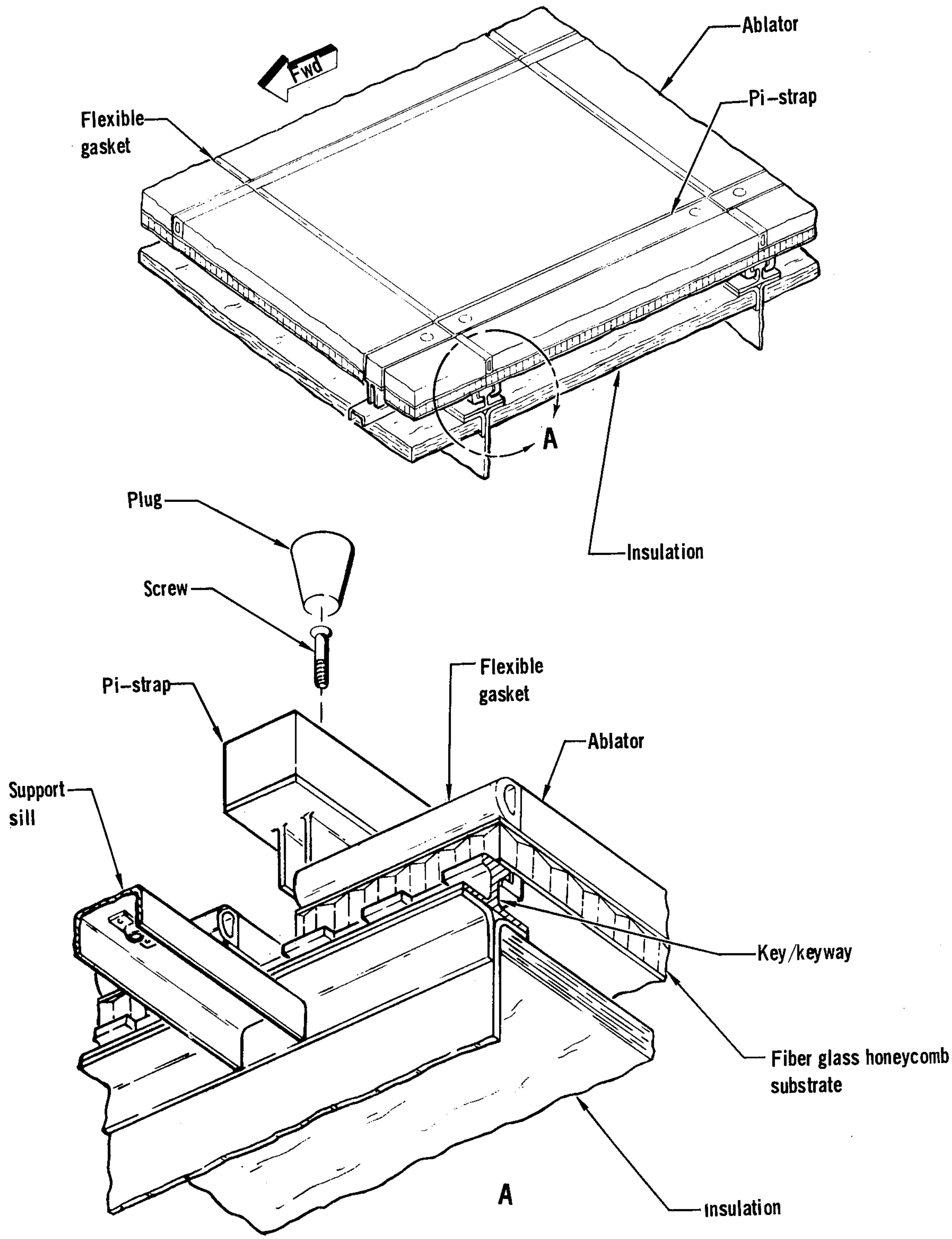


FIGURE 14 KEY/KEYWAY ATTACH CONCEPT

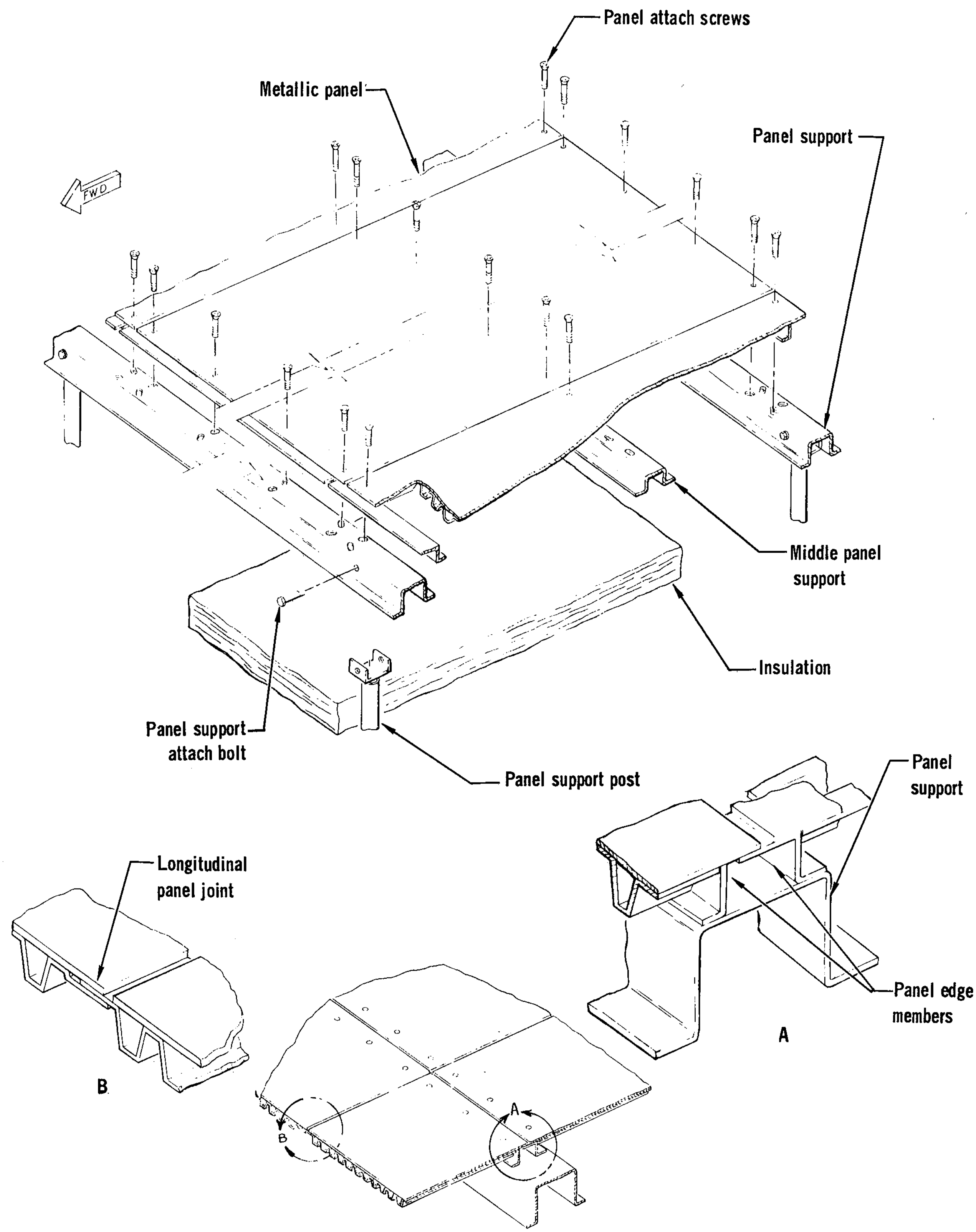


FIGURE 15 FLUSH FASTENER/PANEL ATTACH CONCEPT

Hat section panel support beams are attached to posts which are secured to the primary structure. The panel support shown is one of several possible. Slots in panel support beams are oriented to allow the panel to contract and expand radially from the panel center. This central point (neutral point for thermal expansion) and the center row of fasteners are used for panel positioning.

When installing the panel the screws must be torqued to a value which will adequately tie down the panel but allow the panel to expand and contract under environmental temperature conditions. Other techniques for providing thermal contraction and expansion in the attachment joint are shown in figure 16.

Concepts 7a and 7b - pi-strap attach: The pi-strap attach concepts 7a and 7b, shown respectively in figures 17 and 18, are similar in principal to concept 3. In each concept, two opposite edges of a single skin, corrugated stiffened, panel are placed between a pi-strap ear and a support beam lip. The other two panel edges interlock with adjacent panels as in the flush fastener concept. Having positioned the panel on the support beams, the extruded or machined pi-strap is secured to the support beams by screws spaced at 10-inch intervals. Strap height and panel thickness are closely controlled to provide clamping pressure and at the same time allow for panel contraction and expansion between the pi-strap and support beam.

In concept 7a, panel removal is accomplished by removing only one pi-strap and loosening the fasteners in the pi-strap along the opposite side of the panel. The panel is slipped out from beneath the loosened pi-strap and lifted away from the vehicle.

In concept 7b, an intermediate support is added to stiffen the longer panel. The intermediate panel support consists of an intermittent slot and key arrangement as shown. The key portion is incorporated into the panel stiffener, which is welded to the inner surface of the corrugations, along the middle of the panel. The mating slot portion is incorporated into the middle panel support beam, which is supported in the same manner as panel edge support beams. Since the panel must be moved parallel to the transverse axis to interlock the intermittent slot and key areas of the intermediate panel support, two indexing screws must be installed to keep the center, or neutral, point fixed.

Panel shape is restricted to flat and circular segments because of the interlocking slot and key design feature. Removal of these panels necessitates removing first an end closure segment, such as a chine segment, located at the intersection of the side and bottom fuselage area. Panels are then removed by starting with the end panel and working toward the defective one.

Nonablative, nonmetallic heat shield attachment concepts. - The two candidate materials considered during this study for nonablative, nonmetallic heat shields were the hardened compacted fiber (HCF) compound and an oxidation inhibited carbon/carbon composite. In general, the HCF type heat shield is applicable to large areas of the body while the carbon/carbon material is being considered for localized areas such as the leading edge of aerodynamic surfaces and body chines. Representative application of the carbon/carbon material is discussed in a latter section of this report.

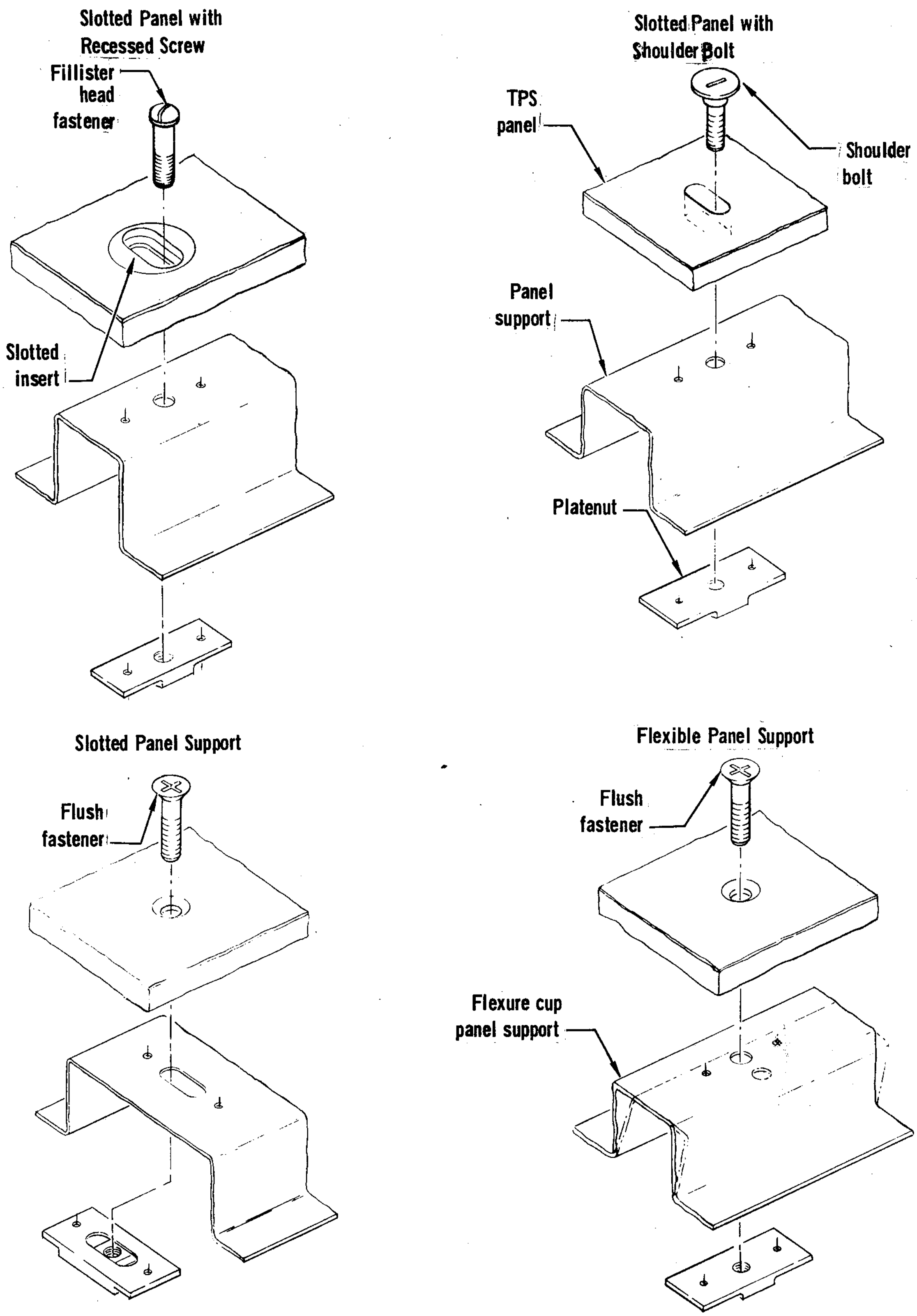


FIGURE 16 MECHANICAL FASTENER PANEL ATTACH VARIATION

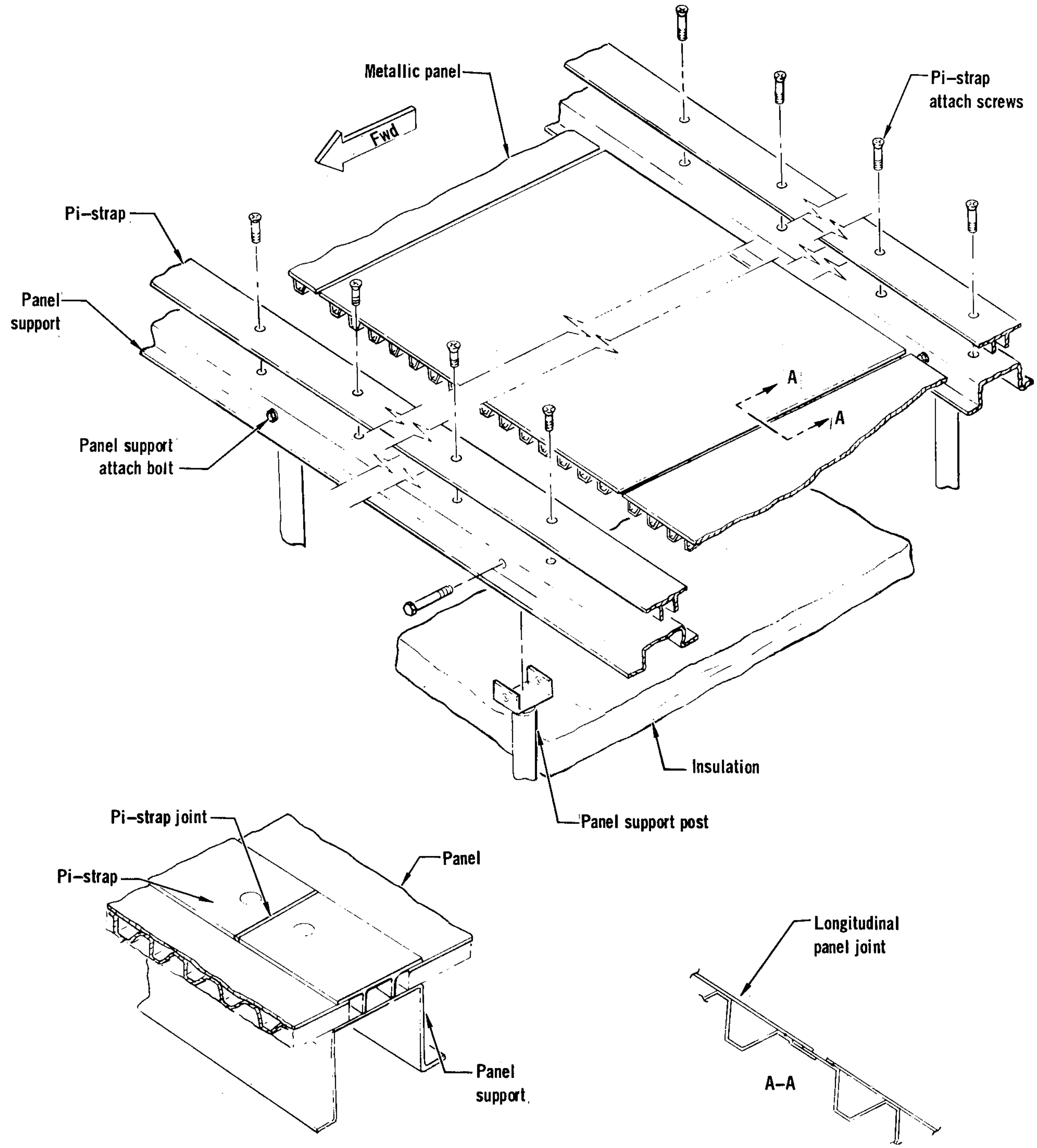


FIGURE 17 PI-STRAP PANEL ATTACH CONCEPT

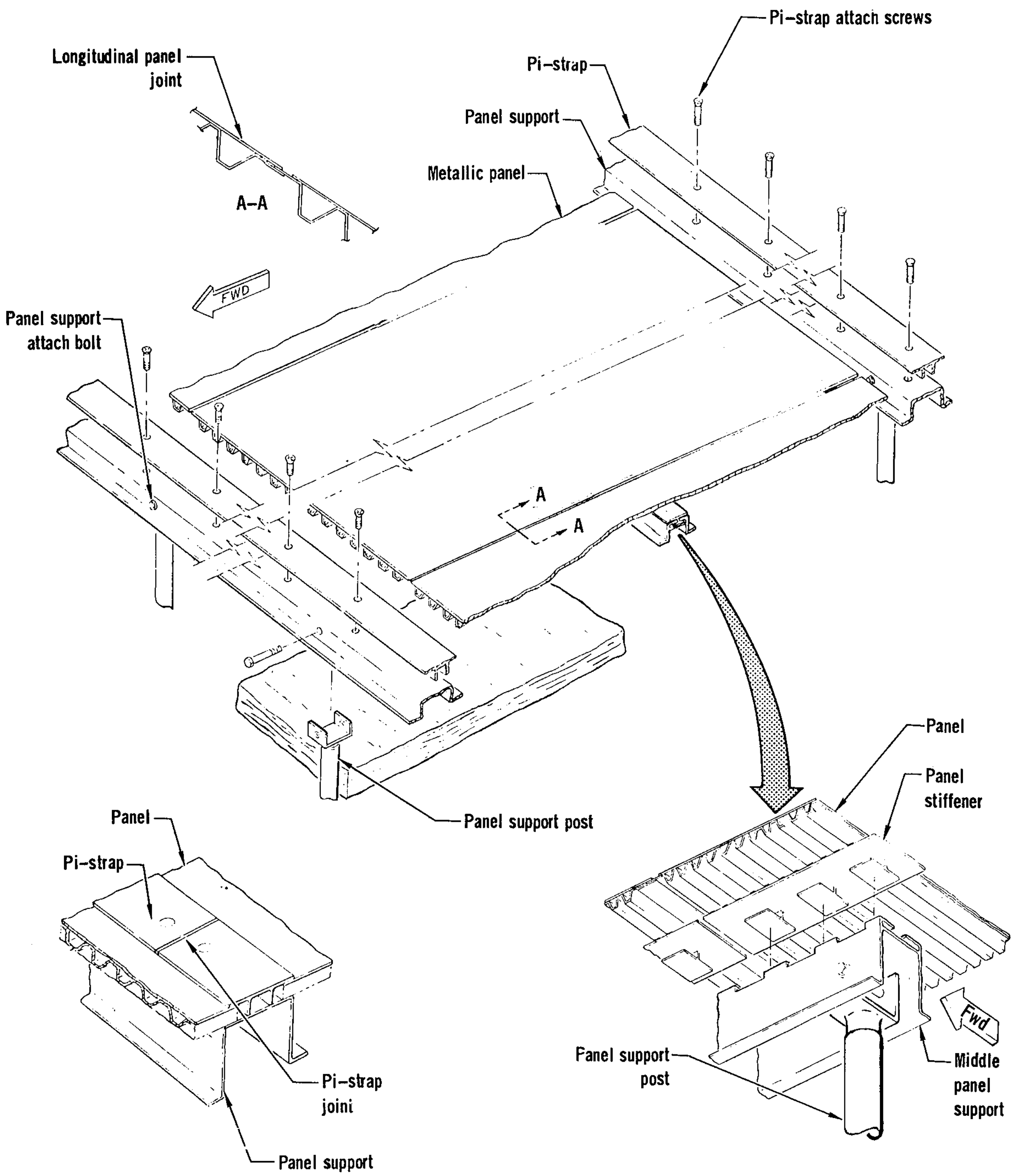


FIGURE 18 PI-STRAP PANEL ATTACH CONCEPT (WITH MIDDLE PANEL SUPPORT)

The nature of an HCF heat shield system is similar in many respects to that of the elastomer ablator except that there is no char layer formed during entry which must be considered during the refurbishment cycle, and HCF reuse life is not as limited as that of the ablator. HCF materials are relatively soft, extremely porous, and lack mechanical strength so that the method of attachment to the primary structure is in most instances by the same techniques as for the elastomer ablator. However, since the HCF material is not strengthened by the use of a honeycomb matrix as is the ablator, primary attachment techniques favor bonding. Attachment methods of concepts 1 through 5 are applicable to HCF heat shield systems.

Heat shield panel interface. - In the area of heat shield attachment one of the most critical design aspects concerning feasibility and related maintenance is the joints and seals between adjacent panels of similar systems. In this area incompatibilities exist. On the one hand gaps between panels must be provided to allow for the normal expansion and contraction of the panels under various environmental extremes. Yet these same gaps have to be minimized, if not eliminated, to prevent the inflow of hot boundary layer gases and water. Gaps are caused by a variety of conditions the most critical of which are attributable to cryo tank shrinkage, primary structure thermal gradients, body deflection during booster separation, panel expansion during entry and manufacturing tolerances. Actual gap requirements vary with gap orientation (i.e., lateral versus longitudinal).

The problem is not as acute with some type of heat shields as with others. In the case of ablative heat shields silastic type seals provide sufficient flexibility to resolve the problem as noted previously. The same problem is solved in the case of metallic heat shields by simply overlapping panel joints. However, in the case of the HCF type heat shield requirements exist which require special considerations. In this instance the goal of the designer is to provide a joint and/or seal which is compatible with the anticipated use life of the basic heat shield material (i.e., 100 flights) so as to minimize refurbishment. Silastic seals in this case have limited application because of their reusability aspects. Overlapping the joints with other high strength-temperature metals or ceramics in combination with various stepped geometry seems to indicate a possible solution.

The basic TPS for a representative space shuttle orbiter could contain several types of heat shield and for this reason the interface between two dissimilar systems becomes important from a refurbishment point of view. One is interested in whether or not either panel can be removed and replaced without disturbing the other or if the interface dictates removal of the adjacent panel first. A typical ablative/radiative panel interface concept is shown in figure 19. Either the ablative or radiative panel can be removed without seriously affecting refurbishment of the other.

In this design concept, particular attention is given to large panel thickness mismatch, panel overlap, and differential thermal expansion. Panel mismatch is resolved by using a stepped panel support configuration. The panel support is attached to a number of support posts which are attached to the primary structure. A metal lip is mechanically fastened to the edge of the ablative panel, thus providing the overlap with the radiative panel. Longitudinal splices between panels are staggered to simplify and maintain sealing at the corners due to differential thermal expansion.

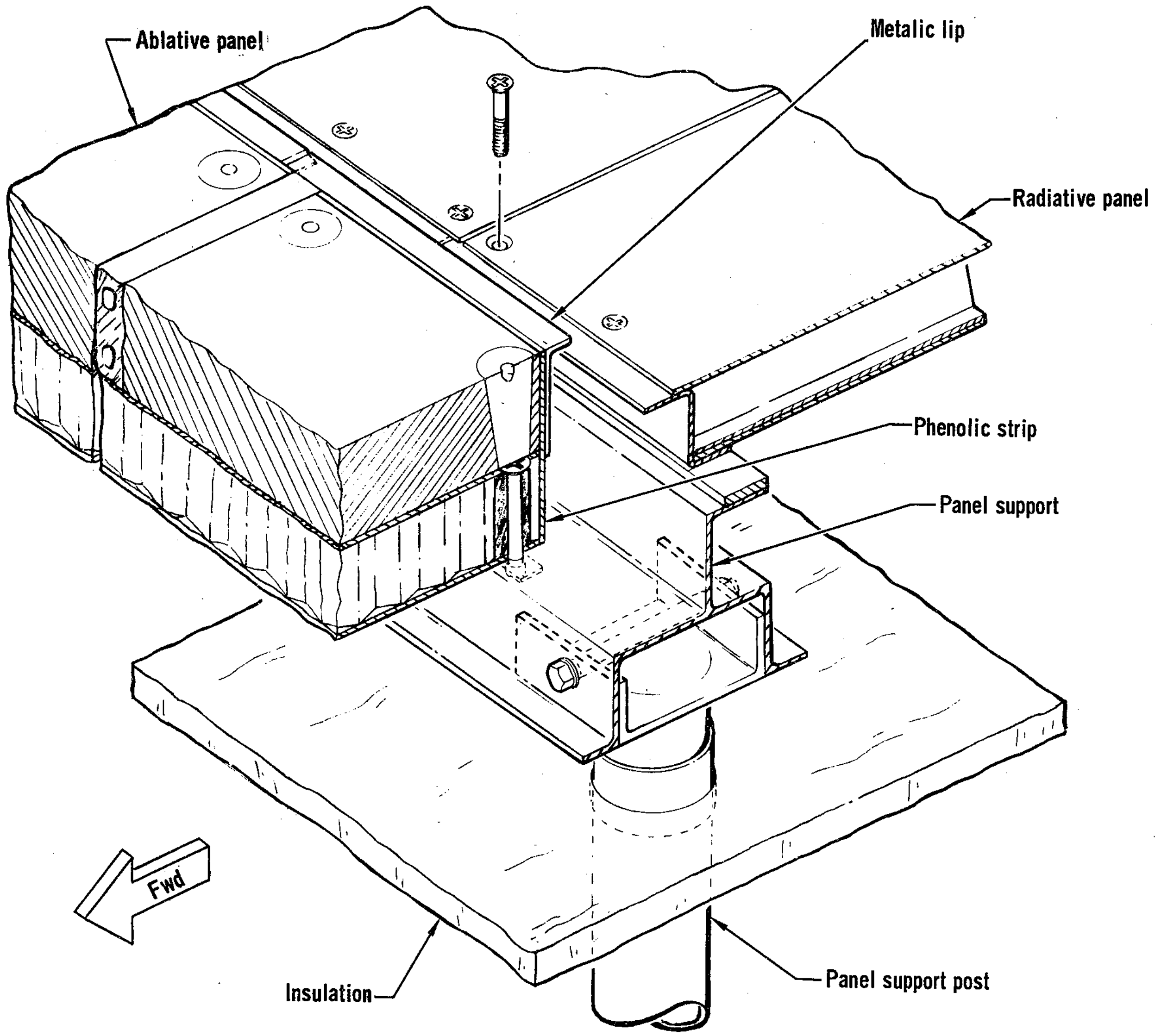


FIGURE 19 ABLATIVE/RADIATIVE PANEL INTERFACE

Insulation installation. - In addition to TPS panel attachment, fibrous (soft) insulation blanket design and attachment is important. Blanket location relative to TPS panels depends on the type of primary structure and its location, subsystem protection required, and thermal-versus-weight tradeoff results. An example of this is shown in figure 20. Insulation blankets in the area of the propulsion tanks are a significant distance from the lower fuselage moldline. Since a purge plenum chamber is required around liquid H_2 or liquid O_2 tanks, the inner foil covering of the insulation can serve as the outer plenum wall or the insulation, less the inner foil covering, can bear against a separate plenum wall. Figure 20 shows the latter case where the insulation blanket is attached so that the inner surface bears against a separately attached plenum wall. The insulation blanket is covered with foil around the edges and one side only. A wire grid stretched across the blanket and attached to the substructure holds the blanket in place. Two edges of the grid are welded to angles which are longitudinally positioned between and attached to panel post attach fittings. The other two grid edges are attached to studs which are riveted to the circumferential bulkheads.

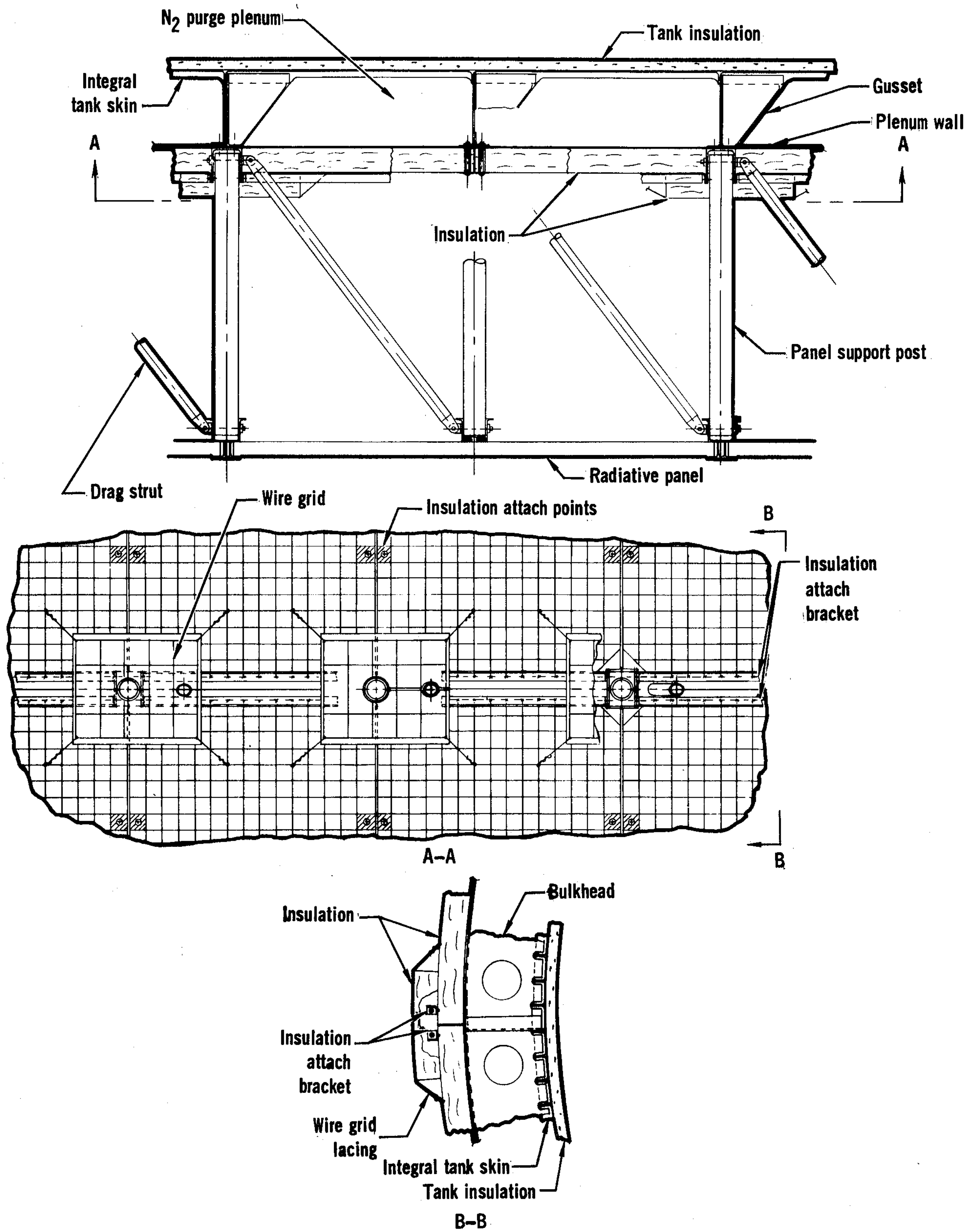


FIGURE 20 INSULATION INSTALLATION

Additional thermal protection is required in the area of the post attachment; consequently, a small slotted blanket is wrapped around each vertical post and drag strut as indicated. This blanket is held in place by a wire grid which is wired to the grid which holds the larger, inward blankets in place.

Another concept for attaching the insulation consists of wrapping all sides and edges of the fibrous material in foil (titanium, inconel, or coated columbium depending on environment temperature) and bolting the reinforced edge members directly to the circumferential bulkheads and added longitudinal support members. The blankets precisely mate with the post support areas allowing the inner surface to be used as the plenum wall. Small studs with snap-on buttons keep the inner and outer sheets separated. Filler insulation strips with retaining straps cover the attach fasteners.

Panel size and attachment spacing. - Two important parameters which influence heat shield system design and subsequent refurbishment activities are panel size and mechanical fastener spacing. During this study an analysis was performed to determine values for these parameters, the results of which are presented in this section. The influencing variables considered for these parameters were weight and pressure. No attempt was made to investigate the effects of panel flutter, creep, or thermally induced stresses, each of which may influence final TPS design.

Panel size: Final panel size is based on a number of considerations including fabricability, handling requirements, weight, cost, attachment method, and location on the vehicle. Large panels provide the obvious advantages of fewer joints, fewer heat shorts to primary structure, and low support structure weight. Small panels weigh less and are easy to handle and fabricate. For this study, panel length was selected on the basis of weight and panel width was variable throughout the study.

Components which make up typical metallic, HCF or ablative thermal protection systems include the following:

Metallic TPS

Panel
Support beam
Link
Pi-strap
Miscellaneous (20% of support beams + links + pi-straps)
Insulation (to maintain 200°F tank temperature)

HCF and Ablative TPS

HCF or ablative (to maintain 500°F bondline temperature)
Panel
Support beam
Link
Miscellaneous (20% of support beams + links)
Insulation (to maintain 200°F tank temperature)

Metallic panel and support structure weights as a function of panel length are shown in figure 21 for Rene' 41, L-605, TD-Ni-Cr and columbium panels.

The design pressure, 3 lbf/in^2, is representative of the pressure experienced by a typical panel on the bottom of a vehicle during ascent or cruise phase. All panels are assumed to be simply supported at each end. Optimum panel length for all materials is approximately 20 inches. Insulation weight to control primary structure temperature is not included because it is independent of material.

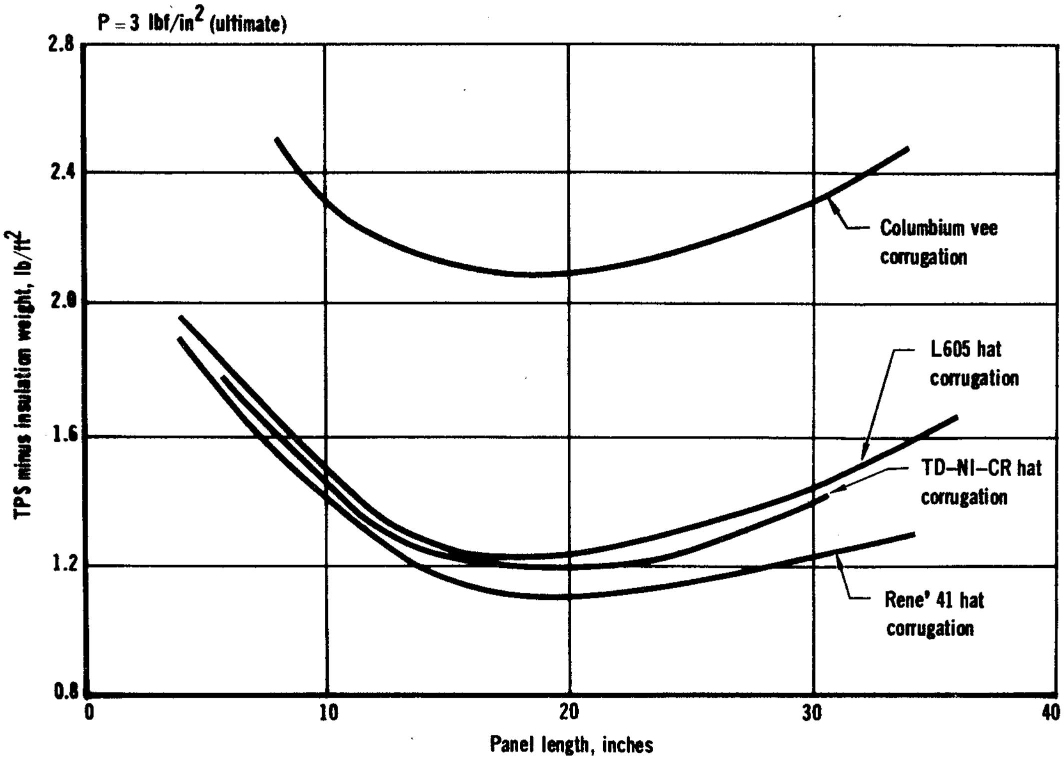


FIGURE 21 METALLIC PANEL LENGTH OPTIMIZATION

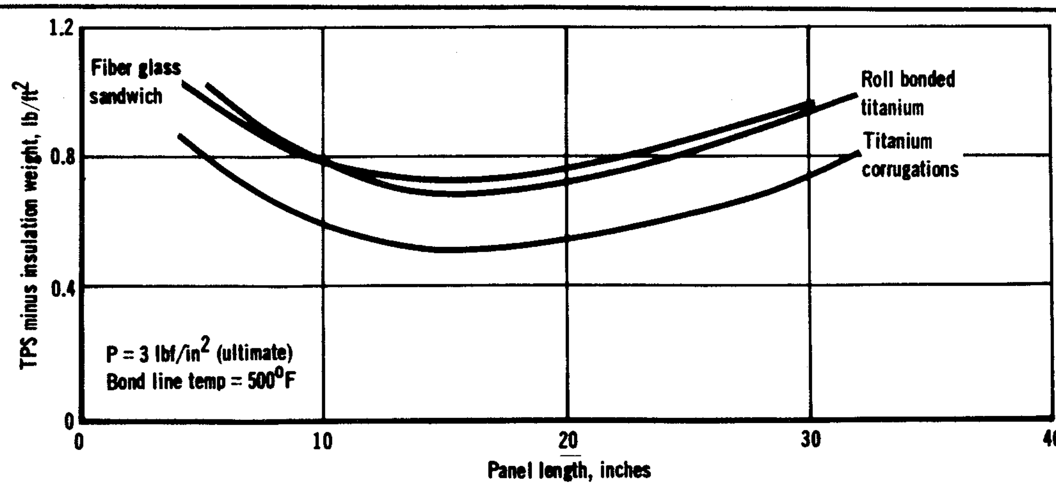


FIGURE 22 ABLATIVE AND HCF PANEL LENGTH OPTIMIZATION

HCF and ablative panel and support structure weights as a function of panel length are shown in figure 22 for fiber glass, roll bonded titanium, and single-faced titanium corrugated panels. Panel weight is insensitive to length in the range of 15 to 20 inches.

Studies have determined effects of making panels continuous over three supports rather than simply supported at each end. Results indicate that there is negligible weight difference between the two concepts. Refurbishment cost studies, therefore, were conducted for both concepts; simply supported 20 inch long panels, and 40 inch long panels continuous over three supports.

Since pressures are beamed longitudinally to transverse support members, panel width is not determined by strength considerations. For cost analysis, the following three panel widths were considered:

Small - 20 inches

Medium - 120 inches

Large - 300 inches.

Attachment spacing: Two types of mechanical attachments, pi-straps and flush fasteners, attach panels to the support structure. Attachment spacings are defined in this section since refurbishment costs are influenced by the number of mechanical attachments. The critical loading condition for determining attachment spacing is a limit pressure of 1 lbf/in^2 acting outward on the panel. This condition could occur during ascent if entrapped air is not allowed to vent rapidly.

The pi-strap attachment technique is shown in figure 17. The straps retain the panel and allow thermal expansions between supports. Bolts are used to attach pi-straps to transverse beams. Pi-strap width is adequate to allow thermal expansion of panels. Height is based on panel height which is a function of panel length and applied inward pressure. Pi-strap thickness and bolt spacing are determined for a limit pressure of 1 lbf/in^2 acting outward. Bolt spacing as a function of applied inward pressure is shown in figure 23 for Rene' 41, L-605, and columbium pi-straps. Pi-strap material is the same as the panel material. Pi-strap height increases with inward pressure which results in increased pi-strap strength and allows bolts to be spaced further apart. For an inward pressure of 3 lbf/in^2 bolt spacing varies between 8 and 12 inches, depending on material. A bolt spacing of 10 inches was selected for this study.

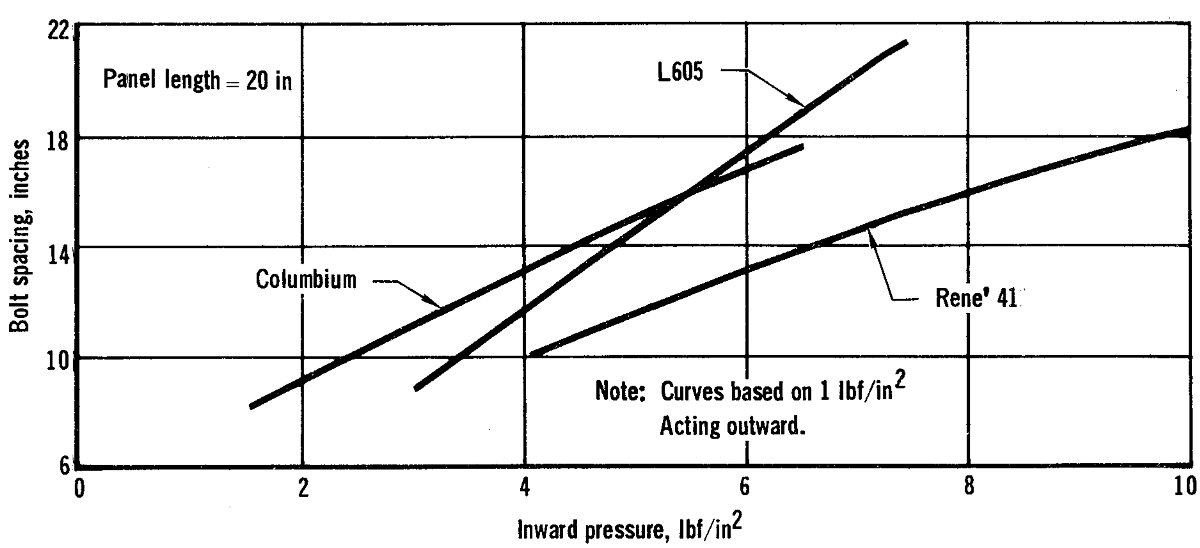


FIGURE 23 BOLT SPACING VS PANEL DESIGN ULTIMATE PRESSURE

The flush fastener technique is shown in figure 15. Edge members provide sufficient strength to beam outward pressures to attachments. Bending strengths of representative panel edge members were evaluated and found to possess approximately half the strength of corresponding pi-straps. Since loads carried in edge members are approximately half those carried in pi-straps, the resulting attachment spacings are the same. Therefore, a 10-inch bolt spacing was used for pi-strap and for flush fastener approaches.

Although the analysis was performed for the metallic heat shield concepts the results are deemed applicable for ablative concepts 2, 3, and 5. An analysis was also performed to determine permissible bolt spacing for the ablator matrix/single-face sheet composite of concepts 4a and 4b. Negative pressures tend to separate the ablator and fiber glass laminate from the support structure. Thus, a negative pressure of 1 lbf/in^2 limit was also used in this case to determine bolt spacing.

Major assumptions in selecting bolt spacing for these ablative concepts include:

> Panel is critical for negative pressure of 1 lbf/in^2 limit which occurs during ascent.
>
> Ablator material has a density of 30 lb/ft^3, ultimate tensile strength (F_{tu}) = 90 lbf/in^2 at room temperature, and an elastic modulus (E) = 230 lbf/in^2 (determined by test on a related project).
>
> Ablator is bonded to fiber glass laminate having following room temperature properties: F_{tu} = 30,000 lbf/in^2, E = 3.2 x 10^6.
>
> Panel size is large compared to bolt spacing.
>
> Safety factor = 1.4.

Bolt spacing for various thicknesses of ablator is shown in figure 24. Two thicknesses of fiber glass laminates were investigated: 0.060 and 0.050 inch. The upper two curves show spacing based on ultimate fiber glass laminate strength. Deflections associated with these bolt spacings would be excessive, therefore, a bolt spacing was determined which limited the deflection to 2% of the distance between bolts which is a value used on previous TPS studies. These results are shown by the lower two curves. For an ablative thickness of 1 inch and an 0.050 inch fiber glass laminate, a 7-inch bolt spacing limits deflection to 0.14 inch at the midpoint between bolts. Although ablative thicknesses for shuttle TPS may exceed 1 inch in some areas, it is recommended that the bolt spacing not exceed 7 inches.

Specialized areas. - Only 5% of the vehicle TPS experiences exceptionally high surface temperatures (generally greater than 2500°F) which limit the application of certain classes of materials. These vehicle areas include the forward body nose tip, fuselage chines, and horizontal control surface leading edges. These vehicle areas require special design consideration since their geometry is particularly configuration oriented. Materials such as ablative and oxidation inhibited carbon/carbon are well suited for this application. In general, attachment techniques specified for basic heat shield systems may be applied in these areas. Representative attachment concepts have been configured to show variations in refurbishment activities which may result over and above those indicated for the basic heat shield concepts.

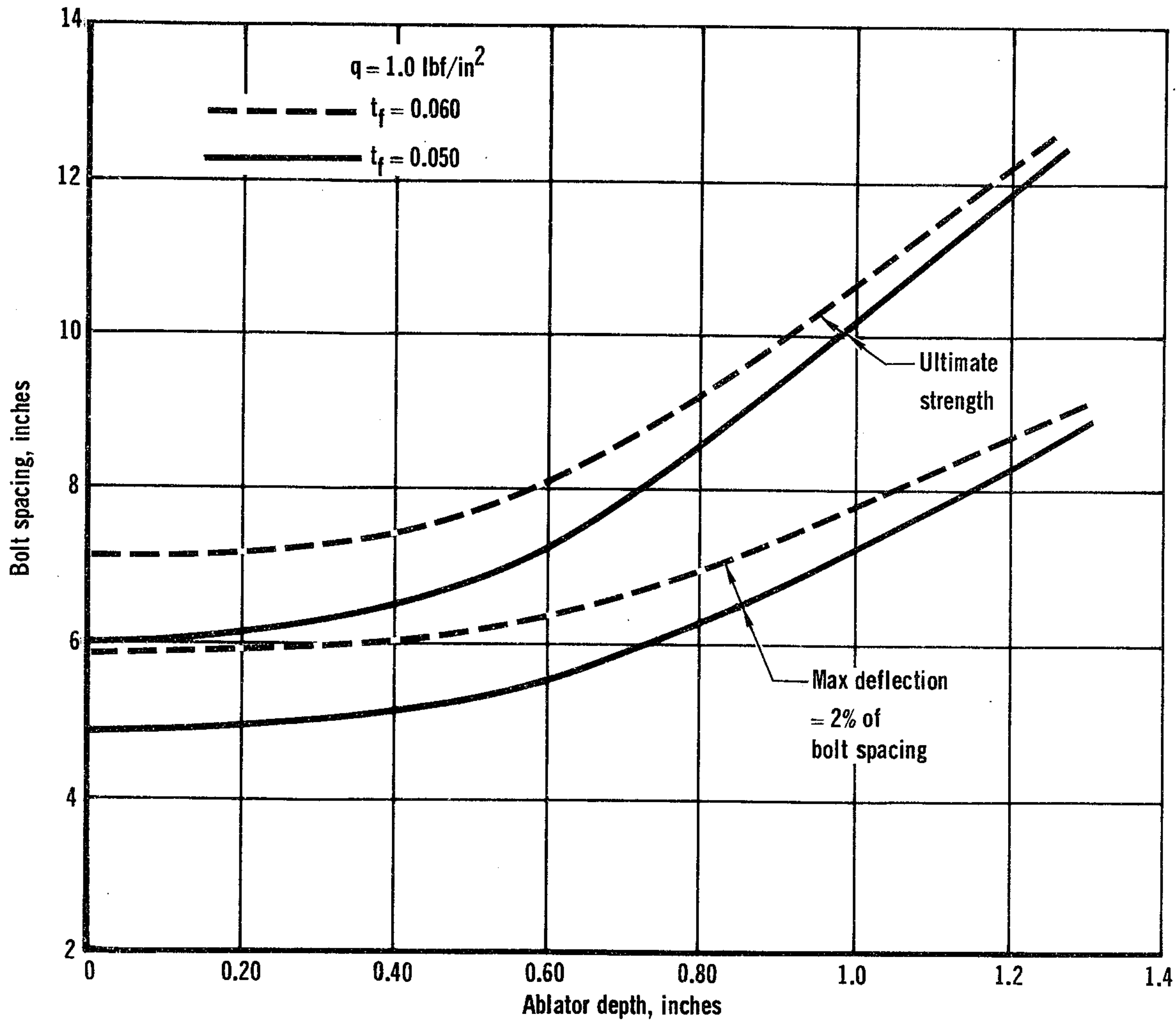


FIGURE 24 BOLT SPACING VS ABLATOR DEPTH

Integral carbon/carbon leading edge: The carbon/carbon concept, shown in figure 25, consists of individual panel segments built up with integral spanwise stiffeners and truss type ribs. These segments form the wing airfoil section aft to the 15% chord line. The length of these panel segments coincides with wing rib spacing which is approximately 20 inches.

Each segment is attached to the main wing box beam at four points. This four point attachment allows for wing bending without inducing significant loads into the leading edge. The arrangement of attach points is such that no direct attachment of panel segments to main wing box beam occurs on the hot (windward) side. Internal insulation, as required, can be used against the lower panel surface as well as over the front side of the wing spar to minimize temperatures at the attach points and the forward spar.

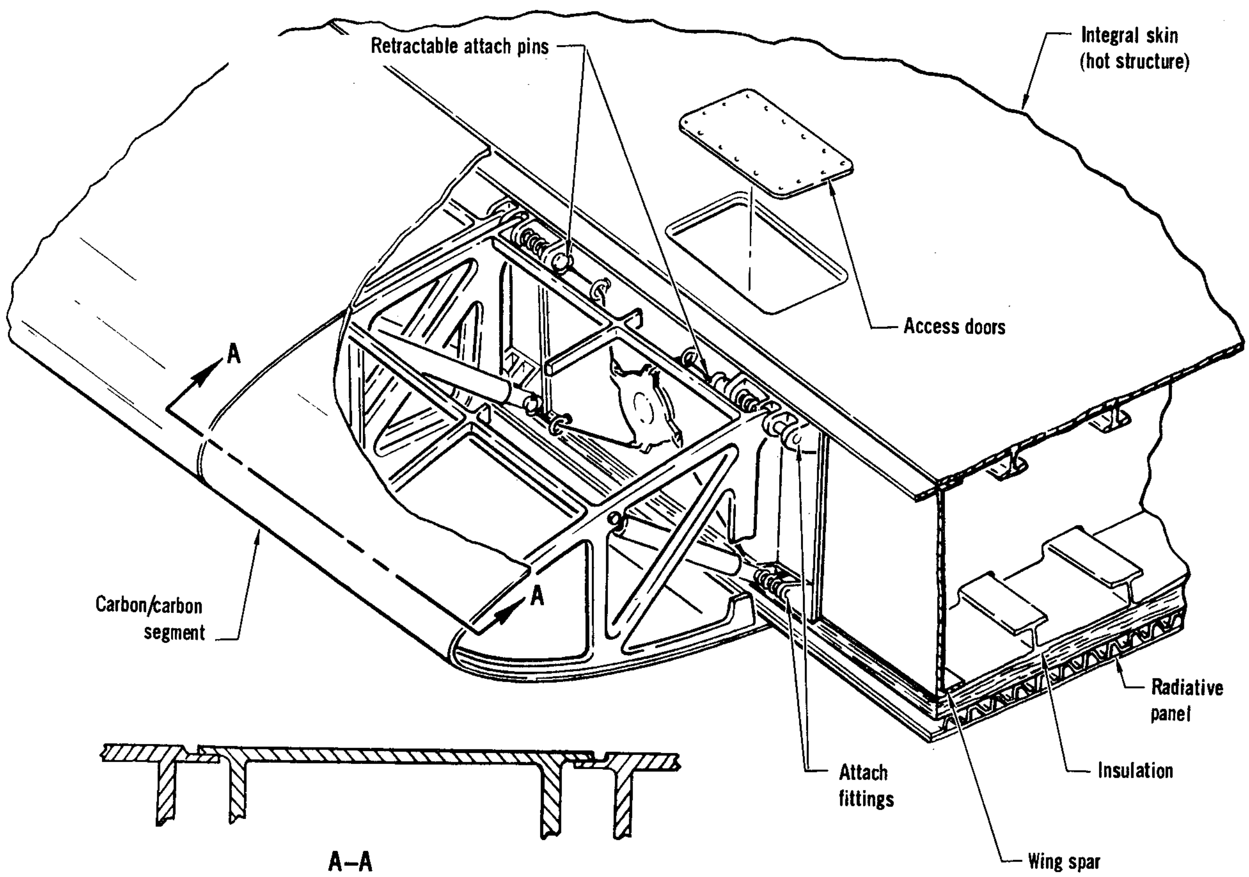


FIGURE 25 CARBON/CARBON LEADING EDGE ATTACH CONCEPT

Access to retractable pins is through a small door in the upper wing surface (hot structure). As shown, small cables are employed to attach each pin to a centrally located sprocket. The segment is unlatched by rotating the sprocket with a wrench, which retracts all four pins simultaneously. With the pins retracted, the segment can be removed and the pins allowed to snap back into position, reattaching the ends of the joining segments. As shown in the figure, overlapping ends allow spanwise motion. This necessitates dropping two adjacent segments before the trapped or middle segment can be removed. The upper aft edge of the carbon/carbon segment rests on the flange of the wing spar, whereas the bottom edge overlaps the radiative TPS panel.

Ablative slip-on leading edge: An alternate to the carbon/carbon leading edge consists of an ablative sleeve which slips over a metal rib structure as shown in figure 26. The metal ribs supporting the ablative sleeve are spaced to coincide with the wing main torque box rib spacing and are attached to the forward wing spar at the 15% chord plane. The sleeve consists of an ablative filled honeycomb matrix, bonded to a double-faced fiber glass honeycomb substrate. The 20-inch long ablative sleeves are attached to the forward wing ribs by flush fasteners similar to those of concept 2. An alternate design and attach concept

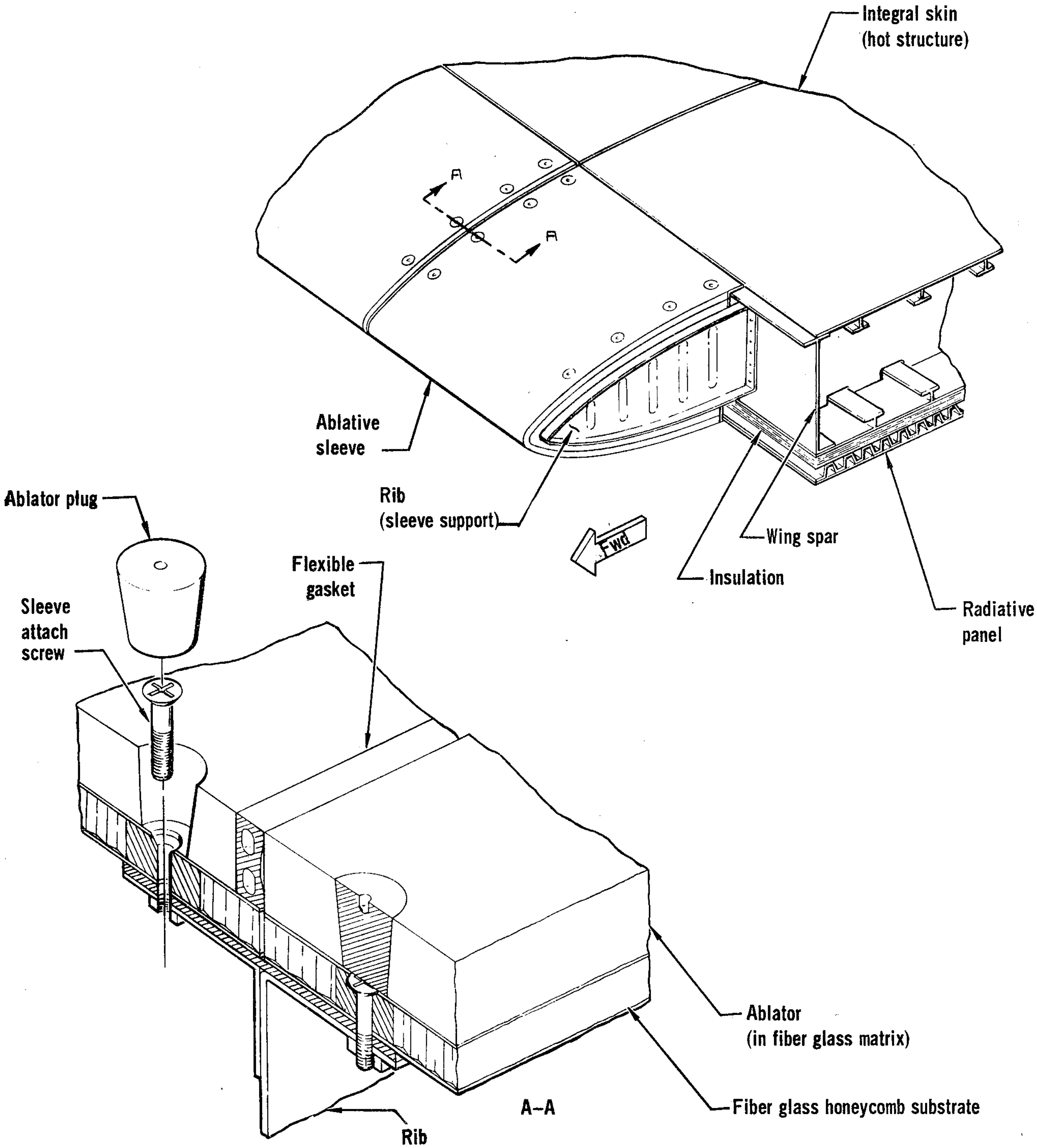


FIGURE 26 ABLATIVE LEADING EDGE ATTACH CONCEPT

uses a 40-inch long sleeve with the ends retained by pi-straps plus an intermediate row of fasteners through the middle of the sleeve.

Metal end caps are attached to top and bottom aft ends of the sleeve, overlapping the flange of the forward spar on the upper surface and the radiative TPS panel on the bottom surface.

Ablative chine TPS attachment: Another specialized area of extreme interest is the intersection between the bottom fuselage and spacecraft sides known as the chine area. This area could incorporate either an ablative or carbon/carbon TPS design. An ablative concept mating with radiative TPS panels is shown in figure 27. The basic ablative chine construction is identical to the previously defined ablative panels, consisting of an ablative filled honeycomb matrix, bonded to a double-faced fiber glass honeycomb substrate. Counterbored holes in the ablator, subsequently filled by bonding in ablator plugs, provide access to individual attach screws. The ablative chine segments are attached to chine supports, which are attached to the bottom and side metallic panel supports. The upper (single) attachment of the chine support acts as a hinge point, allowing for thermal expansion between bottom and side panels. A metal strip attached to the upper edge of the chine segment acts as a bearing strip for a metallic spring seal which is attached to the side metallic panels. At the opposite edge, a formed metallic strip attached to the chine segment forms a sill and seal with the bottom metallic panel. This design concept (with minor modifications) is also applicable for a carbon/carbon chine.

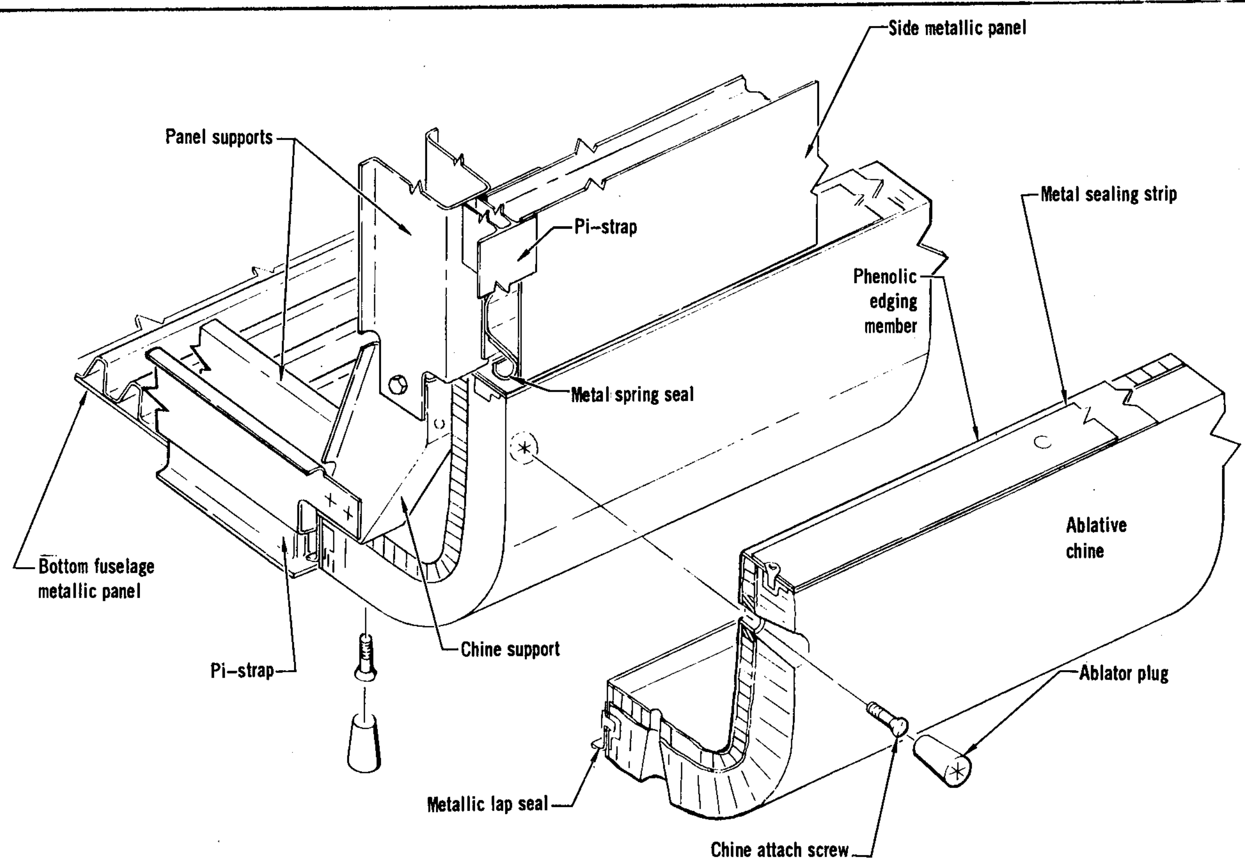


FIGURE 27 ABLATIVE CHINE/METALLIC PANEL INTERFACE

TASK 3 - OPERATIONAL COST ESTIMATE

Detailed operational cost estimates for various combinations of heat shield systems, attachment techniques, and primary structural configurations discussed under tasks 1 and 2 are given in this section. Operational costs, as defined herein, are recurring labor inspection and scheduled and unscheduled maintenance costs associated with typical TPS refurbishment activities for space shuttle orbiter application. In this study, only labor costs to perform refurbishment tasks were estimated since these costs are primarily independent of vehicle configuration and program definition. Costs associated with materials, support equipment, tooling, and facilities were not calculated since they are mainly configuration and program dependent. However, the nature of each of these latter cost elements, regarding type and quantity, was identified for each concept analyzed. In deriving these cost estimates, certain task analyses were conducted outlining step-by-step activities to perform the anticipated refurbishment cycle. These task analyses are summarized in this section and presented in detail in appendix A.

Refurbishment Cost Definition

Costs associated with heat shield system refurbishment for any entry vehicle encompass the complete range of operations from design through disposal. A thorough understanding of relative costs of refurbishing candidate heat shield systems must include definition of the influence of each refurbishment activity and heat shield system concept on all operations. The scope of operations and their interactions are included in figure 28.

Costs defined in this study are those of turnaround operations (recertification) directly associated with the TPS. These are the costs of greatest significance in defining refurbishment costs for a space shuttle and are also the costs which involve the greatest uncertainties as noted in previous program studies. However, for a complete refurbishment cost study, a wide range of support costs must also be considered. These costs not only depend on the TPS concept but also on program characteristics in which the vehicle employing the TPS is used. The magnitude of these supporting costs is primarily dependent on TPS inventory requirements, time available for refurbishment, and the probability of requiring refurbishment after each flight or after all ancillary operations such as ferry flights.

Figure 29 shows the scope of costs which must be considered in a complete TPS concept evaluation in which low cost refurbishment is a goal. However, this study is limited to the definition of the costs and cost uncertainties associated with the TPS inspection, removal, repair, and replacement at a refurbishment facility. The refurbishment process starts with the completion of all preparatory postflight operations at the refurbishment facility. It is terminated after

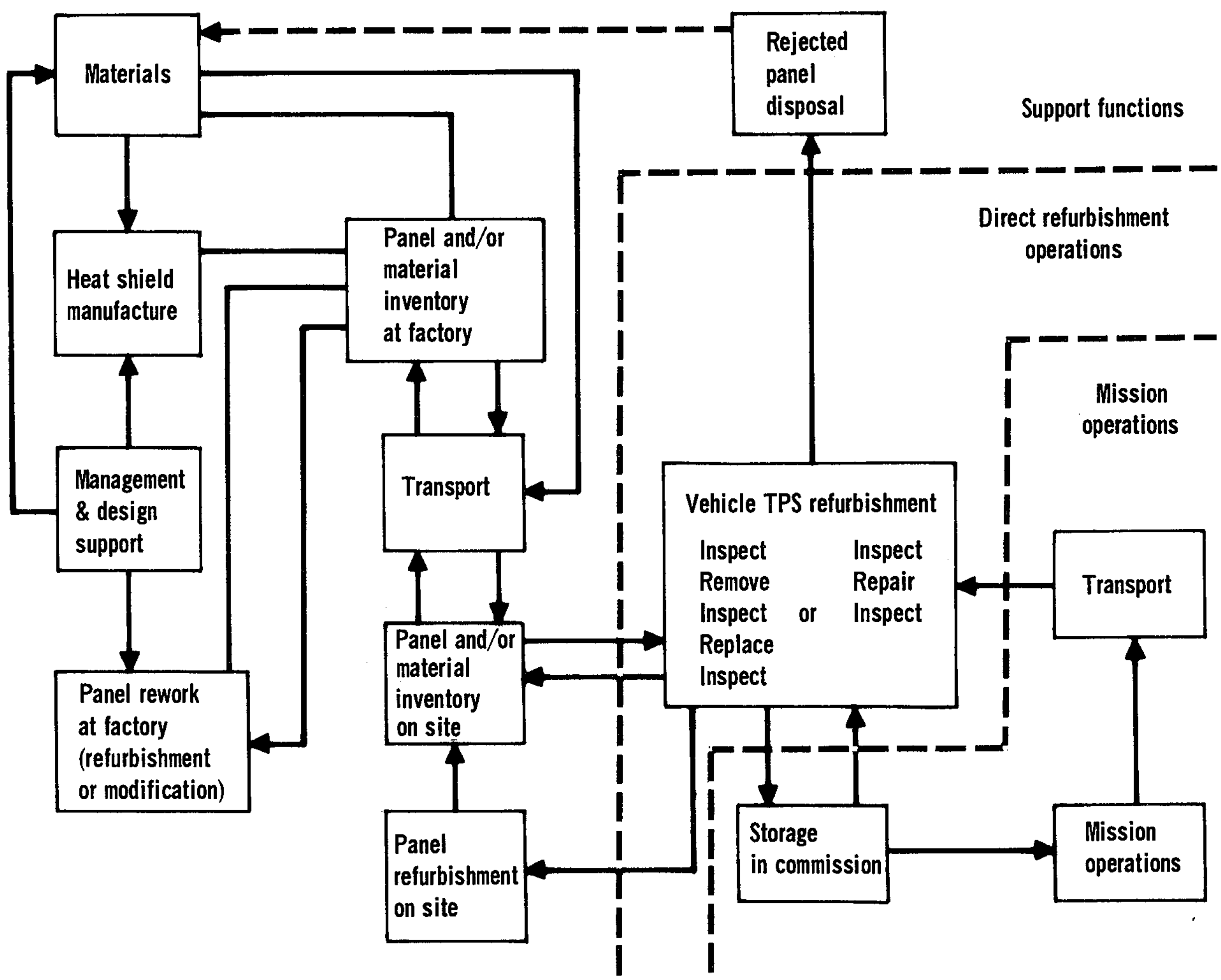


FIGURE 28 TPS REFURBISHMENT COST RELATED FUNCTIONS

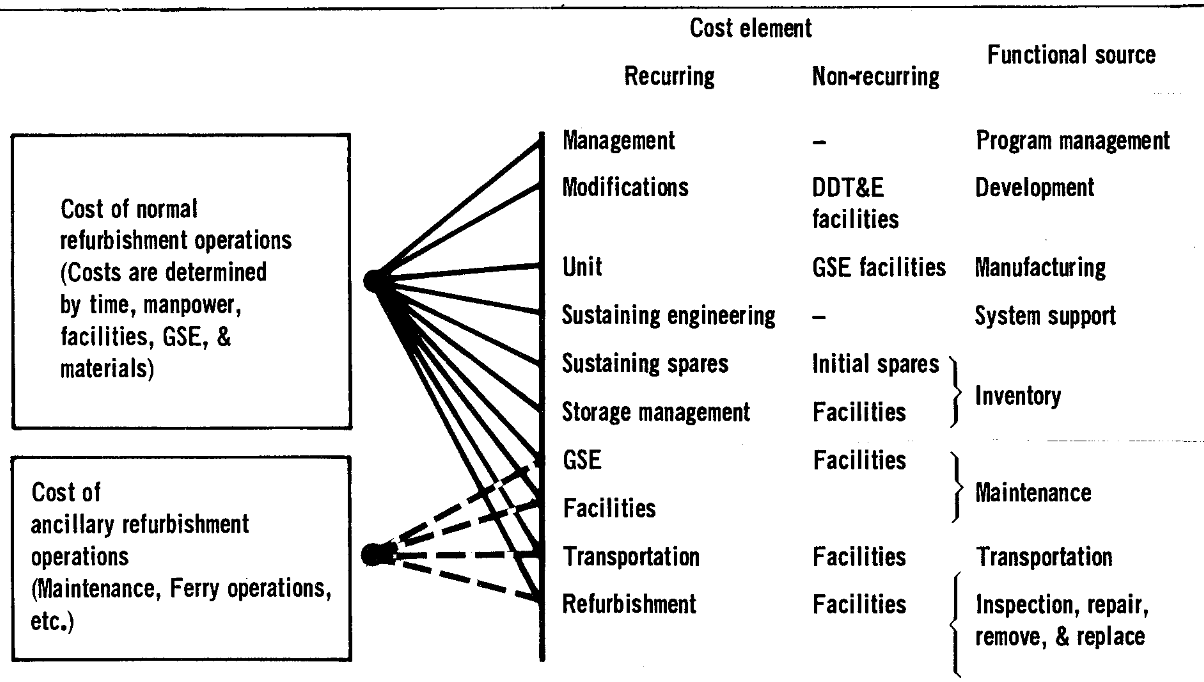


FIGURE 29 TPS REFURBISHMENT COST COMPOSITION

final inspection at the same facility. Labor, material, and equipment requirements for direct refurbishment operations at the refurbishment facility are defined. Principal emphasis is placed on defining labor costs since material and equipment depend on a specific vehicle configuration and turnaround operational requirements. Analyses are conducted on a per-panel basis to provide basic data for eventual total TPS evaluations in a specific program.

The remaining refurbishment cost elements in figure 29 are supporting elements and are affected by the TPS concept, the vehicle configuration, refurbishment operations, the program operational concept, and management and procurement policies selected for a specific program. For example, an ablative TPS which requires refurbishment by bonding a sheet of ablator material to the panel substrate requires minimum logistic support. Ablator material and bonding adhesive are stored in standard sizes and a predictable quantity can be manufactured. Facilities other than those at the refurbishment site are minimum. Specialized storage is not required, transportation is minimized, and rework for modification of panel design is unnecessary if modifications are provided in the form of new substrate panels direct from the factory. On the other hand, direct refurbishment costs are very high.

Similarly, a radiative metallic panel may be returned to the factory for recoating or repair. One or more panels may be required in storage for each vehicle panel. Panels may be shipped for modifications when required. For the radiative metallic concept, many direct costs of the previous concept are transferred to support cost categories, and direct costs for refurbishment are minimized. Also, for the radiative metallic concept, reuse is possible without refurbishment after each flight, which makes refurbishment a probabilistic event. Refurbishment occurs in this case as an average number of replacements or repairs per flight with the actual cost for a specific flight dependent upon many factors but requiring a complete inventory due to the random nature of requirements. Supporting costs for this concept are high when compared with direct costs.

From these examples, estimated total costs are necessary to evaluate TPS concept refurbishment characteristics. These cannot be determined until specific program characteristics are defined. However, the present need is a clear understanding of heat shield concept effects on operation costs in the refurbishment facility independent of its location and ancillary functions. With such an understanding, the influence of the eventual heat shield selection on cost of all program operations, including refurbishment, can be clarified.

The definition of direct refurbishment costs used in this study is on a single panel basis to establish comparative basic cost data that will be applicable to any allocation of costs among the direct and supporting cost elements in an actual program cost analysis. Facility amortization and GSE are excluded since program duration and facility and equipment life depend on program definition. Likewise, inventory costs are not included since they, as well as facility costs, depend on vehicle configuration and program operational concept. Costs which are defined assume panels similar in size and replacement availability for each TPS concept. Refurbishment time is minimized by assuming that a replacement panel is immediately available in storage even though such an inventory may not be required in practice. These assumptions, with the functional span previously defined, establish the scope of operations included in direct refurbishment costs of this study.

Refurbishment Task Definition

The wide range of variables applicable to the conditions under which refurbishment tasks are conducted must be bounded in an organized manner to achieve the study objectives. The refurbishment tasks which are analyzed must provide a coordinated data base from which recommended design concepts can be selected for test in phase II. The method by which the aforementioned variables were bounded to provide the coordinated data base is discussed below.

Variables which define a refurbishment task must also define the environment within which the task is conducted. These variables include:

a. TPS panel and attachments structural design
b. Heat shield material
c. Applicable TPS panel size
d. Refurbishment operation
e. Panel function on the vehicle
f. Panel location on the vehicle
g. Interfaces with TPS performing other vehicle functions
h. Interfaces with TPS of different material or design
i. Number of panels or TPS elements to be refurbished
j. TPS elements repair or refurbishment maintenance environment
k. Operational concept under which refurbishment is conducted
l. Refurbishment rates or turnaround time allowed
m. Vehicle primary structure deflection
n. Allowable panel removal sequence
o. Thermal environment history
p. Vehicle primary structure integrity.

Simplifying assumptions are made for variables (i) through (p). Refurbishment tasks are conducted in a sheltered refurbishment facility on a TPS required by a vehicle similar to those considered for low earth orbit logistic (shuttle) missions. The primary structure is assumed to be sound and deflections with the vehicle at rest are assumed to impose no loads on TPS panels. The vehicle primary structure design is such that no constraint is placed on TPS panel removal sequence except that imposed by TPS design. Refurbishment is assumed to occur after a normal mission, and abnormal thermal environments are not considered. Available turnaround time is assumed long enough to permit use of the most efficient operations compatible with the TPS design being analyzed.

The most suitable cost base would be the unit costs associated with single panel refurbishment. Therefore, only the tasks associated with removal of a single panel are considered except where design requirements necessitate removal of adjacent TPS elements to gain access to the panel being analyzed.

Variables (a) through (f) produce the most significant influence on refurbishment analyses of single TPS elements. Items (a) and (b) are self-explanatory and defined by task 2 of the study.

TPS panel size, item (c), is a major variable affecting removal and replacement and inspection costs. (Repair is considered to be independent of panel size.) The sizes used in the study are defined as small, medium, and large. Small is the smallest that is logically a part of the typical vehicle. Vehicle frame spacings of 20 inches are used and, therefore, a panel of 20 by 20 inches is the smallest considered except for designs including an intermediate support. For these, the small panel is 40 by 40 inches. The large panel is the largest considered on a typical vehicle. This would be between two frames but span the full width of the vehicle on the bottom surface. Such a panel is 20 by 300 inches or, for the concepts including intermediate supports, 40 by 300 inches. The medium size was selected as a reasonable intermediate which will require manpower and handling equipment in addition to that required for the small sizes. This is 20 by 120 or 40 by 120 inches.

Item (d) is categorized into removal and replacement, repair, and inspection functions. Principal emphasis is placed on the analysis of removal and replacement since this function is the one primarily influenced by the panel and attachment designs established in task 2.

Panel functions, item (e), which impose critical refurbishment problems appear to be vehicle surface, aerodynamic surface leading edges (wing and horizontal stabilizer), and body chines. For all other functions, the TPS attachment design either is significantly similar to the basic vehicle surface panel attachments, as in the case of doors or aerodynamic controls, or it is not affected by refurbishment requirements for removal, as in the case of antenna covers. These covers are a part of the TPS panel during removal and replacement operations. Therefore, only the surface panel, leading edge, and body chine functions are analyzed in this study.

Refurbishment cost varies with panel location on the vehicle, item (f), but, since most critical TPS surfaces are on the bottom of the vehicle body or wing, only refurbishment operations on bottom panels are examined in this study. This simplifying assumption also defines tasks which present the greatest variety of removal and replacement problems. Repair is assumed to occur, in most cases, after the panel is removed from the vehicle.

Interface variables considered in items (g) and (h) occur in many places on a typical vehicle. Interfaces with other vehicle functions, item (g), occur when the TPS is used on a segment of the primary vehicle surface (a panel), a wing leading edge, a body chine, door, aerodynamic control surface, antenna cover, or at such critical intersections as that of the vehicle wing and body. At the line where these functions intersect, special design considerations are required. Interfaces with other designs and materials, item (h), also occur at those vehicle positions where the thermal map indicates that a material of more of less thermal capability (and cost) can be used. A typical shuttle vehicle design indicates that material changes for metallic TPS occur frequently on the body or wing surfaces. However, changes in design concept at these locations are infrequent.

Preliminary examination of these interfaces as they apply to TPS designs established by task 2 of the study, determined that the refurbishment task for each design was only affected to a minor degree by most of the interfaces. Only the functional interfaces with the wing leading edge and body chines appear to influence refurbishment cost. Even here, refurbishment cost differs primarily because of the variation in vehicle function and the associated thermal requirements, rather than as a result of the interface. As a result of this examination, these interfaces were eliminated as variables for consideration in defining refurbishment analysis tasks.

As an aid to determining which of these variables is of greatest influence on refurbishment costs, the dependence of costs on several characteristics of the refurbishment task must be considered. These characteristics include determination of handling qualities of TPS elements; the time, manpower, and feasibility to remove and replace TPS elements; and support equipment required and repair requirements for time, manpower, and equipment. These factors were used as criteria for selecting variables that define analyzed refurbishment tasks. Analysis of these variables is essential to either resolve major refurbishment task uncertainties or to define the test program to resolve them. The relationship between criteria and primary variables selected for defining analyses is shown in table 2.

TABLE 2 CRITICAL REFURBISHMENT COST UNCERTAINTY FACTORS

REFURBISHMENT TASK SELECTION CRITERIA	VARIABLES AFFECTED		
	DESIGN CONCEPT	HEAT SHIELD MATERIAL	PANEL SIZE
Handling qualities	✓	✓	✓
Time and manpower		✓	✓
Support equipment	✓	✓	✓
Repair requirements	✓	✓	

Principal variables affected are items (a), (b), and (c) of the list previously discussed in this subsection. The selection of the tasks which are analyzed is based on the following considerations.

a. Tasks are analyzed for each design concept in all sizes applicable to the particular concept.

b. Tasks are analyzed for each representative material applicable to a design concept.

c. Where task analyses give similar results, only one is selected for analysis except where analysis of different materials provides additional data.

d. Those vehicle functions which require only hot structure on the selected typical vehicle are omitted from the refurbishment analysis.

e. Refurbishment of the vehicle body and wing surfaces represents major refurbishment costs and this is the primary TPS application analyzed. Vehicle functions applicable to small areas have little effect on refurbishment costs and are not selected for analysis.

The specific results of this screening process are shown in table 3. The rationale for each concept follows.

TABLE 3 REFURBISHMENT TASKS ANALYZED

REFURBISHMENT FUNCTION / HEAT SHIELD ATTACH CONCEPT		PANEL SIZES		REMOVE AND REPLACE						REPAIR	INSPECTION
				SMALL		MEDIUM		LARGE			
NO.	DESCRIPTION	APPLICATION	MATERIAL	20 by 20 in	40 by 40 in	20 by 120 in	40 by 120 in	20 by 300 in	40 by 300 in		
1	Bonded	Surface	Ablator	✓							
		Surface	HCF	✓							
2	Mechanical fastener	Panel	Ablator	✓		✓		✓		✓	✓
		Panel	HCF							✓	✓
		Leading edge	Ablator	✓							
		Body chine	Ablator		✓						
3	Pi-strap	Panel	Ablator	✓		✓		✓			
4A	Pi-strap/ multiple fastener	Panel	Ablator	✓		✓		✓			
4B	Multiple mechanical fastener	Panel	Ablator	✓		✓		✓			
5	Keyway	Panel	Ablator	✓		✓		✓			
6A	Flush fastener	Panel	Columbium	✓							
6B	Flush fastener/ middle support	Panel	Columbium		✓						
7A	Pi-strap	Panel	Columbium	✓		✓		✓		✓	
7B	Pi-strap/ middle support	Panel	Columbium		✓		✓		✓		✓
		Panel	Rene								✓
	Pinned	Leading edge	Carbon/ carbon	✓						✓	✓

Concept 1. - Only 20 by 20 inch segments are analyzed since the concept considers only the use of tiles of this size in applying new material to the vehicle skin. Repair and inspection include the same operations as the basic refurbishment task.

Concept 2. - Since an intermediate support is not used, panels 20 inches long are analyzed. HCF panel removal and replacement is similar to ablative panel removal and replacement. Where applicable, ablators are analyzed since experience with these materials is greater than with HCF. The ablative leading edges and chines in the sizes selected are the principal functional applications of the TPS other than the vehicle surface. Therefore, these functional applications are also selected for analysis.

Concepts 3, 4A, 4B, and 5. - Since an intermediate support is not used, panels 20 inches long are analyzed. HCF panel removal and replacement is similar to ablator panel removal and replacement, therefore, only ablator panels are analyzed. Repair and inspection operations are similar to those for concept 2 and are not analyzed.

Concepts 6A and 7A. - Since an intermediate support is not used, panels 20 inches long are analyzed. Only the small size is analyzed for concept 6A since the application of this concept to larger sizes appears infeasible.

For metallic heat shield materials, only columbium is analyzed since handling, repair, and inspection considerations are most critical for this material. Removal and replacement of other candidate metallic panels is similar and therefore those are omitted from the analysis.

Concept 6B. - Since an intermediate support is required, panels 40 inches long are analyzed. Only columbium panels are considered as defined for concept 6A. Also, as defined for concept 6A, only the small panel size is analyzed.

Concept 7B. - Since this concept uses an intermediate support, panels 40 inches long are analyzed. Only columbium panels are considered as defined for concept 6A.

Refurbishment Task Analyses

Detailed refurbishment task analyses associated with removal and replacement, repair, and inspection of the various heat shield attachment concepts cited previously are presented in appendix A and summarized below.

Thirty-nine individual task analyses were conducted covering removal and replacement, repair, and inspection activities. Task analyses 1 through 28 analyze removal and replacement activities associated with basic heat shield attachment concepts (concepts 1 through 7) while task analysis 29 deals with removal and replacement of a representative insulation installation. Task analyses 30 through 34 address repair activities associated with three types of heat shield systems investigated, while task analyses 35 through 39 deal with inspection procedures for the same systems.

A typical task analysis format is shown in figure 30. Each task analysis is identified according to heat shield type, principal attachment concept, panel location, and panel size. Within each task analysis, various functions of the refurbishment activity are described in chronological order. Adjacent to each function, cumulative manhours, elapsed time in hours, and the material, parts, tools, and equipment to perform that function are given. The total cumulative manhours quoted for each analysis is on a per-panel basis. Manhour estimates for any particular activity are obtained by multiplying elapsed time (given in 0.1 hr) represented by a bar, by the number of personnel given next to the time bar.

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 3

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (6) panel attaching fastener plugs.	0.05	1	
2. Drill out (6) panel attaching fastener plugs.	0.55	1	1 drill
3. Using a prescribed tool, free panel edges from adjacent panels.	0.60	1	1 edge freeing tool
4. Remove (6) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	0.70	1	1 socket wrench
5. Maneuver the panel free of the vehicle.	0.75	1	1 edge freeing tool
6. Transport panel to storage area for disposition.	0.85	1	
7. Store panel on the prescribed storage rack.	0.90	1	1 panel storage rack
o Inspection			
8. Visually inspect fiberous insulation for damage. Deterioration and signs of overheating.	0.95	1	
9. Remove, replace ... insulation as ...			

FIGURE 30 TYPICAL TASK ANALYSIS FORMAT

Removal and replacement. - Manpower and elapsed time requirements for individual task analyses given in appendix A are summarized in tables 4 through 7.

Removal and replacement task analyses results are presented in tables 4 and 5. Table 4 gives manpower requirements for each principal attachment concept analyzed in terms of manhours per square foot of exposed TPS area and elapsed time in hours to complete the entire refurbishment cycle.

Manpower requirements for ablative and nonablative nonmetallic (HCF) heat shields are the same. Since ablative and HCF materials exhibit similar characteristics (i.e., relatively soft, extremely porous, and mechanically weak), attachment to the primary structure can be accomplished in most cases by the same techniques. Thus, refurbishment activities associated with either heat shield system, for any particular attachment concept, were treated alike and, as such, yield identical manpower requirements. This assumes that handling and workability characteristics of each material are the same. This may or may not be correct. Handling and workability characteristics of ablative materials are fairly well defined, whereas those of HCF are not. Validity of these assumptions will be tested on the full-scale mockup.

Manpower requirements for the metallic heat shield systems do not reflect the difference between different material application. In the case of the metallic heat shield system, coated columbium was treated as the reference material.

The term "small" applies to a 20 by 20 inch panel except in concepts 6B and 7B. In these two cases small implies a 40 by 40 inch panel. These length dimensions are held constant in the medium and large panels whose width dimensions are respectively 120 and 300 inches. Tile sizes for ablative and HCF heat shields as used in concept 1 are restricted to small sizes due to fabrication and handling limitations. In concepts 6A and 6B, maximum panel size is restricted to small due to the large interface panel joint required for accommodating thermal expansion, which becomes excessive for larger size panels. The relatively large elapsed time requirements for concept 1, in comparison with the other concepts, is due to curing time in the refurbishment of these type materials when applied directly to the skin of the vehicle primary structure.

Data presented in table 4 were plotted versus panel size, given in square feet, as shown in figures 31 and 32 to show trends involved with parameter variation. Manpower requirements decrease as panel size increases whereas elapsed time requirements increase as panel size increases. In the case of the removal and replacement of the ablative and HCF heat shield systems (figure 31) there is little cost advantage in refurbishment of panels greater than 20 square feet. In the case of the metallic heat shield systems (figure 32) the break-even point is between 40 and 60 square feet.

Removal and replacement requirements for special areas of the vehicle such as leading edges, body chines, and internal insulation, are given in table 5. In these cases, manpower requirements given are the total manhours to perform refurbishment of a given segment length or insulation area.

TABLE 4 REMOVAL AND REPLACEMENT REQUIREMENTS

HEAT SHIELD ATTACH CONCEPT		MANPOWER (MHR/FT^2)			ELAPSED TIME (HOURS)		
		PANEL SIZE			PANEL SIZE		
NO.	DESCRIPTION	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	LARGE
	ABLATIVE OR HCF						
1	Bonded	1.30	–	–	33.1 (ablative) 39.1 (HCF)	–	–
2	Mechanical Fastener	0.58	0.49	0.47	1.45	2.30	3.35
3	Pi-strap	0.72	0.54	0.50	1.85	2.50	3.50
4A	Pi-strap/multiple fastener	0.72	0.54	0.50	1.85	2.50	3.55
4B	Multiple mechanical fastener	1.17	0.95	0.92	1.95	4.25	5.40
5	Keyway	0.47	0.31	0.26	1.25	1.80	1.95
	METALLIC						
6A	Flush fastener	0.47	–	–	1.25	–	–
6B	Flush fastener/middle support	0.23	–	–	1.45	–	–
7A	Pi-strap	0.49	0.41	0.31	1.25	1.95	2.10
7B	Pi-strap/middle support	0.47	0.28	0.20	3.20	3.50	3.75
	INTERNAL INSULATION (Ref. Figure 20)	–	0.60	–	–	3.15	–

TABLE 5 REMOVAL AND REPLACEMENT REQUIREMENTS - SPECIAL AREAS

CONCEPT	MANHOURS	ELAPSED TIME (HOURS)
Carbon/carbon leading edge (20 inch segment)	1.30	1.20
Ablative leading edge (20 inch segment)	2.15	2.10
Ablative chine (40 inch segment)	1.90	1.85
Insulation (20 by 100 inches)	8.30	3.15

TABLE 6 REPAIR REQUIREMENTS

CONCEPT	MANHOURS	ELAPSED TIME (HOURS)	DESCRIPTION
Ablative	2.10	11.10	1 to 3 in dia
HCF	2.60	28.60	1 to 3 in dia
Carbon/carbon	0.50	3.50	Surface scratches
Metallic	3.35	7.65	Coating

TABLE 7 INSPECTION REQUIREMENTS (PANEL SIZE: 20 X 20 INCHES)

CONCEPT	MANHOURS	ELAPSED TIME (HOURS)
Ablative	0.08	0.08
HCF	0.10	0.10
Carbon/carbon	0.08	0.08
Metallic (C_b)	0.15	0.15

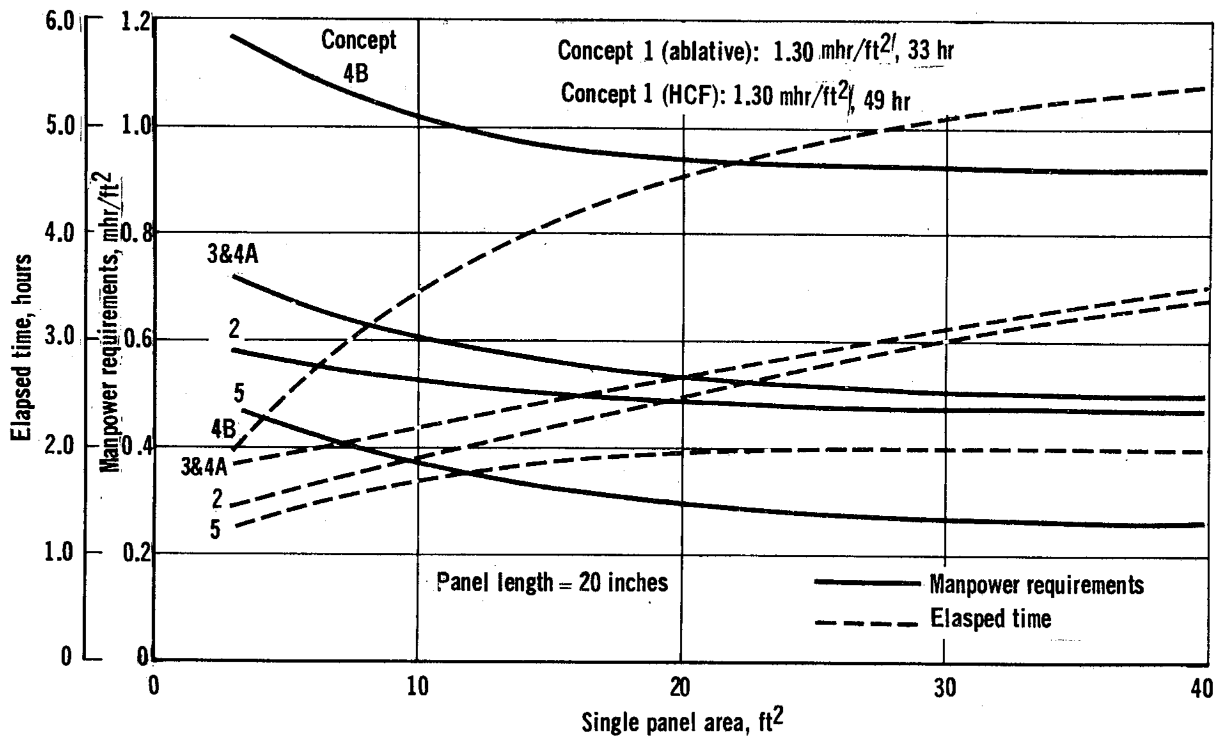


FIGURE 31 REMOVAL AND REPLACEMENT TRENDS, ABLATIVE AND HCF

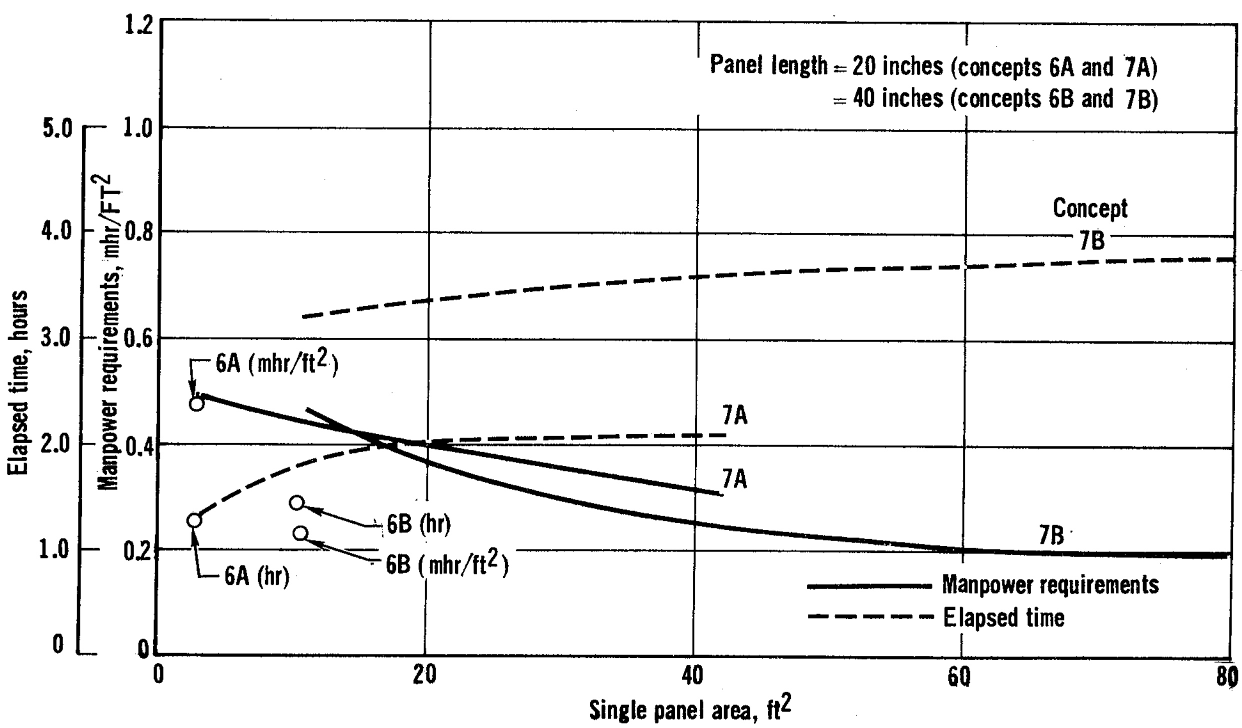


FIGURE 32 REMOVAL AND REPLACEMENT TRENDS, METALLIC

Leading edges of control surfaces and body chine areas represent a small percentage of the total TPS of a representative space shuttle vehicle. However, they do represent extremely high temperature surfaces and, as such, may be subject to more frequent refurbishment than other areas.

Although not subject to extreme temperatures, insulation represents another critical refurbishment area which could significantly effect vehicle recertification. The relative inaccessibility of insulation blankets is of primary concern. To remove and replace, repair, or inspect the insulation requires removal of part of the basic TPS.

Although the requirements shown for the so-called special areas are relatively small, on a unit basis, they could have a significant influence on overall vehicle refurbishment cost when considered for a specific configuration and program definition. Leading edge and body chine areas method of attachment is similar enough to the basic heat shield systems so that no additional refurbishment complications are anticipated.

Repair. - Typical repair problems associated with various types of heat shield systems were investigated and a task analysis prepared for representative material defects. The results of this investigation are given in table 6. Existing procedures, written from the manufacturer's viewpoint, were used whenever possible.

Inspection. - Inspection requirements for various types of heat shield systems were derived. The estimates shown in table 7 are for visual inspection of the exterior surface only and are based on a common panel size of 20 by 20 inches.

Adjusted Manhour Rates

Manpower requirements for removal and replacement of single panels produce errors when used to determine removal and replacement cost of an area involving many panels. This occurs because removing and replacing a single panel contributes to removal and replacement of adjacent panels of the same design and function. To provide data for computing cost of TPS removal and replacement over large areas or over a total vehicle, the single panel costs are adjusted for the edge interface conditions with adjacent panels and an average cost (manhours) per unit area is derived for each concept and panel size. These costs are compiled in table 8. Average costs are derived by dividing the effort related to release, attachment, or sealing of the edges between the two panels at each edge in proportion to the effort applicable to the removal and replacement of each panel. The removal and replacement of each panel is charged with only that portion of the effort that it requires.

TABLE 8 REMOVAL AND REPLACEMENT COSTS ADJUSTED FOR AREA ESTIMATES

HEAT SHIELD ATTACHMENT CONCEPT		PANEL SIZE		SINGLE PANEL COST (MHR/FT^2)	AVERAGE COST (MHR/FT^2)	COST FOR DISCONTINUITIES (MHR/FT)	
NO.	DESCRIPTION	L X W (INCHES)	AREA (FT^2)			EDGE ATTACH	SEALS
	ABLATORS/HCF						
1	Bonded	20 x 20	2.8	1.30	1.27	NA	0.015
2	Mechanical fastener	20 x 20	2.8	0.58	0.56	0	0.008
		20 x 120	16.7	0.49	0.47	0	0.013
		20 x 300	41.8	0.47	0.45	0	0.015
3	Pi-strap	20 x 20	2.8	0.72	0.43	0.218	0.008
		20 x 120	16.7	0.54	0.37	0.118	0.009
		20 x 300	41.8	0.50	0.33	0.124	0.008
4A	Pi-strap/multiple fastener	20 x 20	2.8	0.72	0.43	0.218	0.008
		20 x 120	16.7	0.54	0.37	0.124	0.009
		20 x 300	41.8	0.50	0.33	0	0.008
4B	Multiple mechanical fastener	20 x 20	2.8	1.17	1.14	0	0.011
		20 x 120	16.7	0.95	0.93	0	0.013
		20 x 300	41.8	0.92	0.89	0	0.015
5	Keyway	20 x 20	2.8	0.47	0.31	0.210	0.009
		20 x 120	16.7	0.31	0.26	0.285	0.013
		20 x 300	41.8	0.26	0.22	0.510	0.012
	METALLIC						
6A	Flush fastener	20 x 20	2.8	0.47	0.43	0	0.03
6B	Flush fastener/ middle support	40 x 40	11.1	0.23	0.21	0	0.03
7A	Pi-strap	20 x 20	2.8	0.49	0.36	0.076	0.03
		20 x 120	16.7	0.41	0.36	0.043	0.03
		20 x 300	41.8	0.31	0.27	0.034	0.03
7B	Pi-strap/middle support	40 x 40	11.1	0.47	0.37	0.072	0
		40 x 120	33.4	0.28	0.22	0.045	0
		40 x 300	83.6	0.20	0.17	0.033	0
	Internal Insulation	20 x 100	13.9	0.60	0.60	NA	NA

When the average cost is used to compute the cost of large areas, it is necessary to adjust this cost for special panel edge conditions that occur along those lines when the design or panel function changes. These discontinuities in TPS design can occur when the heat shield material changes or at intersections with leading edges, body chines, doors, etc, as shown in figure 33. The average cost has deleted a portion of effort to release, attach, or seal these edges. Therefore, this portion of effort, or cost in manhours is also derived, per unit length of edge, to provide data for adjusting a total area cost, and thus account for discontinuities within and on the periphery of the area. Cost adjustments for edge discontinuity are compiled in table 8.

Since designs vary extensively in release and attachment, and sealing operation combinations, cost adjustments for discontinuities are separately stated for these two functions. All designs considered in this report can be treated in this manner. Some special considerations are necessary for several of the design concepts since the edge designs vary from side to side of a panel.

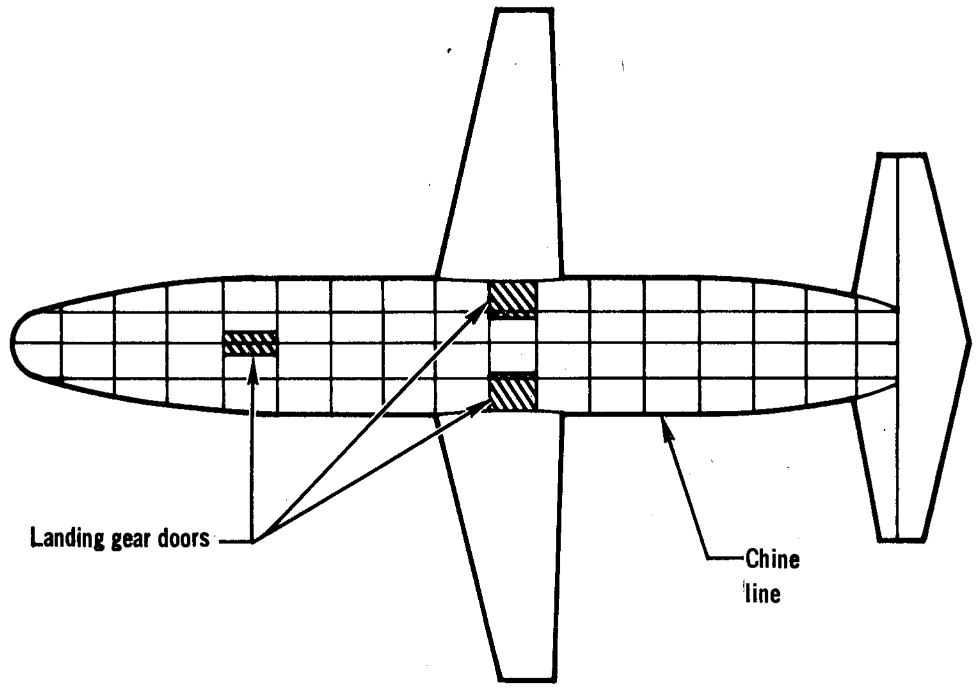


FIGURE 33 PANEL ARRANGEMENT ON ORBITER BODY PLANFORM

Heat shield attachment concepts 3, 4A, and 5 use pi-strap attachment devices covered with either an ablator or HCF. These require sealing on both sides of the pi-strap. Therefore, the value given for sealing must be doubled for the length of the pi-strap. For those edges without a pi-strap, the value as given in the table can be used. Attachment concepts 6A, 6B, 7A, and 7B are metallic heat shield designs but require some effort to insert the panel into the sealing joint on unattached edges. This effort aids both panels, and the adjustment for discontinuities which use this type of joint, is listed under "seals." If the edge at the discontinuity is of the attached type rather than a slip type the adjustment factor in the "edge attach" column should be used. The type of discontinuity must be determined to select the correct column and data treatment.

Data presented in table 8 were derived from the refurbishment analysis conducted in this study. Average costs and an edge factor to compute them are computed as defined in equations (1) and (2).

$$\text{Average cost} = \frac{\text{(total manhours per panel)} - \text{(edge factor x manhours related to edge operations)}}{\text{panel area (square feet)}} \qquad (1)$$

The edge factor represents the portion of the total effort related to edge operations that aid in the removal of adjacent panels. Since edge designs vary, the portion of effort that aids the removal of adjacent panels depends on whether the effort is used for removing and attaching the panel or for sealing the heat shield material. The edge factor computation required that these two operations be considered separately; therefore, the edge factor was computed as in equation (2).

$$\text{Edge factor} = 1 - [(\text{manhours related to edge attachment})\ (\%\ \text{applicable to panel}) + (\text{manhours related to seals})\ (\%\ \text{applicable to panel})] \quad (2)$$

The "% applicable to panel" values are either 100% or 50%.

Cost adjustments for discontinuities were computed as in equation (3).

$$\begin{array}{l}\text{Cost adjustment} \\ \text{for discontinuity}\end{array} = \frac{(\text{manhours for edge attachment (or seals)}(1\text{-}\%\ \text{applicable to panel}))}{\text{Length of edge applicable to attachment (or seals) (feet)}} \quad (3)$$

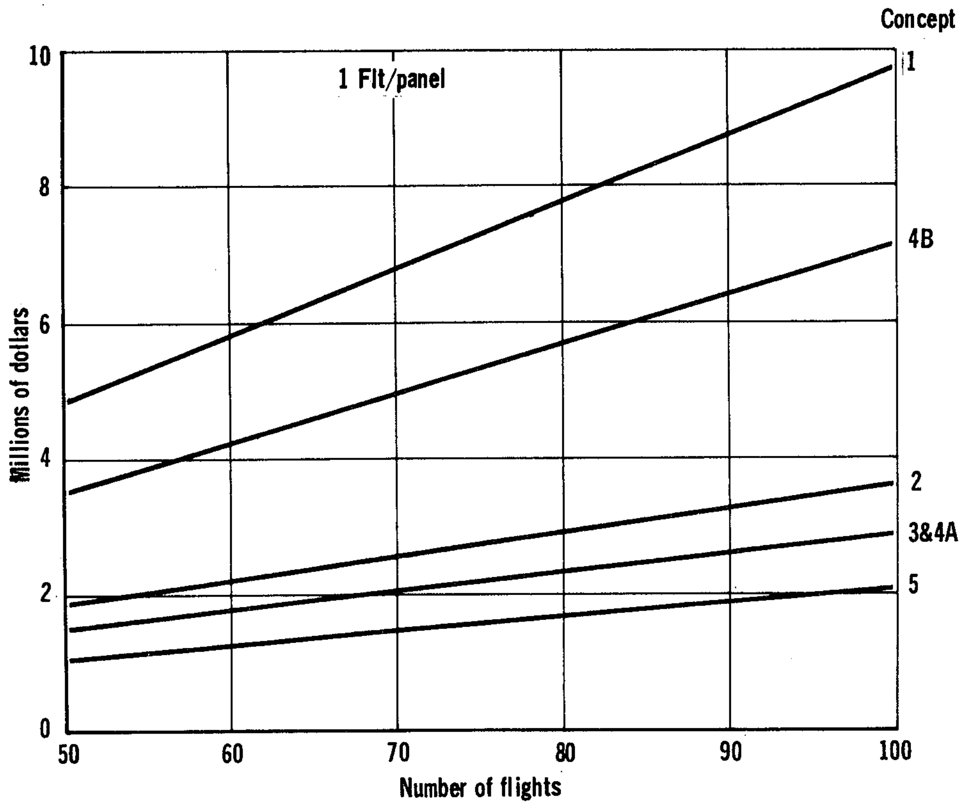
Where pi-straps are used, the length of the edge applicable is double the length of the panel edge along which the pi-straps are installed. Since all computed data are based on estimates used in analyses and since sealing operations are similar and independent of panel area for any given concept, an average of the values given for seal discontinuities may be used for each concept.

Vehicle Cost Projections

To show possible variations in refurbishment labor costs between various heat shield attachment concepts investigated in this study a representative orbiter TPS configuration was considered. The TPS area considered was the planform surface of a representative orbiter vehicle equalling 5000 square feet.

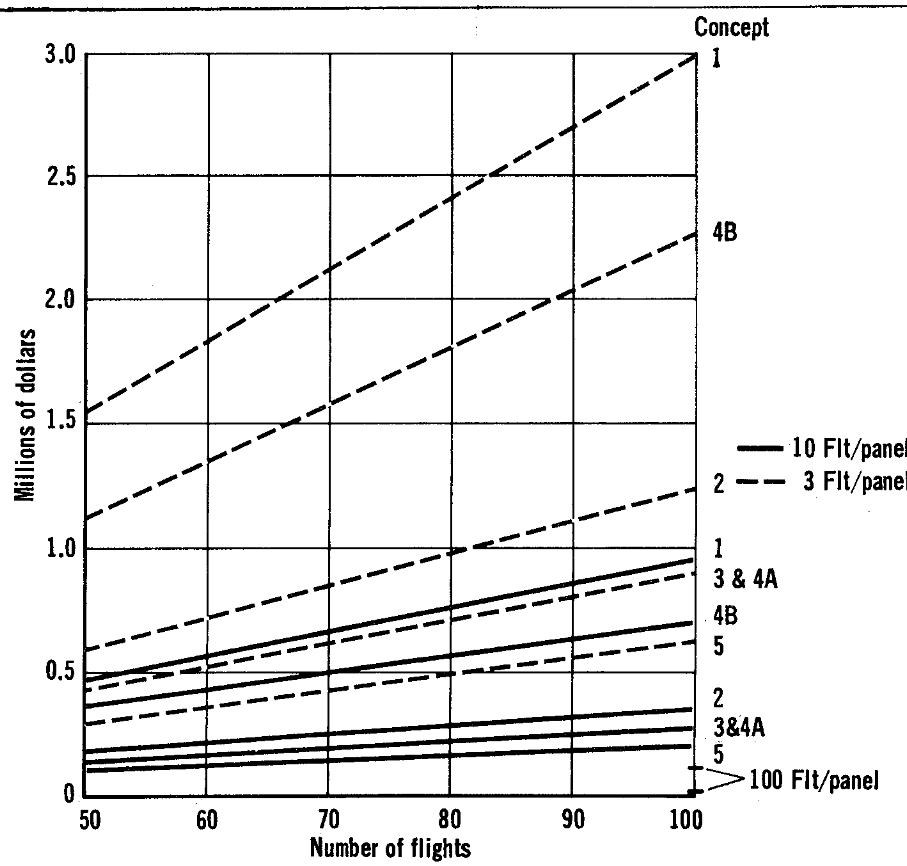
Using average cost data presented in table 8 and a labor rate of $15 per manhour, for specific panel sizes, data presented in figures 34 through 36 were generated. For examples given, general areas of discontinuities were not considered since these areas are highly configuration and program oriented. The curves show differences in refurbishment cost between concepts and the rate of increase in labor costs with increasing number of flights, based on various use life estimates per panel. The various panel sizes and cost data used in the analyses are presented in table 9.

The most significant conclusion is that refurbishment labor costs are very much dependent on the type of heat shield system and attachment concept used. For the examples cited, variations up to $8 million for a 100-flight life can be realized depending on the concept considered. Past experience in cost predictions indicates that RDT&E and investment costs are less sensitive to TPS configuration than operational costs. However, the results of this study show that operational costs are sensitive to configuration and thus design and cost feasibility uncertainties must be established before realistic cost projections can be made.



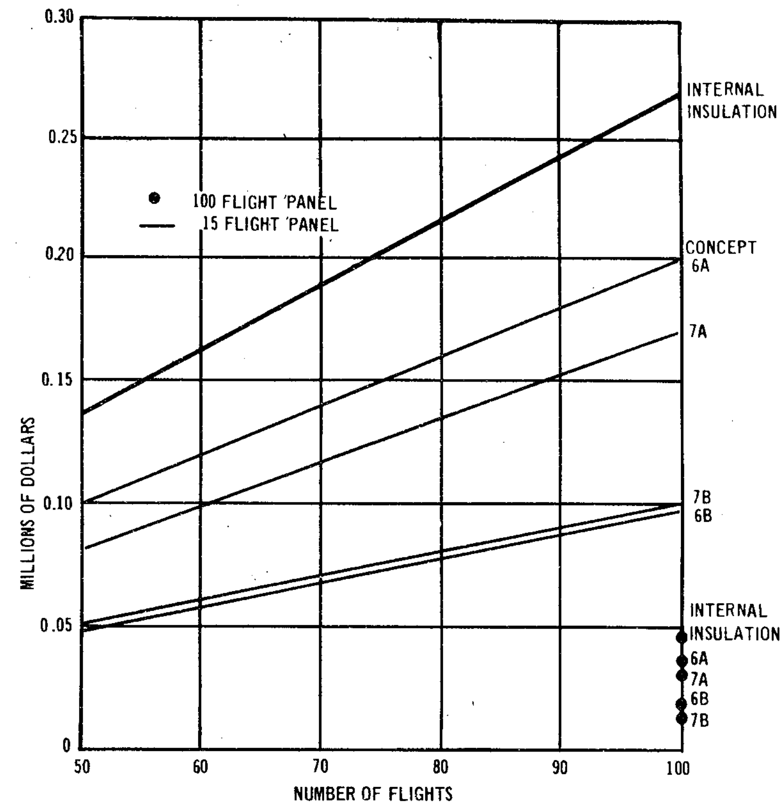
based on \$15/mhr and 5000 ft^2 planform area

FIGURE 34 LABOR COST PROJECTIONS - ABLATIVES



based on \$15/mhr and 5000 ft^2 planform area

FIGURE 35 LABOR COST PROJECTIONS - HCF



BASED ON \$15/MHR AND 5000 FT^2 PLANFORM AREA

FIGURE 36 LABOR COST PROJECTIONS - METALLICS

TABLE 9 REMOVAL AND REPLACEMENT
ADJUSTED MANHOUR RATES

CONCEPT NO.	H/S TYPE	PANEL SIZE L x W (INCHES)	PANEL SIZE AREA (FT^2)	SINGLE PANEL COST (MHR/FT^2)	AVERAGE COST (MHR/FT^2)
1	Ablative/HCF	20 x 20	2.8	1.30	1.27
2	Ablative/HCF	20 x 120	16.7	0.49	0.47
3	Ablative/HCF	20 x 120	16.7	0.54	0.37
4A	Ablative/HCF	20 x 120	16.7	0.54	0.37
4B	Ablative/HCF	20 x 120	16.7	0.95	0.93
5	Ablative/HCF	20 x 120	16.7	0.31	0.26
6A	Metallic	20 x 20	2.8	0.47	0.43
6B	Metallic	40 x 40	11.1	0.23	0.21
7A	Metallic	20 x 120	16.7	0.41	0.36
7B	Metallic	40 x 120	33.4	0.28	0.22
	Internal Insulation	20 x 100	13.9	0.60	0.60

TASK 4 - DESIGN AND COST EVALUATION

Refurbishment activities associated with previously described task analyses, for which cost estimation was difficult and of questionable technical or practical feasibility, were identified and are discussed herein. In accomplishing this task each refurbishment activity was rated according to degree of uncertainty. The format for this evaluation is shown in figure 37.

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. ________

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (26) panel attaching fastener plugs	1	1	
2. Drill out (26) panel attaching fastener plugs	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free panel edges from adjacent panels.	2	3	Can charred gaskets be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator has not been experienced.
4. Position panel dolly for the panel removal.	1	1	
5. Elevate dolly platform for panel retrieval.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on the dolly	1	1	
7. Remove the (26) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolt head filled with charred adhesive.
8. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	1	1	
9. Lower panel dolly platform with panel from the elevated position to the transport position.	2	2	Same as Item 5

FIGURE 37 TYPICAL DESIGN AND COST EVALUATION FORMAT

The basic task analysis format of task 3 was adopted, retaining individual analyses identification and refurbishment activity description. Refurbishment confidence rating was added to the form. This rating scheme identified areas and degrees of uncertainty, not concept relative values.

Two types of criteria were selected for evaluating refurbishment task estimate confidence levels. These criteria are: the operating maintenance experience for estimating task effort and procedures; and state-of-the-art of materials, processes, and equipment used to conduct each refurbishment operation. Table 10 defines four confidence levels for each criterion. The operating maintenance experience ratings range from much data available, i.e., the Gemini program and aircraft maintenance, to little available, i.e., coated columbium fastener removal. Similarly, the state-of-the-art ranges from existing processes, materials, and equipment to similar equipment used in handling aircraft ordnances, to repair processes used only under laboratory conditions, to repair for materials whose final configuration is not defined.

TABLE 10 REFURBISHMENT CONFIDENCE DEFINITIONS

CODE LEVEL	MAINTENANCE EXPERIENCE	STATE-OF-ART
1. Very high	Operation is identical to that for which data is available and the conditions on which source data are based are directly applicable.	Refurbishment process, materials, and equipment are within current technology and have been designed and produced or the operation has been tested in substantially the same configuration for which the estimate is made.
2. High	Operation is the same as that used on a similar type of equipment but must be adapted to satisfy some of the attendant conditions under which the operation is performed.	Refurbishment process, materials, or equipment are within current technology but are not yet designed and produced in the specific configuration for which the estimate is made.
3. Medium	Operation is remotely similar to an operation for which the operating characteristics are loosely defined. Source data are indirectly applicable to the operation being estimated.	Refurbishment process, materials, or equipment require minor development for the application being estimated. Development and test has been conducted at the laboratory level only.
4. Low	The operation is unique and no standards are applicable. Source data are based on the estimator's experience of the most clearly analogous operation.	Refurbishment process, materials, or equipment require extensive development before application and are substantially beyond current technology for handling, installation, or repair procedures. Analogous equipment, materials or maintenance operations have not been developed and tested even in the laboratory.

After each refurbishment activity was rated, according to level of uncertainty, refurbishment operation feasibility was questioned from cost and design standpoints. Questions and rationale are shown on the right-hand side of the design and cost evaluation sheet. All design and cost evaluation sheets generated for this task are contained in appendix B and summarized in this section of the report.

From the detailed cost and design evaluation forms certain questions were raised which can only be answered through experimentation on a full-scale mockup. Some questions concern a particular heat shield system and attachment concept while others are common to all systems. Key questions and rationale for the questions are listed in table 11 in order of their importance.

TABLE 11 COST AND DESIGN UNCERTAINTIES

QUESTION	RATIONALE
Will flight environment distort metal panels and affect ability to line up bolt holes when reinstalling refurbished or new panel?	Replacement panel installation after the structure has undergone repeated temperature extremes and loads has not been experienced in current spacecraft maintenance operations.
Do coated fasteners tend to bind and distort after repeated temperature and load environment making special tools necessary; and what is the use life of these fasteners?	Since current manufacturing costs of coated metals are extremely high, removal and replacement costs should be accurately defined.
Can all panels, regardless of attachment technique, be made to prefit or must they be fit and drilled on site?	Tolerance mismatches in support structure may vary between vehicles and for different locations on vehicle.
What is the probability of fouling panel attachment fasteners and requiring a destructive removal technique (e.g., drilling out the screw)?	Standard aircraft practices are anticipated but may be complicated by screw inaccessibility in certain attachment concepts.
What is the probability of fouling a panel when removing a panel attachment fastener and, if fouled, what is the probable requirement for repair (i.e., recoating only, patching, or resurfacing panel)?	The probability of fouling a panel depends on tools and personnel doing the job. Special procedures may have to be written over and above standard aircraft practices.

TABLE 11 (CONTINUED)

QUESTION	RATIONALE
What are panel size limits for various attachment concepts and how does installation and removal cost vary with size?	Panel size may dictate a particular attachment concept which may not be the one chosen on minimum weight and fabrication cost bases.
How does randomly damaged panel refurbishment affect adjacent panels and what are manhour and elapsed time requirements to replace a damaged unit?	Characteristics of certain attachment methods may dictate special refurbishment techniques for any randomly damaged panel.
What size and nature of repair to either ablative, HCF, or metal heat shields can be accomplished on the vehicle in the maintenance area?	The nature and size of heat shield repair may require removal or protection of adjacent panels.
Do gaskets between ablative and HCF panels provide sufficient flexibility for easy installation of panels?	Installing adequate seals between panels may be difficult and time consuming due to close tolerances and possible mismatches.
What are frequency and cost of installation and removal of flexible seals between panels?	Degree of seal degradation may vary with material used and cost is a function of removal technique.
In what sequence should panel attachment screws be removed and installed to prevent excessive loads due to panel weight or deflection on the remaining screws; and how does this influence personnel holding panel in place?	Panel size and working conditions may influence the number of personnel working in a specified area which would influence refurbishment cost and time.
How difficult is it to replace adjacent panels that have interlocking attachment mechanisms?	Interlocking attachment methods to prevent water and hot boundary layer gas inflow may cause time consuming refurbishment problems.

TABLE 11 (CONTINUED)

QUESTION	RATIONALE
What is the procedure for and cost associated with new panel installation inspection?	Existing methods of inspection may be inadequate.
Are small pilot holes in ablator and HCF plugs (used in concepts 2, 3, 4A, 4B, and 5 over panel attachment screws) sufficient for locating and subsequent removal of plugs?	Pilot holes may not be distinguishable after exposure to entry environment due to material loss under plasma flow conditions.
Can ablator and HCF plugs be removed with a hand drill or is a jig fixture required?	Experience in removing thermally exposed plugs on large scale structures is nonexistent.
What are manpower and elapsed time costs for removing and replacing multiple plugs?	Cost depends on removal and replacement technique used and plug condition.
What are manpower and elapsed time costs to remove ablator and HCF to various depths during field operations?	Removal cost may be a function of area to be removed and its vehicle location.
Can ablative and HCF material/panel substrate bondline integrity be established on the vehicle in the field by existing techniques within the time estimated?	Experience is limited in microwave and x-ray testing on large scale structures.
Do ablative and HCF pi-straps permit adjacent panel contraction and expansion without distortion of attachment screws and can pi-straps be installed and removed with the manpower and in the time estimated?	Attachment concept is new and has not been tested under operational conditions.

TABLE 11 (CONTINUED)

QUESTION	RATIONALE
Are conventional handling tools and ground support equipment sufficient for handling panels of various sizes and with special protective coatings?	Handling characteristics of certain materials, methods of attachment, and panel geometry may dictate the use of special equipment which could significantly influence operational maintenance cost.
What tools or fixtures are required to align panels with correct tolerances and how is panel held in place until screws are attached?	Tools and fixtures for aligning and securing panels in place may vary with location on vehicle.
What are the handling characteristics of ablator or HCF/single face sheet composite in concepts 4A and B when mounting to support panel substrate?	Flexibility of large scale composites (i.e., 40 by 72 inches) may be impractical and time consuming during installation and removal.
Can ablator or HCF panel (concept 5) be installed and removed with manpower and in time estimated?	Possible distortions or mismatches due to temperature and loads may cause binding of the key/keyways.
What is the effect of bolt hole spacing on refurbishment time in concepts 4A and B?	Minimum weight and refurbishment times may not be the same for a given bolt hole spacing.
Do coated metals require special handling procedures during panel removal and installation?	Handling characteristics of coated metals is limited on large scale structures.
Can depth of ablator and HCF plugs be accurately determined to avoid damage to panel substrate and attachment screw during plug removal?	Surface recession during entry environment may cause unequal depth penetration.

TABLE 11 (CONTINUED)

QUESTION	RATIONALE
What are techniques and procedures for removing ablator or HCF material down to substrate bondline without damaging substrate panel and attachments?	Postflight condition of ablator or HCF and bondline material may dictate one or several procedures (i.e., hand versus fixture removal techniques).
Will repeated use of suction type panel removal and installation tools deteriorate panel coatings?	Suction tools of the type proposed have only been used on plate glass structure and its adaptability to TPS has not been demonstrated.
Can primer, adhesive, or dispersion coating be applied to external insulation material on the vehicle in the refurbishment maintenance area, and for the projected costs?	Primer, adhesive, or coating contamination during drying, surrounding area polution, and parallel maintenance operations curtailment are possible.
Can adhesive seal material used in special joint applications be cured on the vehicle while in maintenance area?	Limited experience is available in this type of operation.
Can air bags be used to apply contact pressure for repair of ablative and HCF insulation material?	Limit design loads of TPS support structure may curtail certain repair techniques and procedures.
Can a thermal spray gun, used to repair ablative material, be used on the vehicle without damaging adjacent TPS areas?	Use of a thermal spray gun under normal maintenance operations is limited.

TASK 5 - MOCKUP DESIGN AND TEST PLAN PREPARATION

This task accomplished planning activities for conducting phase II of the study, including TPS component part design for a full-scale mockup, detailed plans for parts fabrication and refurbishment operations experiments. Plans include component part quantities, number of personnel, personnel skills, experiment procedures, measurement and evaluation requirements, equipment requirements, schedules, and costs.

In fulfilling these requirements, a task plan was followed which involved a series of discrete functions. This task plan, shown schematically in figure 38, gives the reader some insight into the logic for generating the test plans outlined later in the report. The figure also serves as a table of contents, since pertinent logic flow elements are discussed in chronological order. Experiment and fabrication costs are discussed in part 3 of this report. These data are proprietary and therefore have limited distribution.

Task Input Data

Input data to this task involved design and cost uncertainties resulting from the evaluation in task 4, selected TPS arrangements, full-scale mockup characteristics, and task guidelines and constraints. The nature of each of these input data is discussed in subsequent paragraphs insofar as they effect the development of the experimental test program that follows.

Design and cost uncertainties. - Cost and design feasibility questions or uncertainties resulting from the evaluation of specific refurbishment activities were caused, for the most part, by lack of experience in maintaining a reusable TPS on a space shuttle vehicle. These uncertainties can best be classified under the following categories:

Concept practicality

Material effects

Fastener removal and installation

Size limitations

Tool and equipment configurations

Repair procedures.

Each of these categories is interwoven to some degree with each other. Only those uncertainties which can be resolved through experimentation on a full-scale mockup are delineated in test plans.

Selected TPS arrangements. - At the completion of task 4, an oral briefing was made at NASA-LRC at which time MDAC-East presented study progress and recommended candidate heat shield systems and associated attachment methods to receive more detail study during task 5. These recommendations were considered by NASA-LRC and a mutually agreed upon concept selection was made by NASA-LRC and MDAC-East, the results of which are described herein.

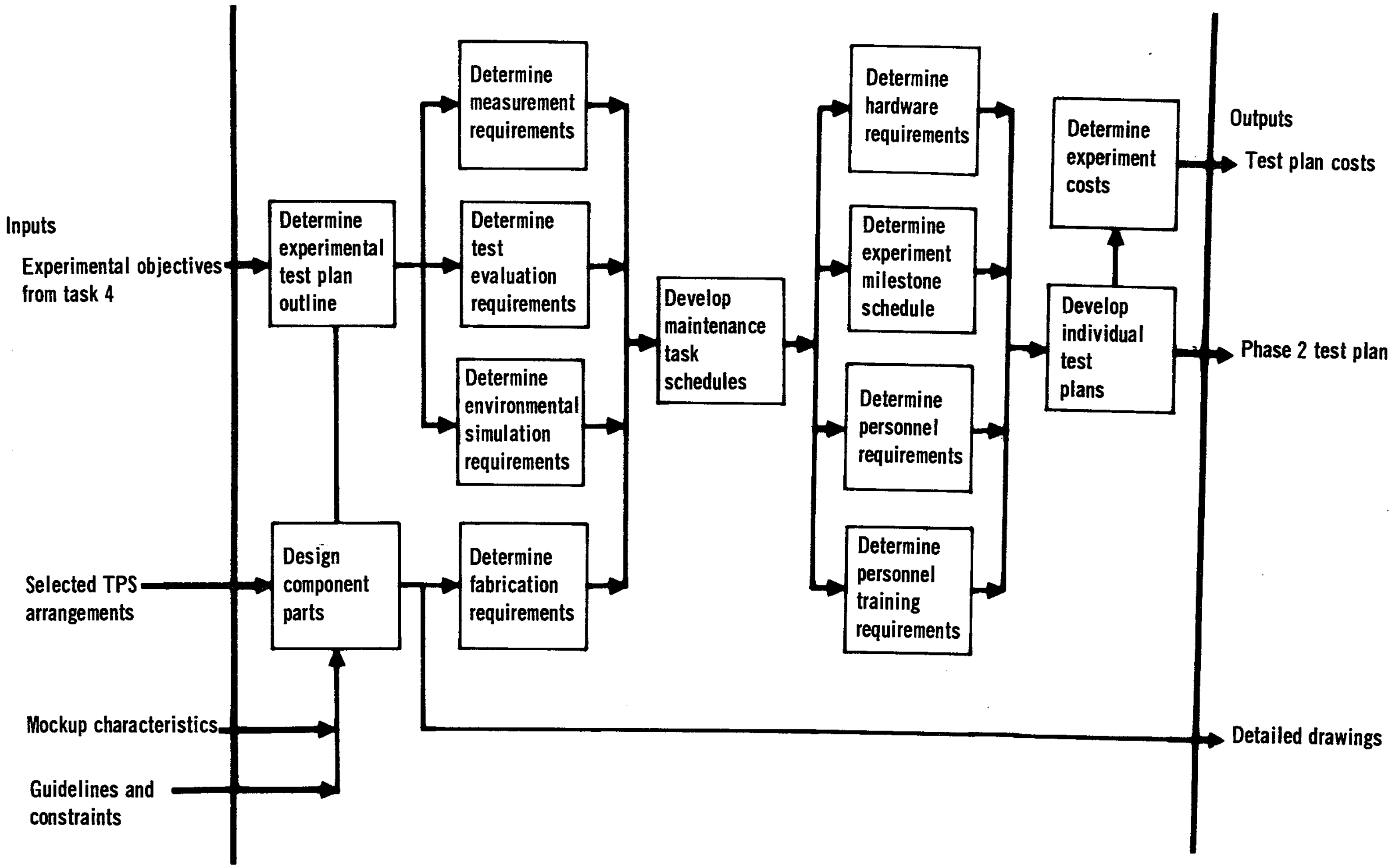


FIGURE 38 TASK 5 LOGIC FLOW

Those individual concepts chosen for detailed study are:

Ablative

Concept 4A: multiple mechanical fasteners/pi-strap (figure 12)
Concept 4B: multiple mechanical fasteners (figure 13)

HCF

Concept 5: key/keyway (figure 14)

Metallic

Concept 6A: flush fastener (figure 15)
Concept 7A: pi-strap (figure 17).

In selecting these TPS concepts for further detail study, two primary objectives were considered:

to select those concepts with desirable individual characteristics to minimize refurbishment activities associated with future space shuttle maintenance

to select those concepts which, when combined in an experimental program, cover the full spectra of anticipated refurbishment problems.

To satisfy the first objective, concepts were chosen on the basis of low cost refurbishment potential and applicability to near future space shuttle use. The second objective was met by selecting those concepts which encompass a variety of approaches, permit examination of significant refurbishment problems, and provide the most data for the least cost.

Guidelines and constraints. - Certain guidelines and constraints had to be adopted for program definition to resolve major uncertainties involved in maintaining a representative space shuttle TPS and at the same time minimize experimental costs of a full-scale mockup. Some of these guidelines and constraints were specified by NASA-LRC while others were generated based on study results of tasks 1 through 4. Specifically these guidelines and constraints are:

All test panels, except simulated leading edges and body chines, are flat members.

Test panels, attachments, supports and standoffs allow for thermal expansion.

Panel supports and standoffs to accommodate a maximum number of different TPS panels.

Test panels and supports do not necessarily withstand aerodynamic and acoustic environments.

TPS panels are attached to coincide (parallel) with the test fixture panel support channels (NASA drawing #522929).

Maximum panel width is 10 feet and minimum panel length is 20 inches.

All TPS panels, supports, and standoffs will be fabricated with the least cost materials, fabrication techniques, and quality control procedures consistent with mockup requirements.

Refractory metal coatings will be simulated on conventional type metals.

Antennas, doors, cutouts, etc, will not be simulated.

A representative thermal environment will be simulated as required either by strip type radiant lamps or gas heater.

Panel substrate stiffness requirements will be maintained where possible.

Full-scale mockup configuration. - TPS components and experimental test plans generated during this task center around the use of a full-scale mockup designed and built by NASA-LRC. The general mockup arrangement is shown in figure 39. The major portion of the mockup features a cylinder segment with an approximate 200 ft^2 planform area. This segment is representative of a space shuttle primary structure such as a propellant tank wall. The cylindrical segment is of a sandwich type of contruction consisting of 0.25 inch face sheets mounted to seven, 5-inch deep, channels, equally spaced on the perifery. On the outer surface of the sandwich, additional channels are provided to attach TPS support structure. Each end of the simulated tank wall structure is trunnion mounted, at the mid-chord, to an A-frame structure. A drive mechanism rotates the section to simulate vehicle fuselage top, side, and bottom.

Component Part Design

The design portion of task 5 consisted of preparing detailed drawings of TPS component parts suitable for fabrication. The component parts include selected heat shield panels and associated attachments, the panel support structure between TPS panels and the basic mockup, and TPS panel arrangement and mockup installation.

These drawings were prepared using MDAC-East standard drawing procedures which are based on industry accepted drafting and dimensioning practices. Standard company drawing forms were used which conform to the intent of MIL-STD-100A. These forms contain an integral parts list, drawing zones, and other standard drawing information blocks such as title and revision.

Each drawing is numbered and controlled by a central documentation control function which also serves as the release point for completed drawings issued for production. If modifications are requested by NASA after initial release, standard contractor change forms will be used. All changes are numbered and released according to company drawing control procedures.

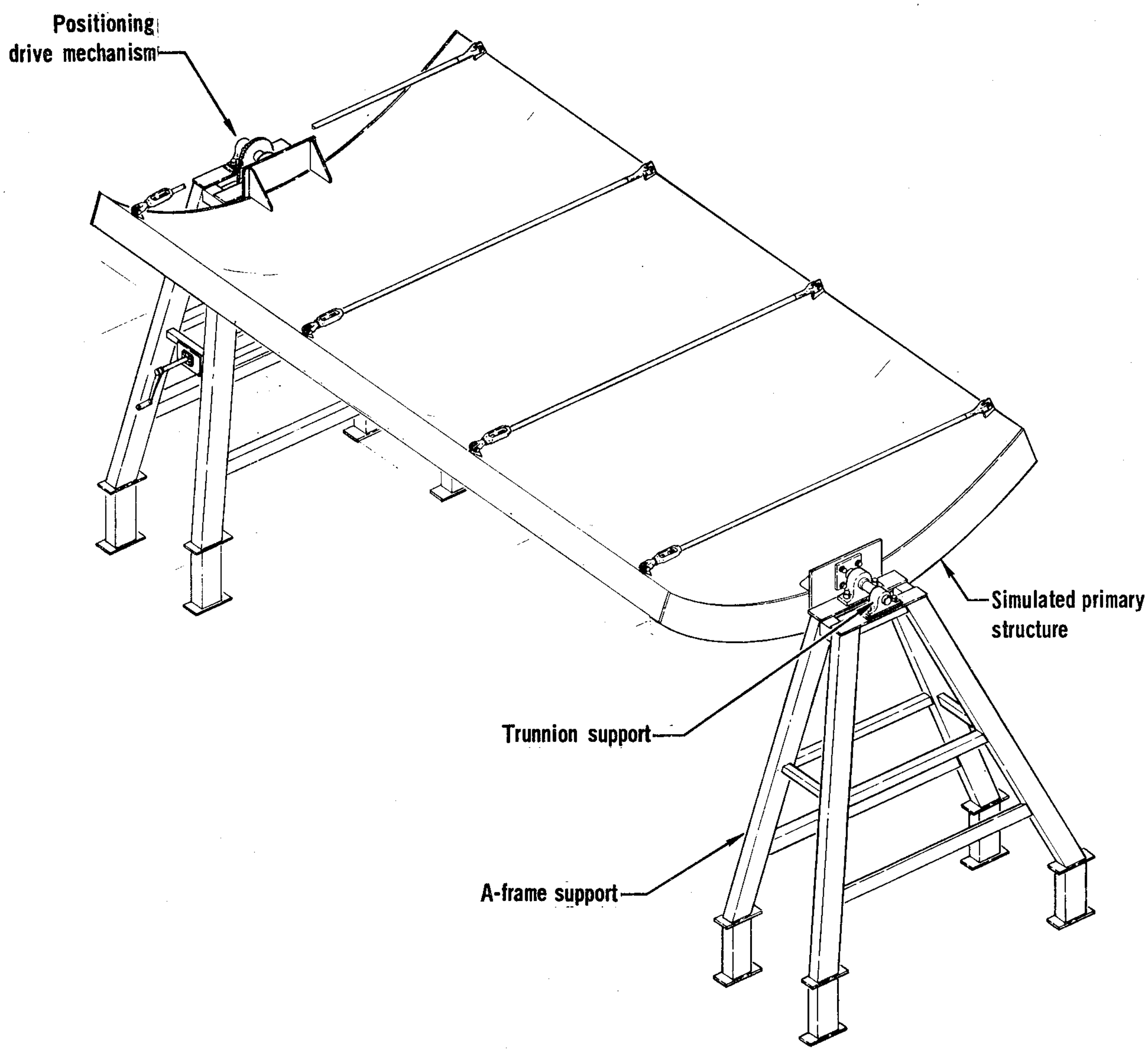


FIGURE 39 NASA-LRC FULL-SCALE MOCKUP

The specific drawings generated during this task for incorporation into the phase II program include:

MDAC DRAWING NUMBER	DESCRIPTION	FIGURE NUMBER
64T020001	TPS panel installation assembly	40
64T020002	TPS panel support assembly (mockup modification)	41

Drawing no. 64T020001. - Panels for metallic concepts are arranged, one following the other, on one end of the mockup, while the HCF and the ablator panels are attached on the other end, as shown in figure 40. Panel test sequence is important because certain mockup modifications are required, such as riveting the key to the hat section support beams for holding the HCF panels. If tested first, these parts must be removed before the ablator panels can be installed.

In addition to panel arrangements and edge interfaces, this drawing specifies hardware for attaching TPS panels to the panel support beams.

Drawing no. 64T020002. - This drawing (figure 41) details the TPS support structure. Heat shield panels are distant from the basic mockup structure and tubular links are in a post arrangement for panel support and attachment. The panels are supported by 2.7 inch wide hat section beams, spanning laterally across the mockup, a distance of 120 inches. These hat section beams are spaced at 20 inch intervals along the longitudinal axis of the mockup. Mockup length is 240 inches. The hat section beams are supported off the mockup structure by 1.0 inch tubular posts of variable length. Drag struts, between the hat section beams and mockup structure support channels, are provided for longitudinal stability. Also shown on the drawing are simulated chine assemblies and the key detail for the key/keyway concept shown in drawing number 64T020004.

Drawing no. 64T020003. - This drawing (figure 42) details concept 4A. The design features a 1.0-inch thick elastomer resin filled honeycomb matrix bonded to a 0.047 inch fiber glass facesheet. The composite (honeycomb matrix/fiberglass facesheet) is mechanically attached to a 0.375 inch thick, solid, fiber glass support panel by standard (no. 10) bolts spaced approximately every 7 inches on center. The approximate size of the heat shield panel is 19 by 70 inches. Four, 1.75 inch wide pi-straps, each 35 inches long, secure two edges of the panel to the hat section beams using five equally spaced bolts over the length of an individual pi-strap.

Drawing no. 64T020004. - This drawing (figure 43) details concept 5. The design features four, 1.0 inch thick, HCF tiles bonded to a 0.375 inch thick, solid, fiber glass support panel. Each HCF tile is approximately 10 by 10 inches, with the support panel dimensions being 19.8 by 20.0 inches. A keyway or female part consisting of two split wedge shaped rails is bonded and mechanically fastened to the panel substrate at opposite ends of the panel. The key, male part, which also serves as the panel support sill, is attached to hat section beams and spaced to mate the panel split keyways. This key portion is detailed in figure 41. Intermittent notches are machined into both the key and keyways allowing the panel to drop over the key, after which the panel is moved along the keys ~0.75 inches to achieve a mechanically attached assembly.

A 2.00 inch wide spacer is positioned after every third or fourth panel along the longitudinal edges, allowing selected panels to be removed without starting at the chine interface.

In order to restrict the inflow of hot boundary layer gases and moisture in the lateral joints between panels, overlapping, metallic shingles are added along the lateral edges of the panels. These shingles are mechanically attached on the outer surface of the HCF tiles. For the longitudinal joints, where the gaps are considerably smaller, a step is machined in the HCF tiles and a compressible sponge silicone gasket is bonded to one edge of the fiber glass support panel. Interlocking sills are added to the edges of the panel at the longitudinal joints to prevent out of phase deflections between adjacent panels and subsequent damage to the stepped HCF tile interfaces.

Drawing no. 64T020005. - This drawing (figure 44) details concept 6, less the middle support member. The basic attachment concept principle (figure 15) is retained in the detail parts drawing, except for panel edge members. Since concept 6 was generated, further analysis has indicated a more feasible design and cost approach. Hence, some changes were made and are reflected in the detail drawing.

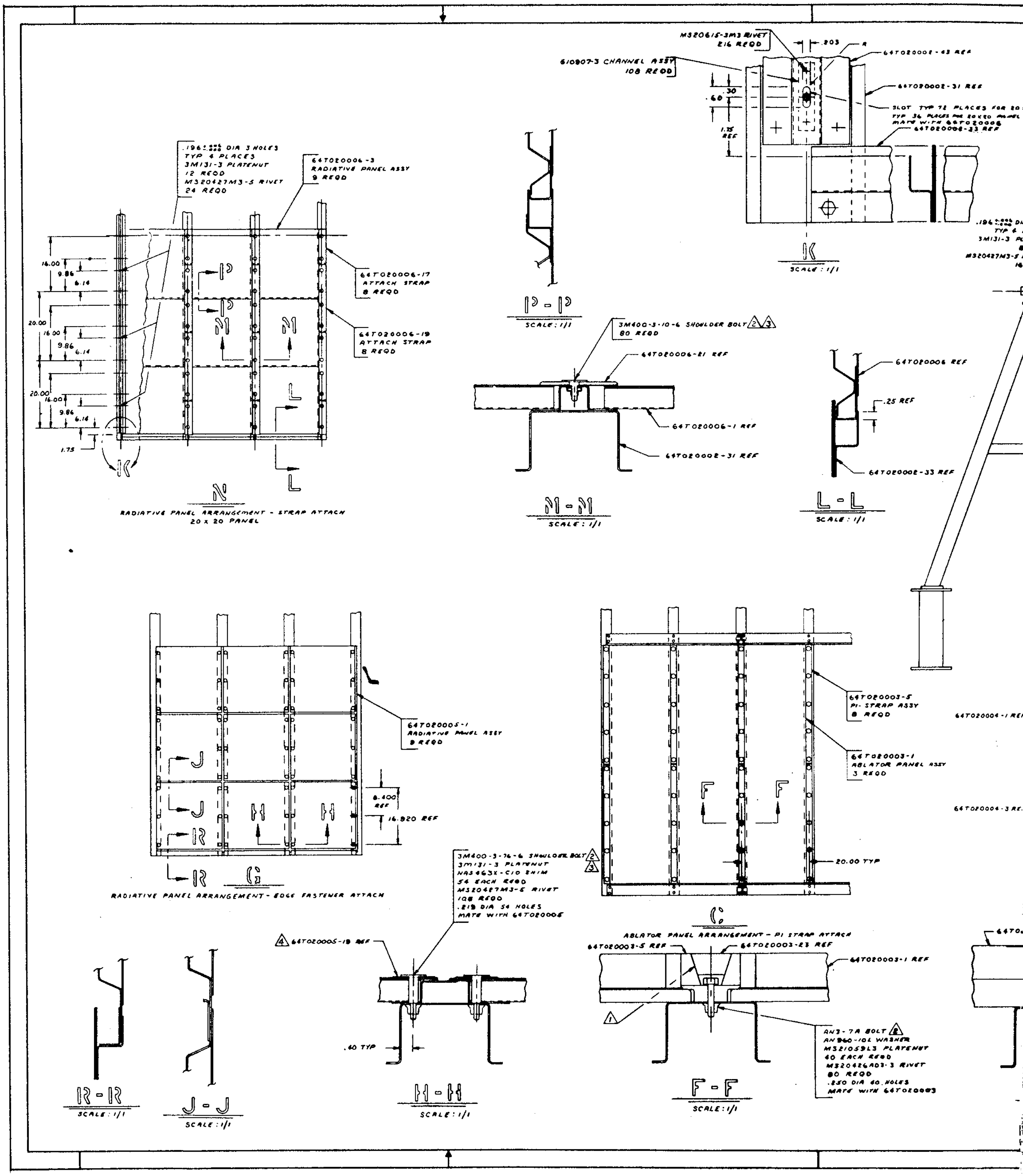
The design features a 20 by 20 inch single-face corrugation panel made of L-605. The 0.010 inch thick corrugation is 0.70 inch high and the facesheet is 0.010 inch thick. Z-section close-out members (0.020 inch thick) are welded to two opposite panel edges to help distribute panel load to the attachments. The other two panel edges are unsupported except for adjacent panel interlocking members shown in section J-J. At five of the six attachment points, slotted holes provide for thermal contraction and expansion. The sixth attachment point is a restrained reference point for positioning the panel during installation. Standard Hasteloy X shoulder bolts are used for attaching the panel to hat section support beams. An aluminide coating is applied to the top external surface of these L-605 panels to simulate coated columbium panels.

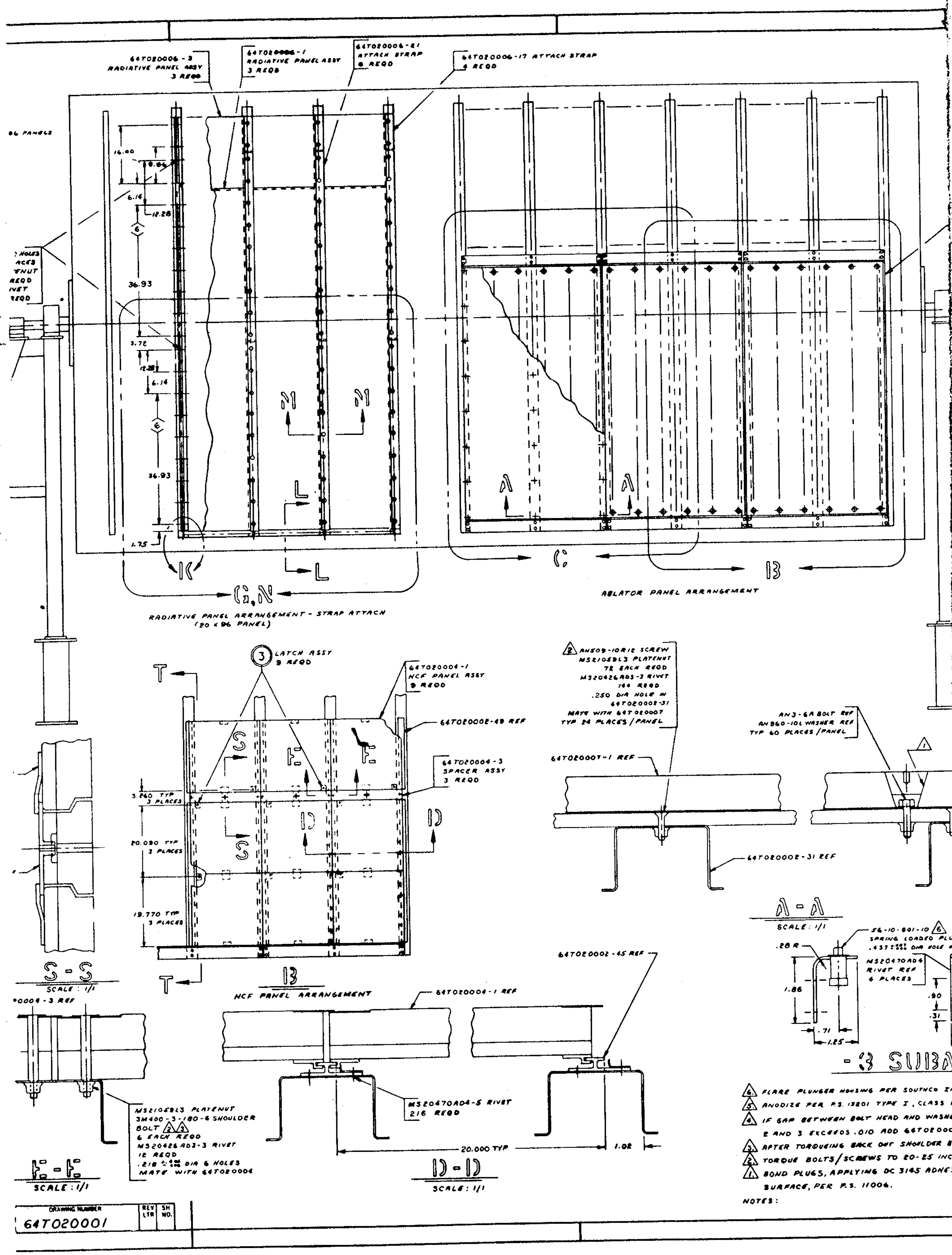
Drawing no. 64T020006. - This drawing (figure 45) details the present phase B shuttle baseline design. This attachment concept is similar to that of concept 7A (pi-strap attach). However, the two pi-strap feet are deleted and panels are held in place by flat, 2.34 inch wide straps. The panel skin extends across the attach joint and overlaps the adjacent panel providing a more positive, moisture-proof joint similar to house shingles. The middle support of concept 7B is deleted.

Two different size panels are detailed, a 20 by 20 inch panel which coincides with the panel size selected for the shuttle's phase B structural test program, and a 20 by 96 inch panel. Both assemblies are of single-faced corrugation construction with skin and corrugations made from 0.010 inch L-605. These two panel assemblies are identical except for width.

As in the previous design the longitudinal edges are unsupported except for interlocking 0.020 inch thick members which are welded to opposite ends of the panel.

Drawing no. 64T020007. - This drawing (figure 46) details concept 4B. The design features a 1 inch thick elastomer resin filled honeycomb matrix bonded to a 0.047 inch fiber glass facesheet. The composite (honeycomb matrix/fiber glass facesheet) is mechanically attached to a 0.375 inch thick, solid, fiber glass support panel by standard (no. 10) bolts spaced approximately every 7 inches on center. In this concept, the ablator composite is attached to the panel substrate after the substrate is attached to the primary structure. The ablator composite is bolted to the panel substrate through predrilled holes in the ablator composite. After installation, the holes are filled with premachined elastomer plugs which are bonded in place. The approximate heat shield panel size is 40 by 70 inches. A compressible gasket is attached along one edge of the panel providing a tight fit (no gap) between adjacent panels.


MS20615-3M3 RIVET 216 REQD
610807-3 CHANNEL ASSY 108 REQD
64T020002-43 REF
64T020002-31 REF
SLOT TYP 72 PLACES FOR 20 X
TYP 36 PLACES FOR 20 X 20 PANEL
MATE WITH 64T020006
64T020002-33 REF
K
SCALE: 1/1
.196 DIA 3 HOLES
TYP 4 PLACES
3M131-3 PLATENUT
12 REQD
MS20427M3-5 RIVET
24 REQD
64T020006-3
RADIATIVE PANEL ASSY
9 REQD
64T020006-17
ATTACH STRAP
8 REQD
64T020006-19
ATTACH STRAP
8 REQD
N
RADIATIVE PANEL ARRANGEMENT - STRAP ATTACH
20 x 20 PANEL
P - P
SCALE: 1/1
3M400-3-10-6 SHOULDER BOLT
80 REQD
64T020006-21 REF
64T020006-1 REF
64T020002-31 REF
M - M
SCALE: 1/1
64T020006 REF
.25 REF
64T020002-33 REF
L - L
SCALE: 1/1
64T020005-1
RADIATIVE PANEL ASSY
9 REQD
8.400 REF
16.820 REF
G
RADIATIVE PANEL ARRANGEMENT - EDGE FASTENER ATTACH
64T020003-5
PI-STRAP ASSY
8 REQD
64T020003-1
ABLATOR PANEL ASSY
3 REQD
20.00 TYP
C
ABLATOR PANEL ARRANGEMENT - PI STRAP ATTACH
64T020004-1 REF
64T020004-3 REF
3M400-3-14-6 SHOULDER BOLT
3M131-3 PLATENUT
NAS463X-C10 SHIM
54 EACH REQD
MS20427M3-5 RIVET
108 REQD
.213 DIA 54 HOLES
MATE WITH 64T020006
64T020005-19 REF
.40 TYP
H - H
SCALE: 1/1
64T020003-5 REF
64T020003-23 REF
64T020003-1 REF
AN3-7A BOLT
AN960-10L WASHER
MS21059L3 PLATENUT
40 EACH REQD
MS20426AD3-3 RIVET
80 REQD
.250 DIA 40 HOLES
MATE WITH 64T020003
F - F
SCALE: 1/1
R - R
SCALE: 1/1
J - J
SCALE: 1/1


64T020006-3 RADIATIVE PANEL ASSY 3 REQD
64T020006-1 RADIATIVE PANEL ASSY 3 REQD
64T020006-21 ATTACH STRAP 6 REQD
64T020006-17 ATTACH STRAP 4 REQD
16.00
6.14
12.28
36.93
3.72
1.75
L
M
A
C
B
K
RADIATIVE PANEL ARRANGEMENT - STRAP ATTACH (20 X 96 PANEL)
ABLATOR PANEL ARRANGEMENT
LATCH ASSY 9 REQD
64T020004-1 HCF PANEL ASSY 9 REQD
64T020002-49 REF
64T020004-3 SPACER ASSY 3 REQD
3.260 TYP 3 PLACES
20.090 TYP 3 PLACES
19.770 TYP 3 PLACES
HCF PANEL ARRANGEMENT
AN509-10R12 SCREW
MS21059L3 PLATENUT 72 EACH REQD
MS20426AD3-3 RIVET 144 REQD
.250 DIA HOLE IN 64T020002-31
MATE WITH 64T020007
TYP 24 PLACES/PANEL
64T020007-1 REF
64T020002-31 REF
AN3-6A BOLT REF
AN960-10L WASHER REF
TYP 60 PLACES/PANEL
A-A
SCALE: 1/1
S-S
SCALE: 1/1
64T020002-45 REF
64T020004-1 REF
MS20470AD4-5 RIVET 216 REQD
20.000 TYP
1.02
D-D
SCALE: 1/1
MS21059L3 PLATENUT
3M400-3-180-6 SHOULDER BOLT
6 EACH REQD
MS20426AD3-3 RIVET 12 REQD
6 HOLES
MATE WITH 64T020004
E-E
SCALE: 1/1
.28 R
1.86
.71
1.25
.90
.31
-3 SUBA
FLARE PLUNGER HOUSING PER SOUTHCO
ANODIZE PER P.S. 13201 TYPE I, CLASS I
IF GAP BETWEEN BOLT HEAD AND WASHE
2 AND 3 EXCEEDS .010 ADD 64T02000
AFTER TORQUEING BACK OUT SHOULDER B
TORQUE BOLTS/SCREWS TO 20-25 INC
BOND PLUGS, APPLYING DC 3145 ADHES
SURFACE, PER P.S. 11006.
NOTES:
DRAWING NUMBER
64T020001
REV LTR
SH NO.

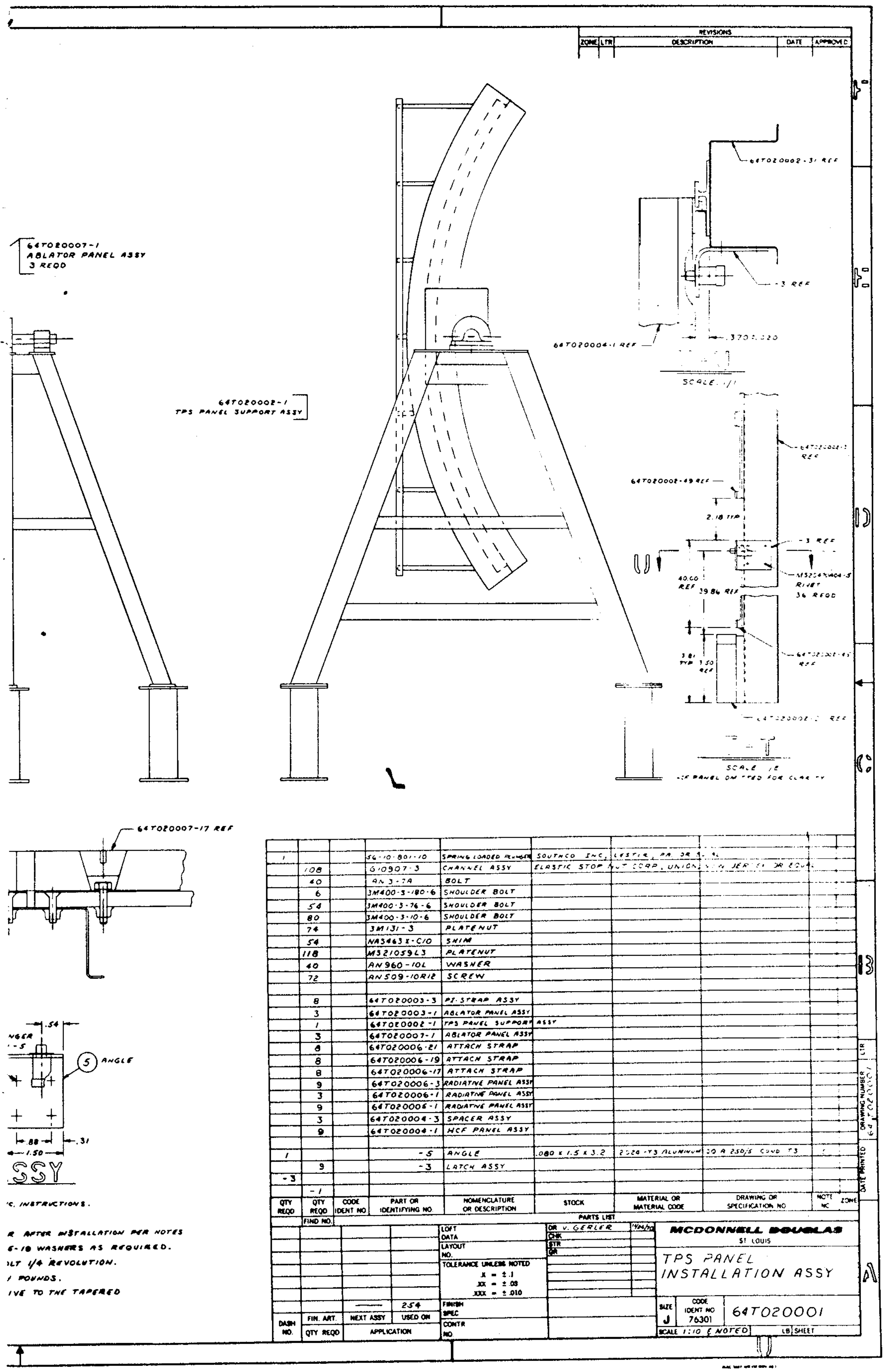
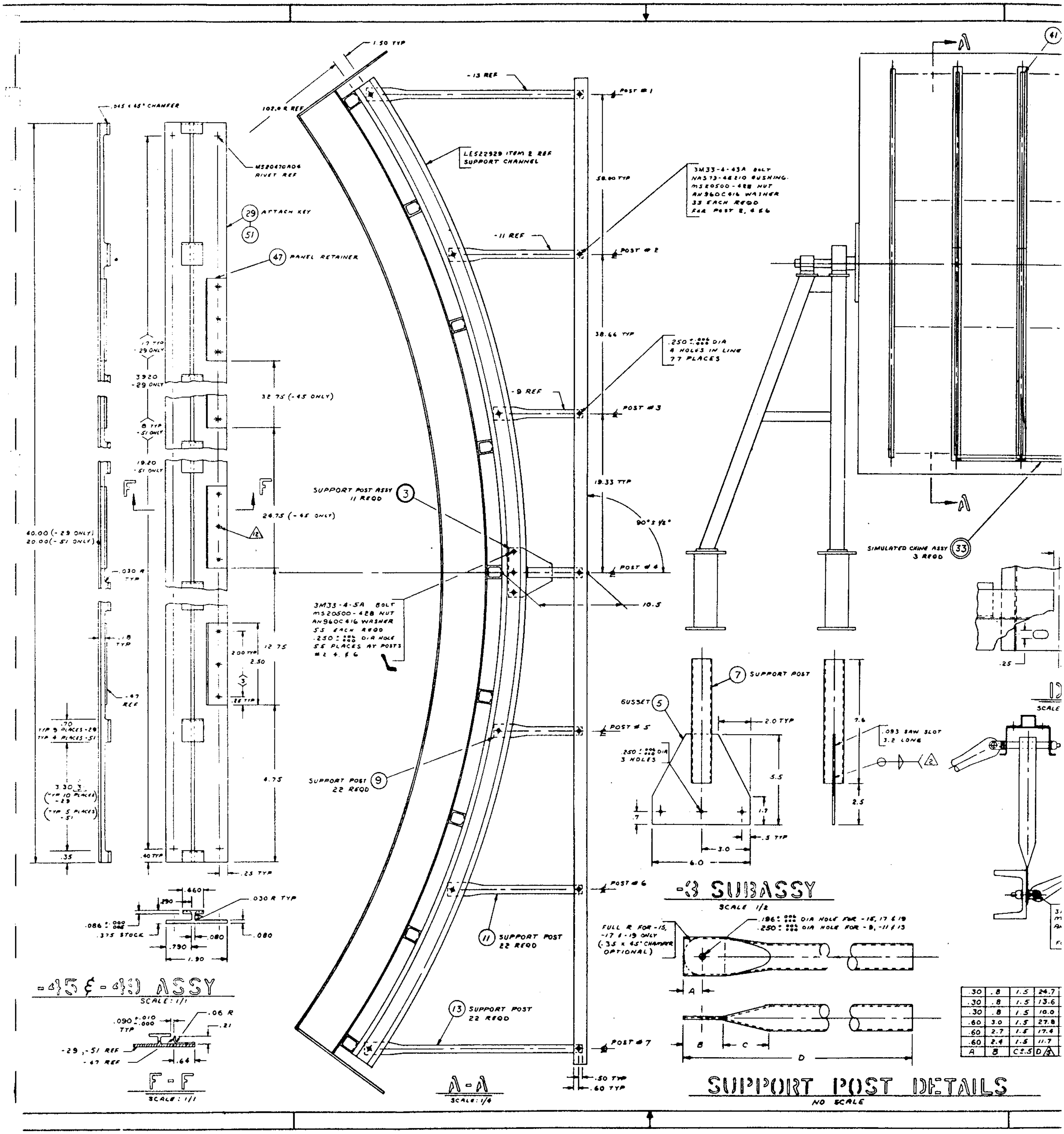
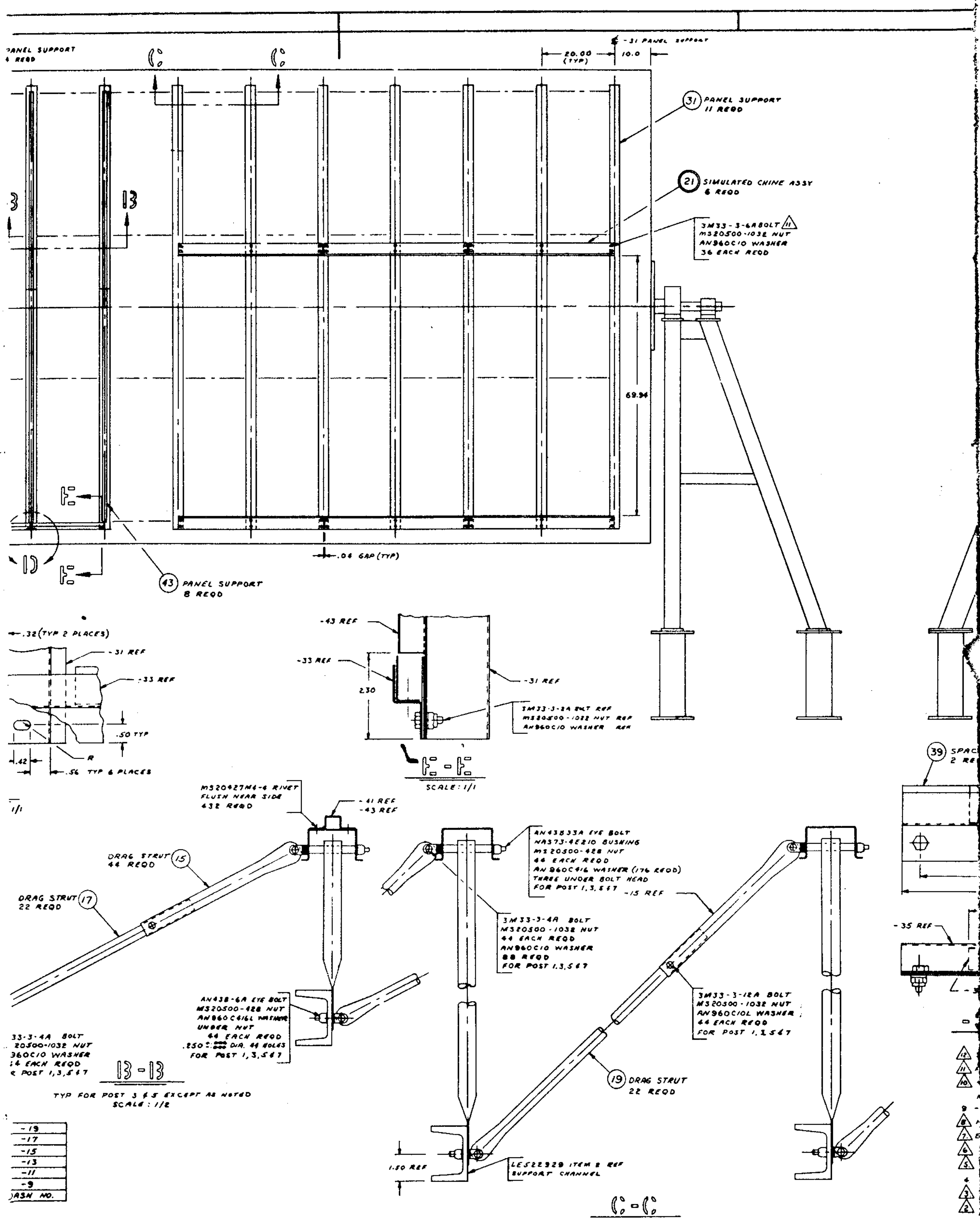


FIGURE 40 TPS PANEL INSTALLATION ASSEMBLY



.30	.8	1.5	24.7
.30	.8	1.5	13.6
.30	.8	1.5	10.0
.60	3.0	1.5	27.8
.60	2.7	1.5	17.4
.60	2.4	1.5	11.7
A	B	C±.5	D



DRAWING NUMBER	REV LTR	SH NO.
64T020002		

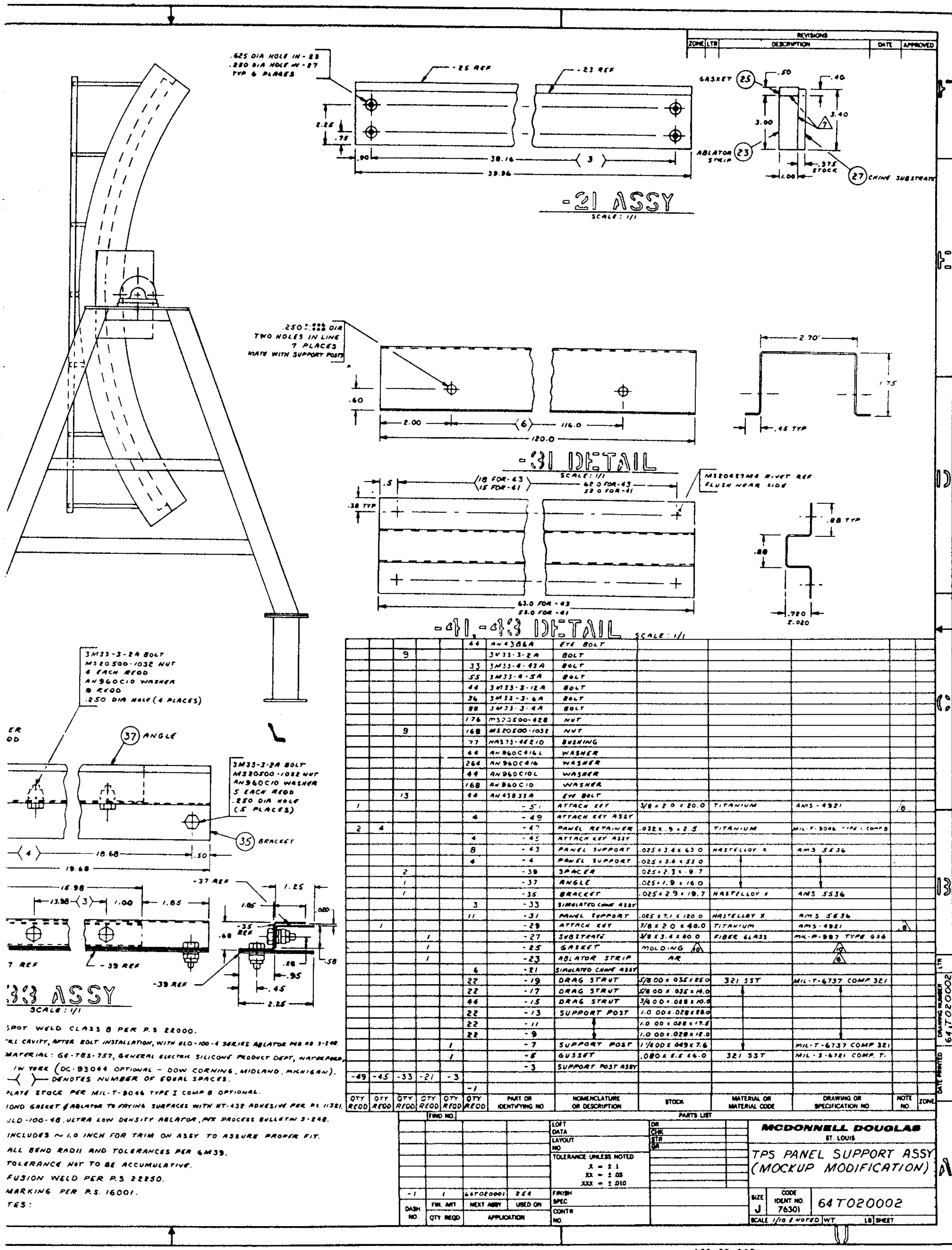
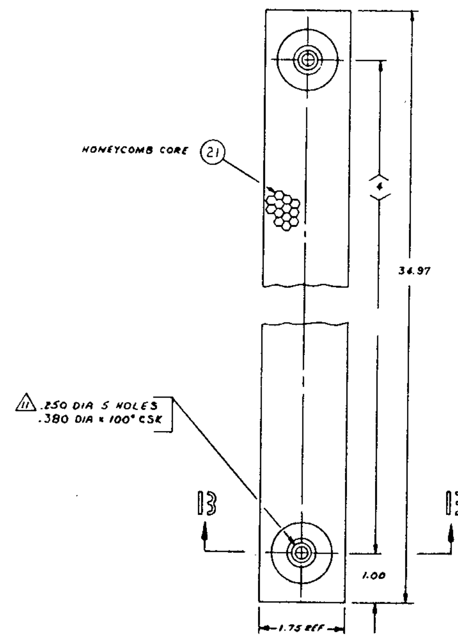
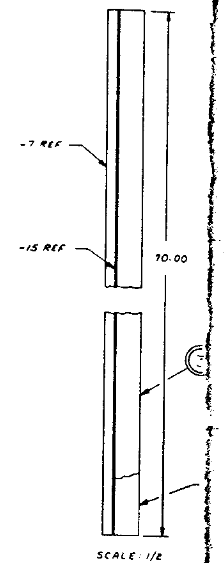
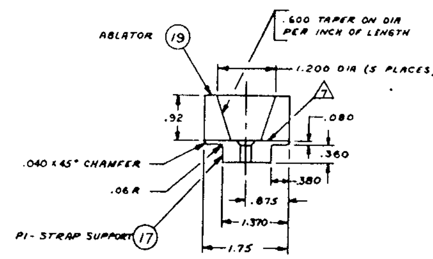


FIGURE 41 TPS PANEL SUPPORT ASSEMBLY (MOCKUP MODIFICATION)



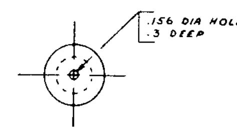


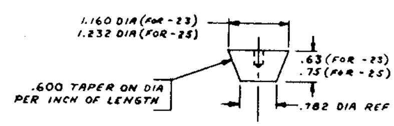


13-13

-5 ASSY

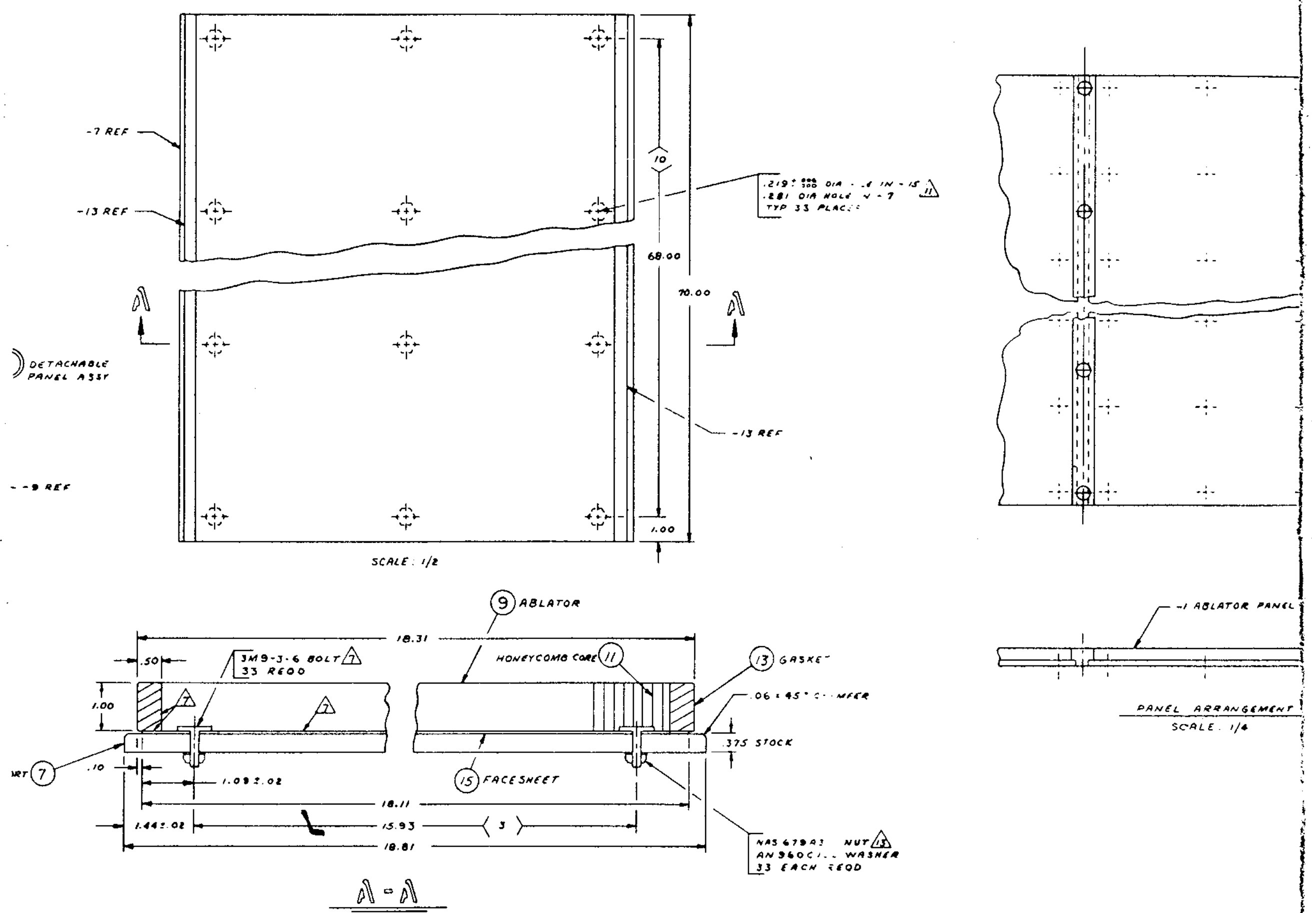
PANEL SUPP





-23,-25 DETAIL

SECURITY CLASSIFICATION	DRAWING NUMBER	SH
U	64T020003	



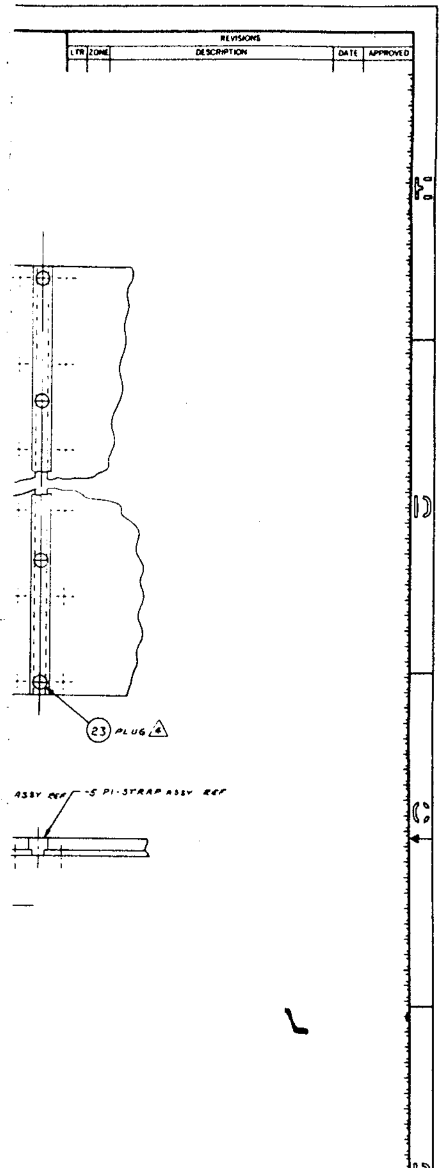
13. TORQUE NUTS 15-20 INCH POUNDS.
12. MATERIAL: GE-TBS-757, GENERAL ELECTRIC SILICONE PRODUCT DEPT, WATERFORD NEW YORK (OPTIONAL - DC 93044, DOW CORNING, MIDLAND, MICHIGAN).
11. ATTACH PATTERN TO BE IDENTICAL BETWEEN LIKE PARTS.
10. ULD-100-4B, ULTRA LOW DENSITY ABLATOR, PER PROCESS BULLETIN 3-248
9. -23 PLUG SAME AS 64T020008-17.
8. PLATE STOCK PER AMS 4918 OPTIONAL.
7. BOND HONEYCOMB CORE, BOLTS AND GASKETS TO FAYING SURFACES PER P.S. 11321 WITH HT-432 ADHESIVE.
6. ULD-100-4 SERIES, ULTRA LOW DENSITY ABLATOR, PER PROCESS BULLETIN 3-248.
5. HRP-3/16-GF11-4.0 LB/FT³ HONEYCOMB CORE PER MMS-703, TYPE III (HEXCEL CORPORATION, GRAND PRAIRE, TEXAS).
4. INSTALLATION PART.
3. BREAK ALL SHARP EDGES PER P.S. 23041.
2. —⟨ ⟩— DENOTES NUMBER OF EQUAL SPACES.
1. MARKING PER P.S. 16001.
NOTES:

		33	NAS679A3W	
		33	AN960C10L	
	33		3M9-3-6	
			-25	10
5			-23	10
1			-21	5
AR			-19	6
1			-17	MIL-T-9047 TYPE III COMP C
	1		-15	MIL-P-997 TYPE
	2		-13	12
	1		-11	5
	AR		-9	6
		1	-7	MIL-P-997 TYPE G
		1	-3	
	-3			
-5		-1		
QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	DRAWING OR SPECIFICATION NO.
	FIND NO.			

DASH NO.	ASSY QTY REQD	ART. QTY REQD	NEXT ASSY (APPLICATION)	USED ON (APPLICATION)
-25			64T020003	254
-5			64T020003	254
-1			64T020003	254

LOFT DATA
LAYOUT NO.
TOLERANCE UNLESS NOTED
.X = ±.1
.XX = ±.03
.XXX = ±.010
FINISH SPEC
CONTR NO.

FIGURE 42 ABLATOR PANEL ASSEMBL



	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL OR MATERIAL CODE	NOTE NO.	ZONE
	NUT				
	WASHER				
	BOLT				
	ABLATOR PLUG				
	ABLATOR PLUG	AR			
	HONEYCOMB CORE	.92 x 1.8 x 35.00			
	ABLATOR				
B	PI-STRAP SUPPORT	1/2 x 1.75 x 35.00	6AL-6V-2Sn TITANIUM		
3G	FACESHEET	3/64 x 18.2 x 72.0	FIBERGLASS		
	GASKET	MOLDING 10			
	HONEYCOMB CORE	1.0 x 18.0 x 72.0			
	ABLATOR				
3G	PANEL SUPPORT	3/8 x 19.0 x 72.0	FIBER GLASS		
	DETACHABLE PANEL ASSY				

PARTS LIST

DR	J GERLER	11/7/70
CHK		
STR		
GR		

MCDONNELL
ST. LOUIS, MISSOURI

ABLATOR PANEL ASSY–
PI-STRAP ATTACH

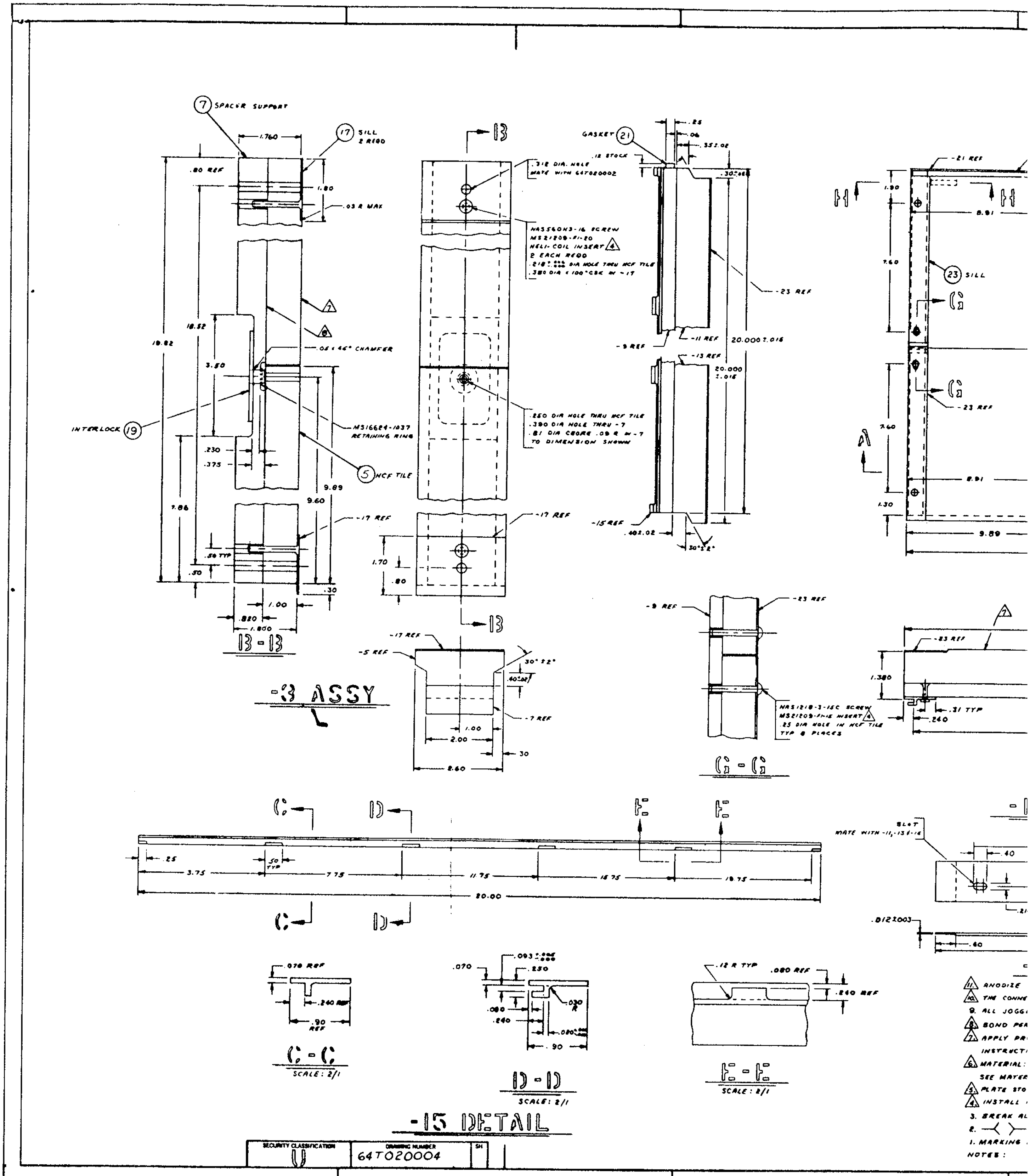
SIZE	CODE IDENT NO.	
J	76301	64T020003

SCALE FULL & NOTED | WT LB | SHEET

LTR A | DRAWING NUMBER 64T020003 | DATE PRINTED

489-07-007

.Y - PI-STRAP ATTACH



SPACER SUPPORT
SILL 2 REQD
INTERLOCK
MS16624-1037 RETAINING RING
HCF TILE
.04 x 45° CHAMFER
13 - 13
-3 ASSY
GASKET
.312 DIA. HOLE MATE WITH 64T020002
NAS560K3-16 SCREW
MS21209-F1-20 HELI-COIL INSERT
2 EACH REQD
.250 DIA HOLE THRU HCF TILE
.390 DIA HOLE THRU -7
.81 DIA CBORE .09 R -7 TO DIMENSION SHOWN
-23 REF
-11 REF
-13 REF
-9 REF
-15 REF
-17 REF
-5 REF
-7 REF
SILL
G - G
NAS1218-3-15C SCREW
MS21209-F1-15 INSERT
.25 DIA HOLE IN HCF TILE TYP 8 PLACES
SLOT MATE WITH -11, -13 & -15
C - C
SCALE: 2/1
D - D
SCALE: 2/1
E - E
SCALE: 2/1
-15 DETAIL
ANODIZE
ALL JOGGL
BOND
APPLY
MATERIAL:
SEE MATER
PLATE STO
INSTALL
3. BREAK AL
1. MARKING
NOTES:
SECURITY CLASSIFICATION
U
DRAWING NUMBER
64T020004
SH

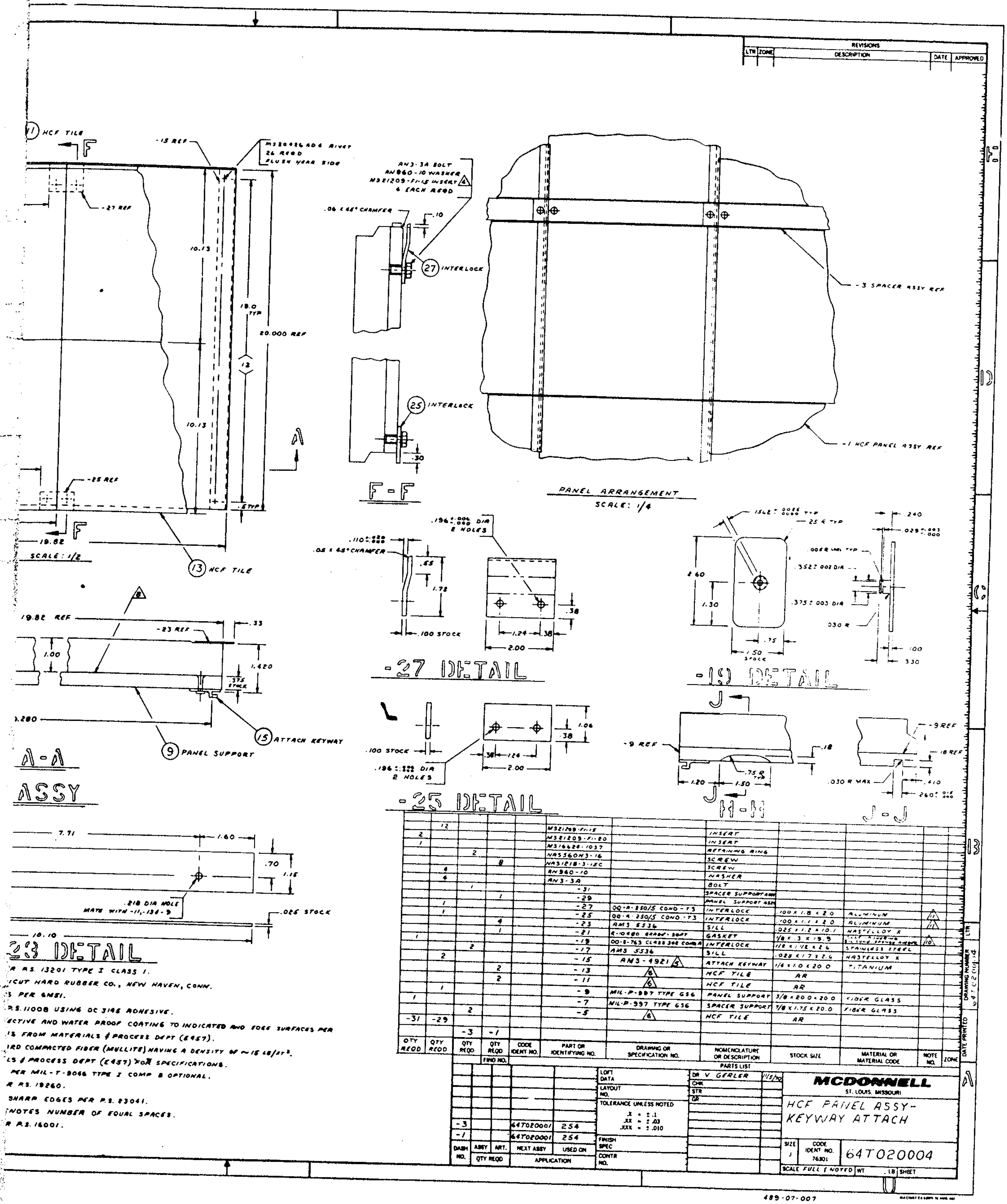
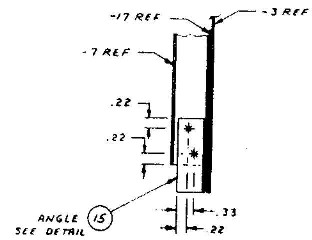


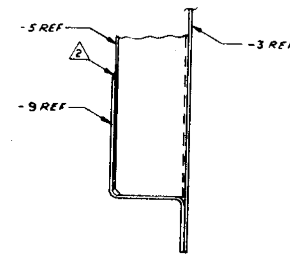
FIGURE 43 HCF PANEL ASSEMBLY - KEYWAY ATTACH

NOTES:

1. ATTACH PATTERN TO BE IDENTICAL BETWEEN PANEL ASSY'S.
2. WELD PER P.S. 22250.
3. DIAMETERS TO BE CONCENTRIC WITHIN .04 TIR.
4. INSTALLATION PART.
5. SPOT WELD CLASS 8 PER P.S 22000.
6. —< >— DENOTES NUMBER OF EQUAL SPACES.
7. MARKING PER P.S. 16001.
8. ALL BEND RADII AND TOLERANCES PER 6M39.

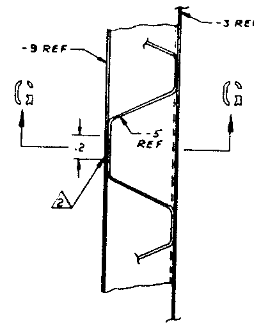


D-D



G-G

SCALE: 2/1

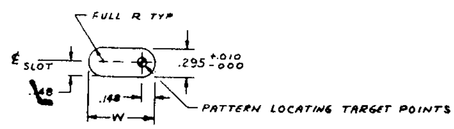


F-F

SCALE: 2/1

WELD EDGE OF -7 & -9 TO -5 TYP 12 PLACES EACH

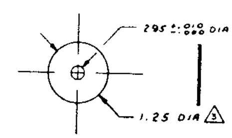
CORR



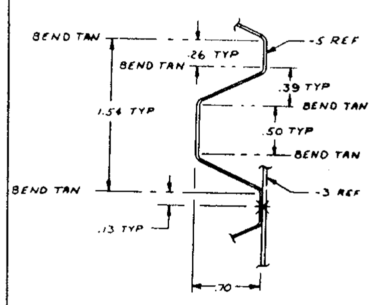
SLOT	SLOT LENGTH "W"	SLOT THRU
A	.500	-3, -5 & -7
B	.660	-3, -5 & -9
C	.700	-3, -5 & -9

SLOT DETAIL 1

BEA

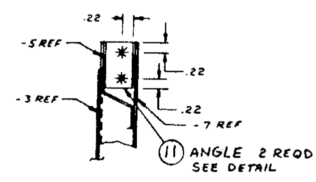


-19 DETAIL

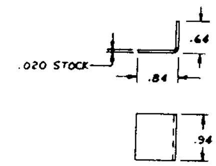


E

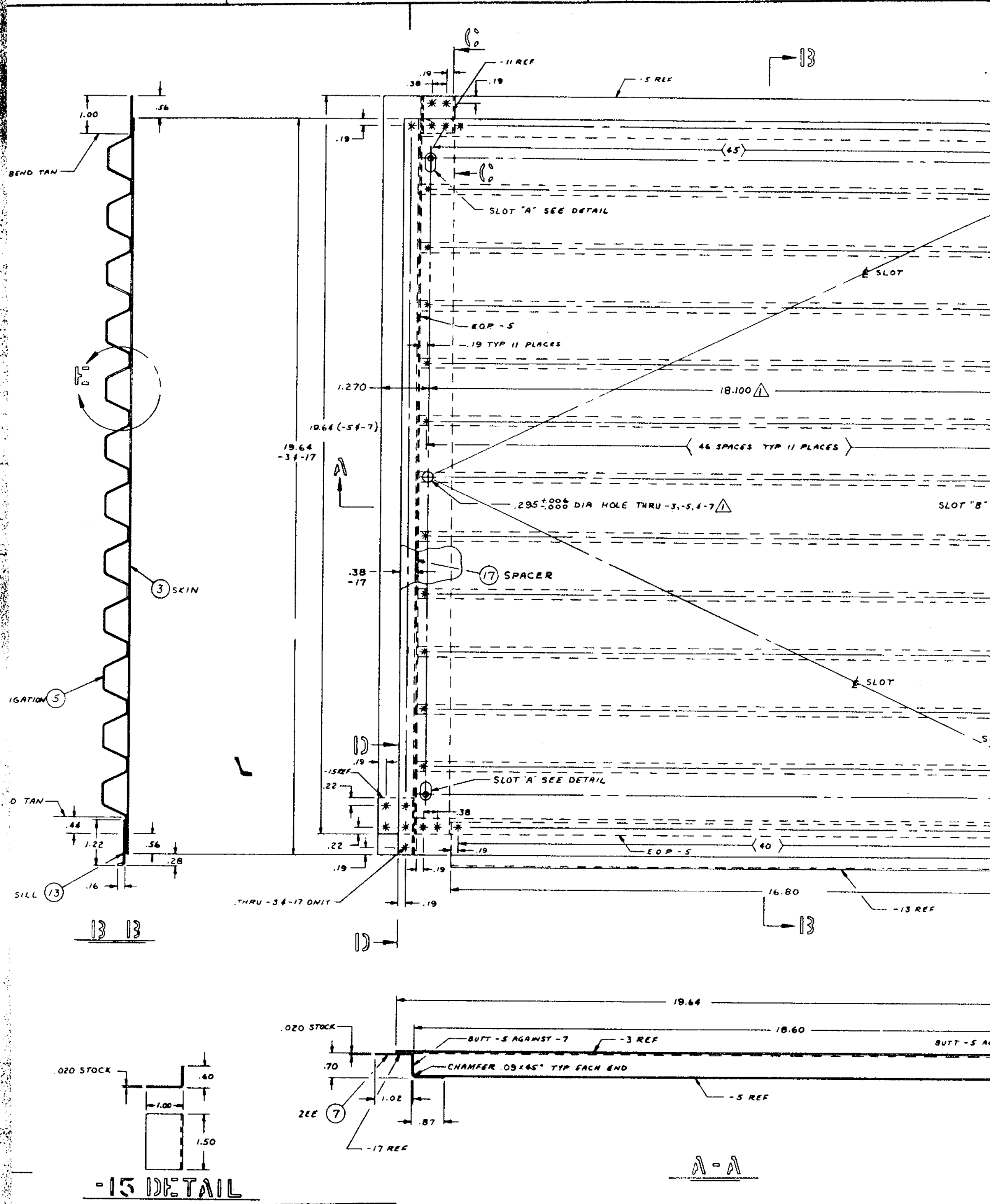
SCALE: 2/1



C-C



-11 DETAIL



SECURITY CLASSIFICATION	DRAWING NUMBER	SH
U	64T020005	

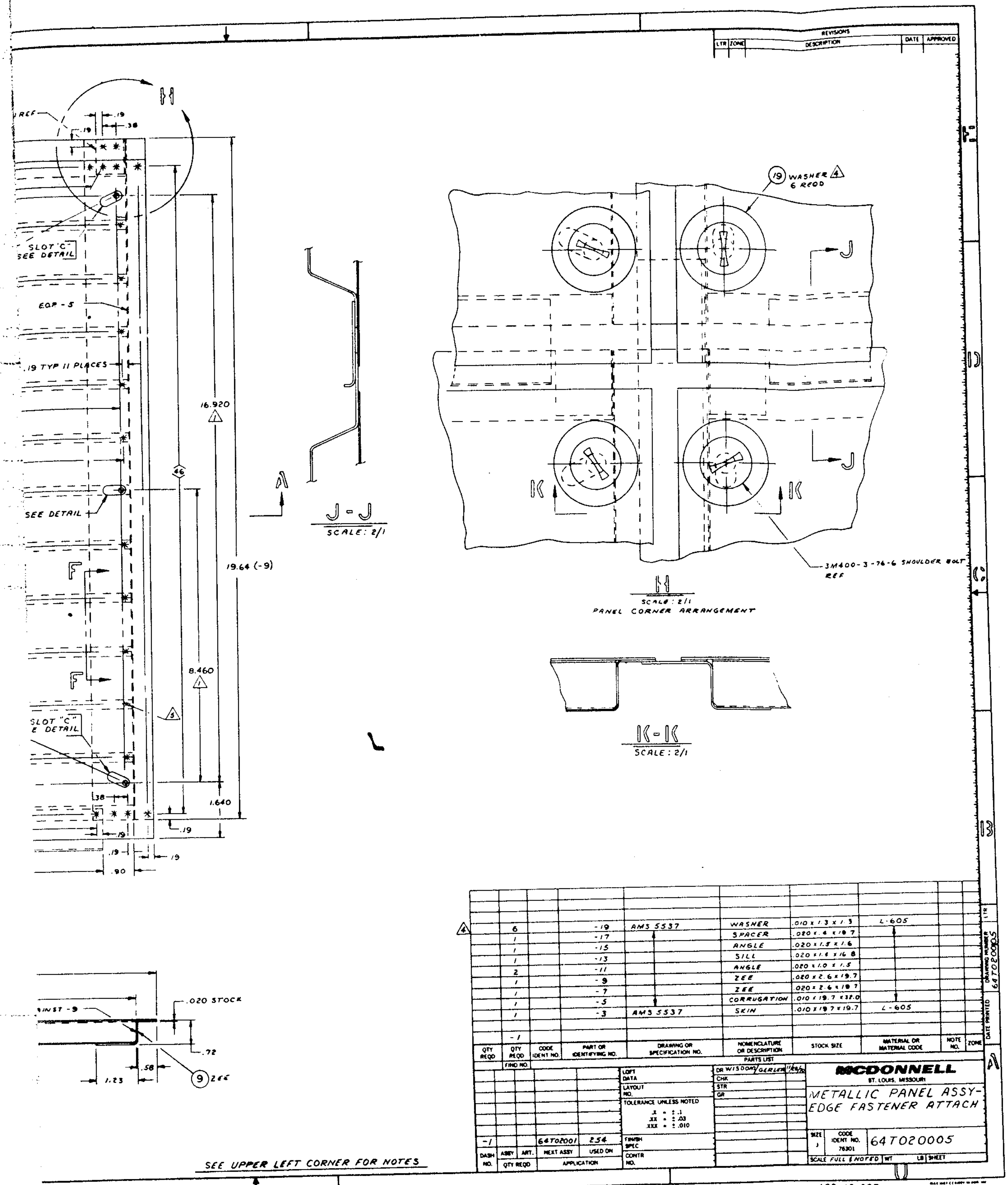
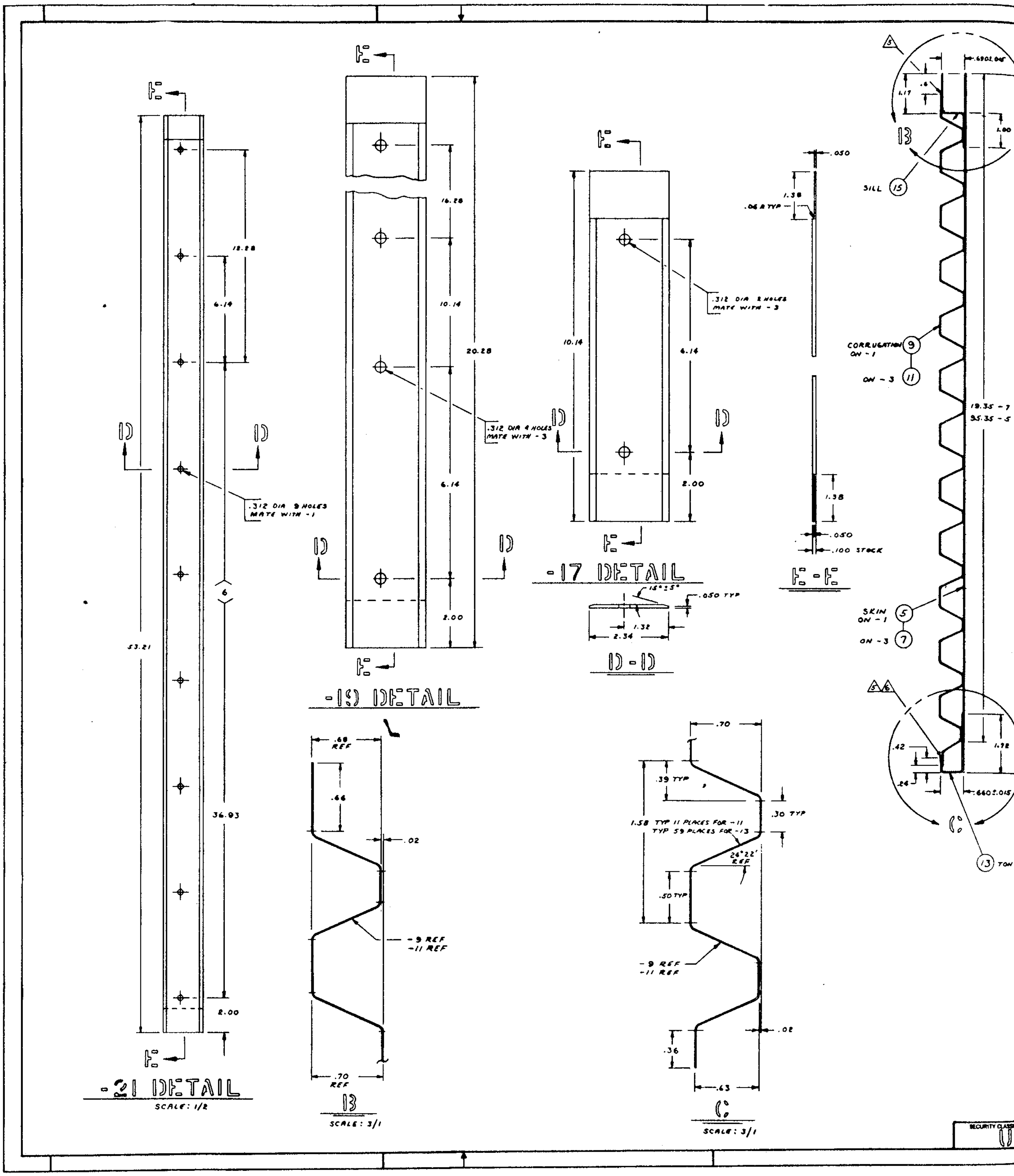
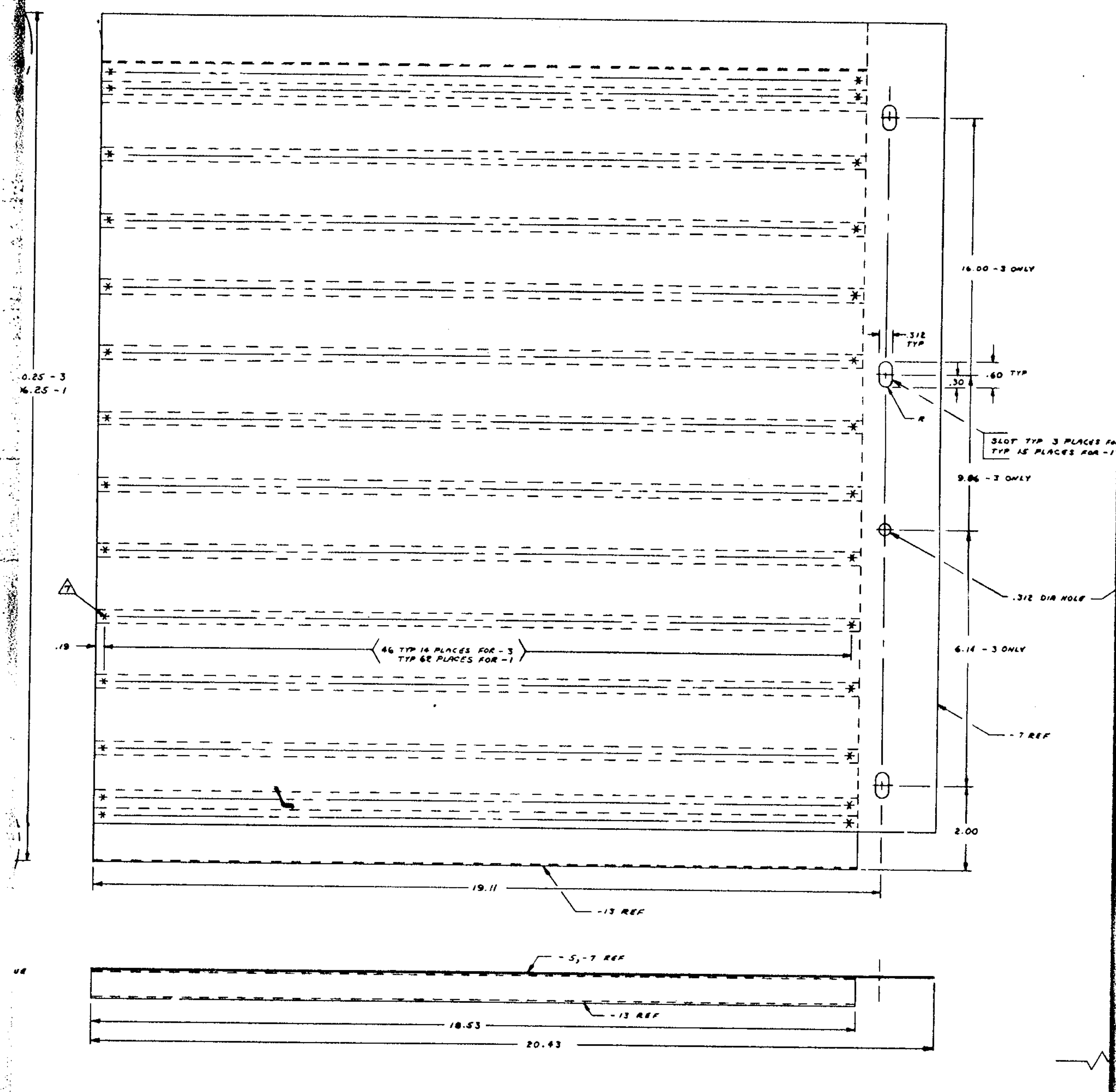


FIGURE 44 METALLIC PANEL ASSEMBLY - EDGE FASTENER


-21 DETAIL
SCALE: 1/2
-19 DETAIL
-17 DETAIL
E-E
D-D
B
SCALE: 3/1
C
SCALE: 3/1
.312 DIA 9 HOLES MATE WITH -1
.312 DIA 4 HOLES MATE WITH -3
.312 DIA 2 HOLES MATE WITH -3
SILL 15
CORRUGATION 9 ON -1
ON -3 11
SKIN 5 ON -1
ON -3 7
13 TONG
19.35 -7
35.35 -5
1.58 TYP 11 PLACES FOR -11
TYP 59 PLACES FOR -13
-9 REF
-11 REF
.100 STOCK
SECURITY CLASSIF
U



NOTES:

1. MARKING PER P.S. 16001.
2. ALL BEND RADII AND TOLERANCES PER 6M39.
3. —⟨ ⟩— DENOTES NUMBER OF EQUAL SPACES.
4. ATTACH PATTERN TO BE IDENTICAL BETWEEN PANEL ASSY'S & ATTACH
5. TACK WELD -13 & -15 TO -9 & -11 CORRUGATIONS, ON 1.0 INCH CENTERS PE
6. GRIND WELDS FLUSH WITH OUTSIDE SURFACE OF -13.
7. SPOT WELD CLASS B PER P.S. 22000.
8. BUTT WELDING OF STOCK IS PERMISSIBLE TO ALLOW USING STANDARD
9. APPLY ALUMINIDE COATING TO THE EXTERNAL SURFACES OF -3, -17 & -19 PE

CATION	DRAWING NUMBER	SH
	64T020006	

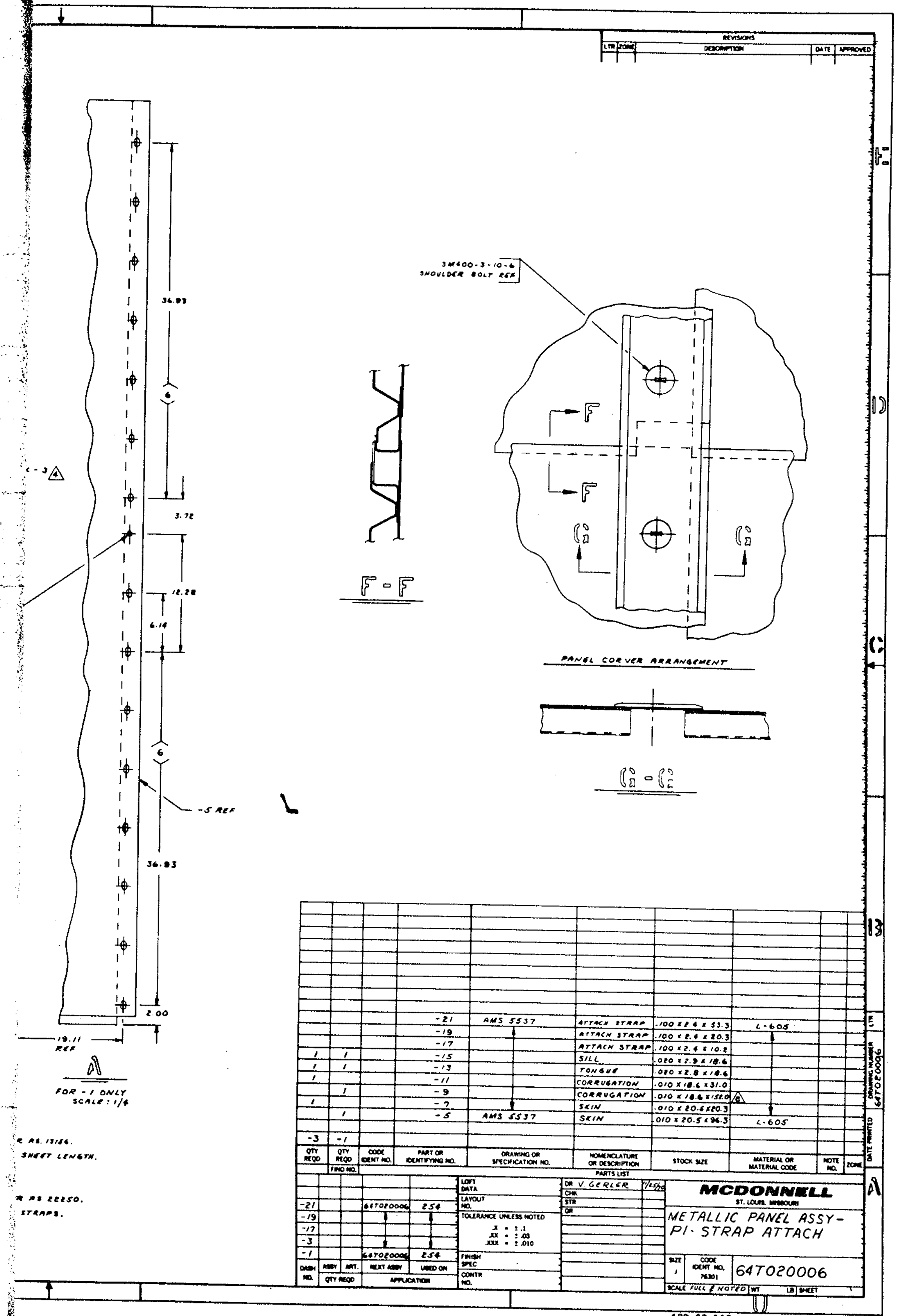
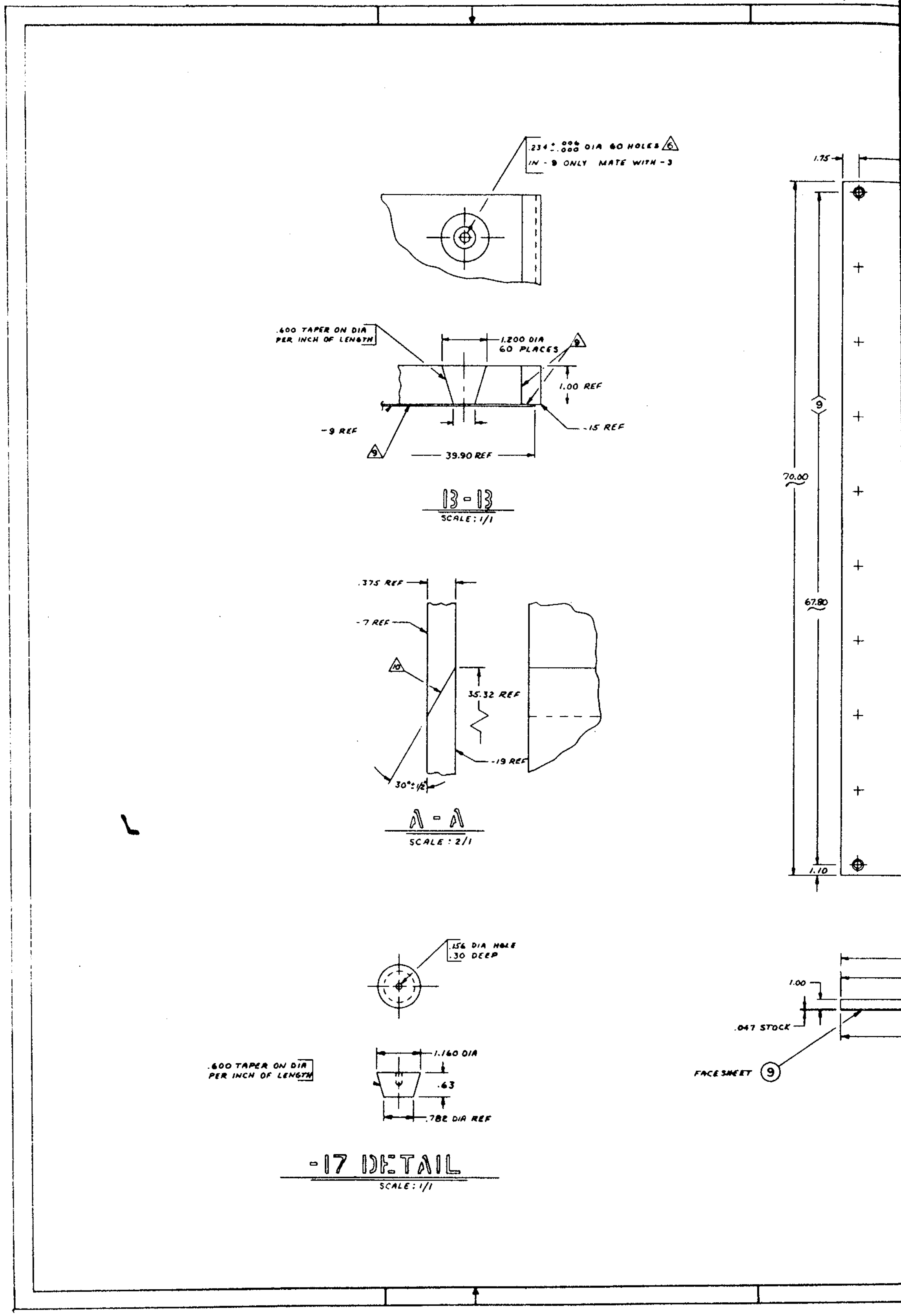
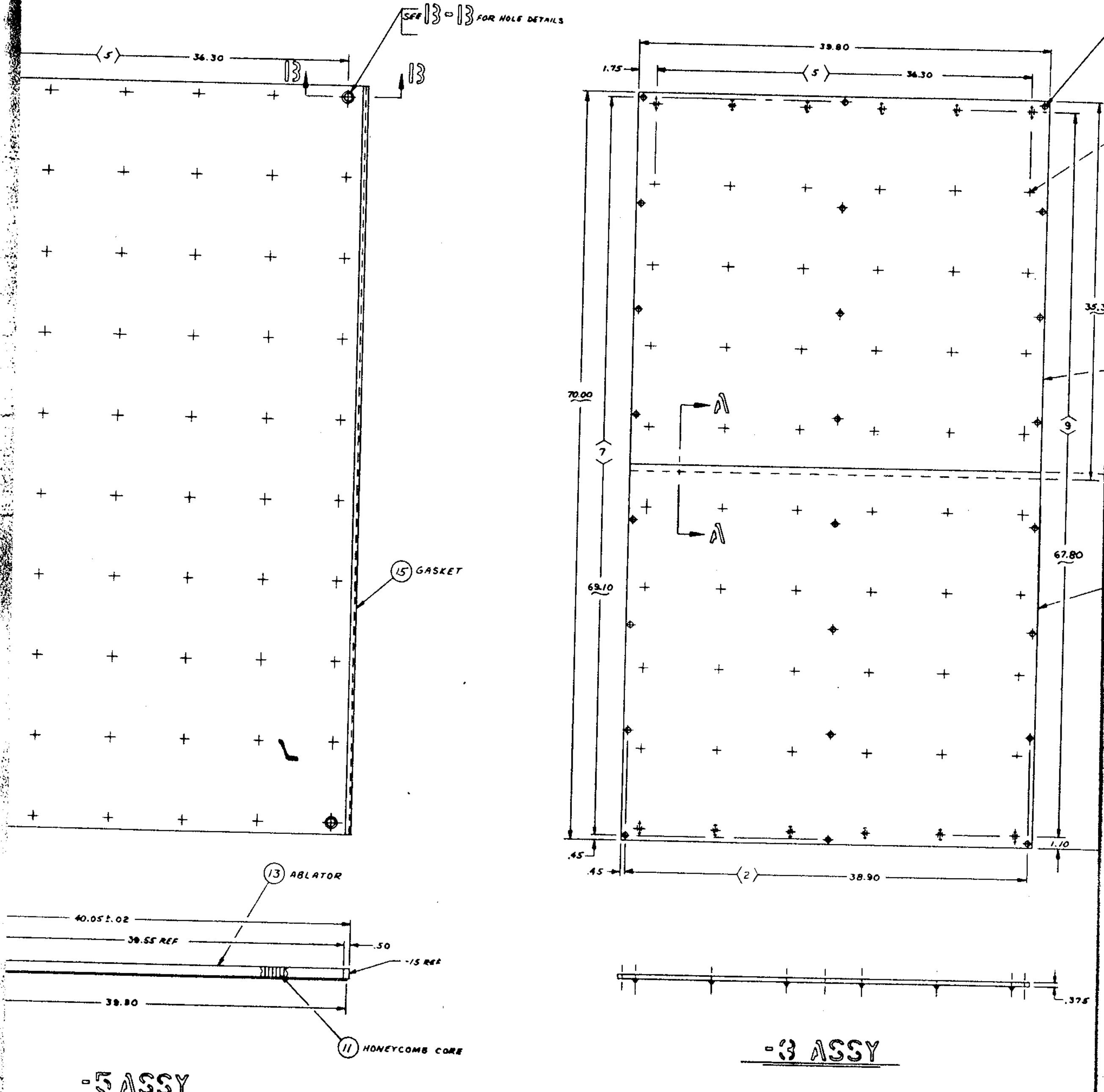


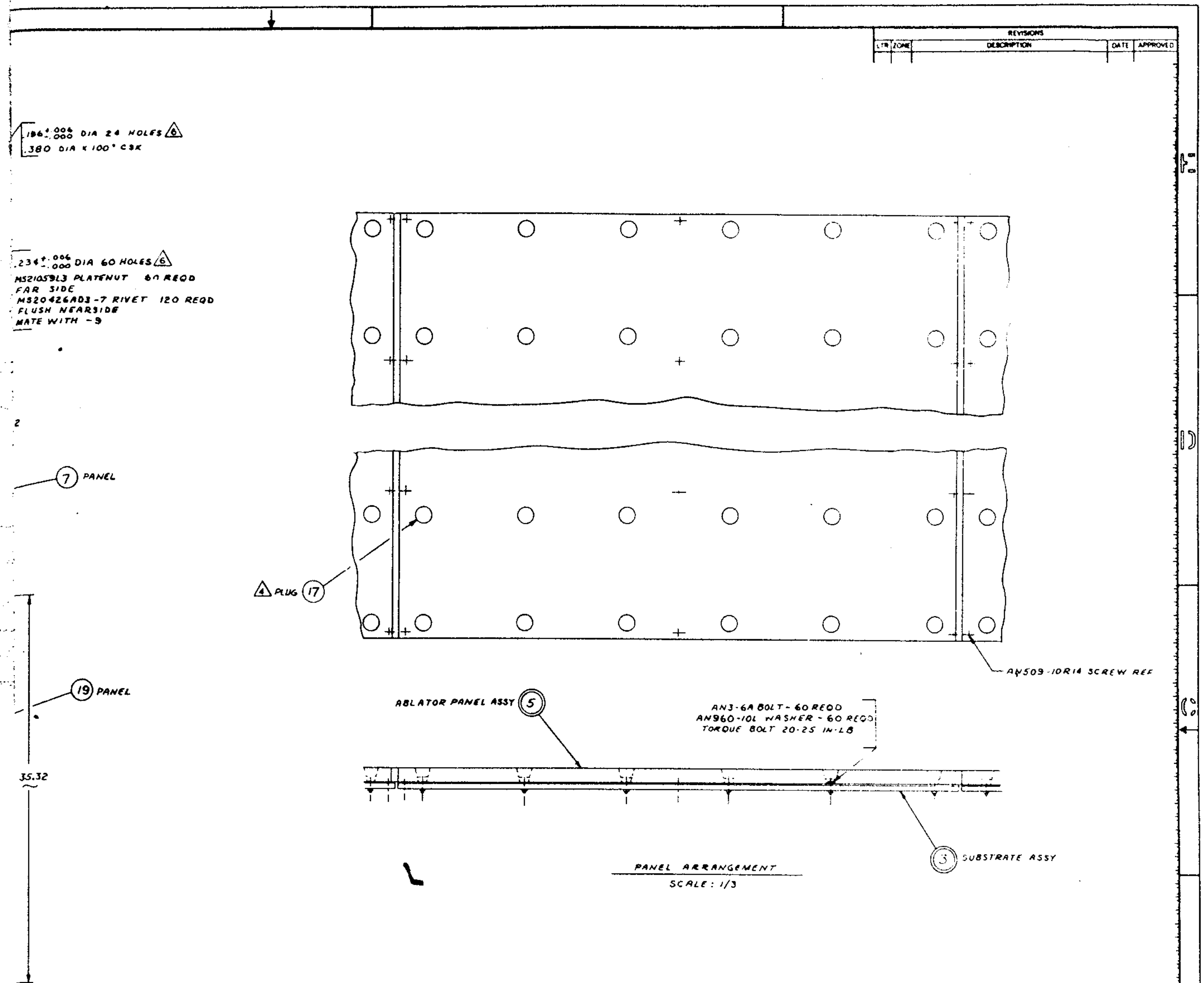
FIGURE 45 METALLIC PANEL ASSEMBLY - PI-STRAP



.234 +.006 -.000 DIA 60 HOLES 6
IN -9 ONLY MATE WITH -3
1.75
.600 TAPER ON DIA PER INCH OF LENGTH
1.200 DIA 60 PLACES
9
1.00 REF
-9 REF
-15 REF
9
39.90 REF
13 - 13
SCALE: 1/1
.375 REF
-7 REF
10
35.32 REF
-19 REF
30° ± 1/2°
A - A
SCALE: 2/1
70.00
67.80
9
1.10
.156 DIA HOLE .30 DEEP
.600 TAPER ON DIA PER INCH OF LENGTH
1.160 DIA
.63
.782 DIA REF
-17 DETAIL
SCALE: 1/1
1.00
.047 STOCK
FACESHEET 9



SECURITY CLASSIFICATION	DRAWING NUMBER	SH
U	64T020007	



STOCK

NOTES:

1. MARKING PER P.S. 16001.
2. —⟨ ⟩— DENOTES NUMBER OF EQUAL SPACES.
3. BREAK ALL SHARP EDGES PER P.S. 23041.

4. INSTALLATION PART.
5. ULD-100-4 SERIES, ULTRA LOW DENSITY ABLATOR, PER PROCESS BULLETIN 3-248.
6. ATTACH PATTERN TO BE IDENTICAL BETWEEN LIKE PARTS.
7. HRP-3/16-GF11-4.0 LB/FT³ HONEYCOMB CORE PER MMS-703, TYPE III (HEXCEL CORPORATION, GRAND PRAIRE, TEXAS).
8. -17 PLUG SAME AS 64T020003-23.
9. BOND CORE AND GASKET TO FAYING SURFACES WITH HT-424 ADHESIVE PER P.S. 11321.
10. BOND WITH HT-424 ADHESIVE PER P.S 11308.
11. MATERIAL: GE-TBS-757, GENERAL ELECTRIC, SILICONE PRODUCT DEPT, WATERFORD NEW YORK (OPTIONAL - DC 93044, DOW CORNING, MIDLAND, MICHIGAN).

PARTS LIST

QTY REQD	QTY REQD	QTY REQD	PART OR IDENTIFYING NO.	DRAWING OR SPECIFICATION NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL OR MATERIAL CODE	NOTE NO.	ZONE
	60		MS21059L3		PLATENUT				
		60	AN960-10L		WASHER				
		60	AN3-6A		BOLT				
	1		-19	MIL-P-997 TYPE GSG	PANEL	3/8 x 35.4 x 39.8	FIBER GLASS		
		60	-17		PLUG		8		
1			-15		GASKET	MOLDING 11			
AR			-13		ABLATOR		5		
1			-11		HONEYCOMB CORE	1.0 x 39.6 x 70.0	7		
1			-9	MIL-P-997 TYPE GSG	FACESHEET	3/64 x 39.8 x 70.0	FIBER GLASS		
	1		-7	MIL-P-997 TYPE GSG	PANEL	3/8 x 35.4 x 39.8	FIBER GLASS		
		1	-5		ABLATOR PANEL ASSY				
		1	-3		SUBSTRATE ASSY				
-5	-3								
		-1							

FIND NO.

DASH NO.	QTY REQD ASSY	QTY REQD ART.	NEXT ASSY	USED ON
-1			64T020001	254

APPLICATION

LOFT DATA
LAYOUT NO.
TOLERANCE UNLESS NOTED
.X = ±.1
.XX = ±.03
.XXX = ±.010
FINISH SPEC
CONTR NO.

DR LESNIAK/GERLER 11/4/70
CHK
STR
GR

MCDONNELL
ST. LOUIS, MISSOURI

ABLATOR PANEL ASSY -

SIZE J CODE IDENT NO. 76301 64T020007
SCALE 1/4 & NOTED WT LB SHEET

489-07-007

FIGURE 46 ABLATOR PANEL ASSEMBLY

Fabrication Requirements

TPS component parts to be used on the mockup will be fabricated at the MDAC-East facility. This affords best control of cost, delivery, quality control, and coordination with engineering. Fabrication techniques for this program are within the state-of-the-art and no serious program requirement problems are anticipated. Fabrication and assembly activities will be closely monitored and controlled through cost-effective administrative control systems.

The current plan is to use our advanced materials fabrication area and production shops. To make best use of certain equipment and labor skills, ablative and HCF panels will be fabricated in the advanced materials fabrication area. The rest of the work will be done in the production shops. Fabrication will be done using standard shop equipment. No special tooling is required except a low cost template to align attachment holes.

Detailed instruction sheets for each part will be prepared by production planning personnel. These documents will prescribe fabrication processes for making the parts. This planning document is also used as a release sheet and work authorization and is released to the fabrication shops according to schedule requirements. These work instruction/authorization orders are delivered to the shop with the raw material and blueprints. Skilled shop personnel, using this information, lay out the particular part configuration on the raw material. Subsequently, the material is machined, trimmed, drilled, formed, painted, etc, as required to make a part which conforms to the drawing.

TPS panels fabricated for mockup use need not be of flight quality, which minimizes quality controls. Standard quality procedures pertaining to raw material requirements, panel and attachment dimensions, and attachment hole location will be adhered to only to the extent necessary to ensure product conformance. Control of these parameters, within the tolerances specified, is required to achieve the replaceability design goal.

Inspection procedures (i.e., receiving, product, radiographic, and shipping) will be performed to the degree necessary to substantiate product conformance to the level of detail shown on the engineering drawings. In the case of ablative and HCF heat shield panels, no specific void rejection criteria will be adhered to. However, radiographic ablative and HCF panel inspection will be performed to determine location and number of voids for reference only.

Nonconformances will be documented for disposition by the designer. Nonconformances which would adversely affect test hardware refurbishment operation will be corrected before shipment. Completed panel quality and configuration records will be maintained which will include completed planning and nonconformance data.

Test Measurement Requirements

Keys to a successful test program, such as the one proposed herein, are the manner in which data is obtained, the accuracy of the data, and methods by which the data are presented. This is especially true in the case of the maintenance tasks associated with the refurbishment aspects of space shuttle TPS, since many events occur simultaneously.

Maintenance task evolution and conditions under which they are performed are multifaceted and must be examined in real time. Various factors or items must be considered in this evaluation such as the TPS component parts, tools, equipment, procedures, and personnel performing the particular refurbishment operation. Normal visual observation and a handwritten history of events is not adequate since much of what occurred is lost in translation from one observer to another.

In specifying test measurement requirements for this program, it became apparent that a permanent record of events must be obtained so that the test could be rerun without additional cost, and interpretation accuracy would be maximum. These factors narrowed the field measurement techniques to those involving a movie camera or videotape recording.

Candidate techniques. - The movie camera permanently records various maintenance tasks and allows detail analysis at a later time. However, this technique has a few drawbacks. Recording time is limited to relatively few minutes, depending on magazine size. This means that refurbishment activities would have to be stopped for reloading or that some event which cannot be stopped would not be recorded during reloading. Secondly, movie cameras provide slow feedback from focus, exposure, and framing errors. Incorrect settings or limited view are not known until after the film is processed, resulting in loss of data. In many cases more work is required to obtain a good sound track.

An alternate approach is video tape recording (VTR) which overcomes many of the problems associated with the movie camera. This technique is proposed for use in this study. In the following paragraphs some of the salient VTR features are discussed.

VTR equipment proposed for this study has been used successfully in the McDonnell Douglas Human Performance Laboratory to evaluate ejection seat development, space reconnaissance, and human engineering aspects of F-4 aircraft subsystems. The technique was also examined under contract to the Air Force Human Resources Laboratory, Wright Patterson Air Force Base, Ohio, MDC Report E0044, October 1969.

Some advantages of using the VTR technique are:

- Full hour of uninterrupted recording
- Quick playback of recording making it possible to immediately assess results and rerecord substandard data
- No film processing
- Relatively easy to operate and to assess
- Reclaimable tape can be used many times
- Recorded data can be viewed as actual tasks are performed.

In general, the VTR system provides identification and quantification of many aspects of human performance without requiring information from the subject. Recorded data provide the time to perform a task, the number of times a particular subtask is performed, a record of task difficulty based on unsuccessful attempts and errors, degree of dependence on procedures, degree of dependence on supervision, and frequency and types of problems.

VTR equipment. - The VTR system is composed of three basic units: a television camera, a magnetic recorder capable of recording/reproducing picture and sound, and a monitor that displays the image. This system (figure 47) is similar to those used by commercial television networks for recording programs for later playback.

The camera has a wide variety of fixed focal length lenses. Previous work with the system indicates that zoom (variable focal length) lenses have certain basic advantages. A zoom lens allows the operator to vary framing and image size without changing camera position. Frequently, the long focal length position (telephoto) allows the operator to see detail on the monitor that he cannot see with the naked eye. By using a short focal length (wide angle) to start the scene, the evaluator can be oriented to the location of a particular unit with respect to the mockup or primary pieces of equipment.

During task recording, an occasional return to wide angle aids in reorienting the evaluator. Zoom lens focus is accomplished by zooming in on the area to be recorded and adjusting the focus ring until the image is sharp on the monitor screen. On subsequent zooming out (reducing focal length) the lens maintains focus at all focal lengths.

Cameras can be equipped with a turret containing several fixed focal length lenses. However, lens selection and adjustment under a continuing scene results in interruptions and momentary poor picture quality while focusing and framing.

To obtain sufficient data, some complex tasks should be recorded simultaneously from different camera angles. For example, a task may involve a crew of four people who at times are separated. A wide angle shot shows positions but is useless for details. A camera working on details does not show the positioning

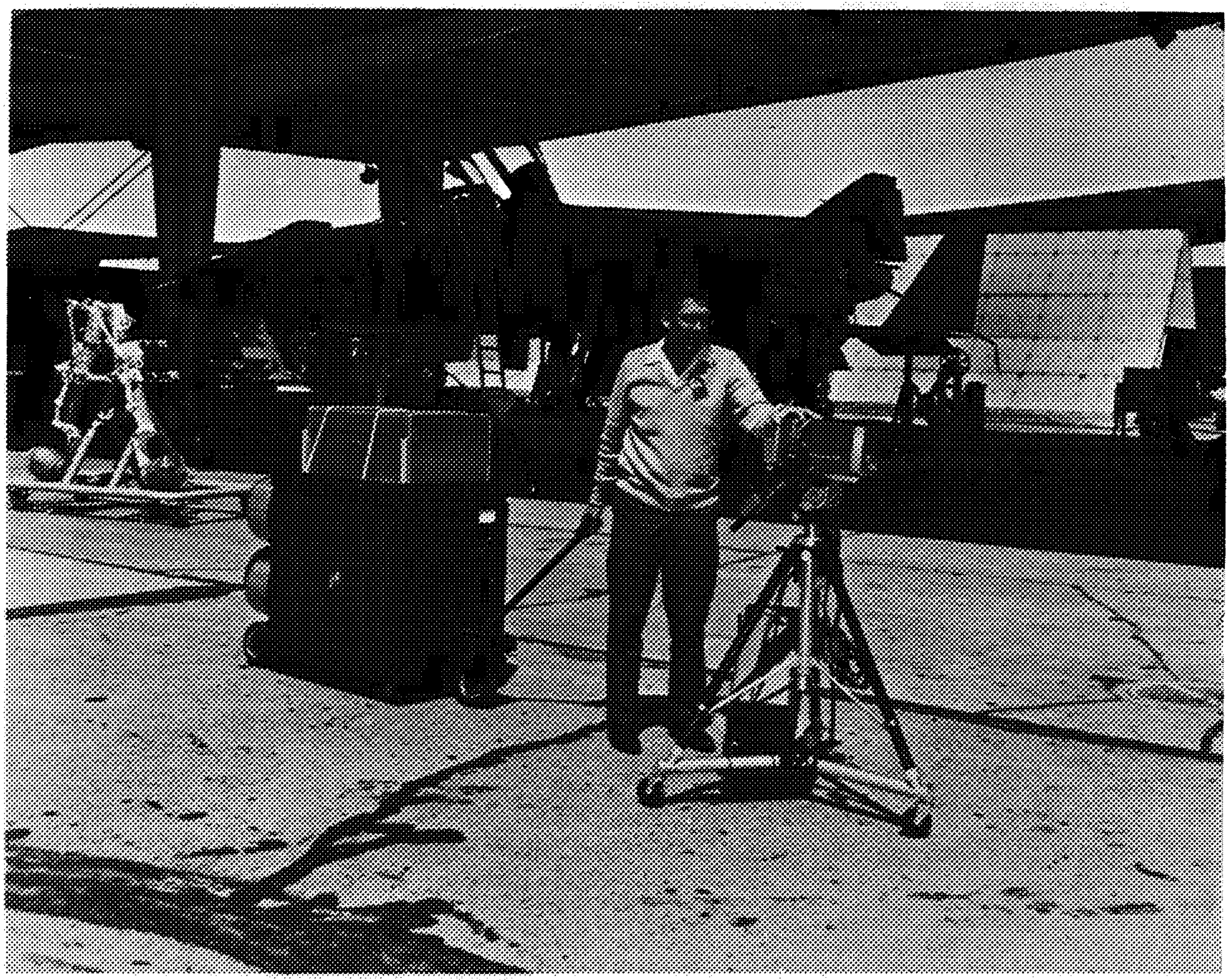


FIGURE 47 VTR EQUIPMENT

of the team. To minimize this problem, an additional handheld camera will be keyed by audio recording to the primary camera.

The monitor serves two functions. First, it gives the operator video feedback for framing, focus, and exposure. The monitor is essential to the camera/operator station. The controls on the monitor allow for electronic adjustment of focus, contrast, brightness, horizontal, and vertical. In the VTR system the video signal can be displayed directly from the camera, as with TV, or routed through the video tape recorder, to confirm most of the recorder electronics.

Secondly, it provides a playback display. Playback may be used immediately after recording to verify content and quality. Also, the playback may be used for detailed analysis, usually in a more quiet environment. Displays in addition to the video picture on the monitor consist of an audio level meter, video level meter, and counter.

The need for adequate illumination was demonstrated in early recording attempts. Although recordings can be made in relatively low light (6 to 12 foot candles) the images produced on the monitor are flat with a decided lack of contrast and overall clarity. Also, when the camera beam and target controls are set to compensate for low light levels, brighter image portions persist. When the camera is zoomed or panned, the bright areas smear or appear as multiple images. Under these high gain conditions electrical interference is more prevalent. A combination of portable commercial lights and fixtures is adequate for video requirements.

The tape used in the recorder is similar to that used in magnetic audio recorders and is supplied on 9-3/4 inch reels holding 3000 feet. Sensitivity to x-rays, magnetism, dirt, and heat requires reasonable care in use and storage. The recorder is relatively easy to operate. An hour or two of instruction is adequate for simple recording and playback operations. This type of measurement equipment can:

Measure human performance

Provide data useful to program effort

Produce minimum interference with test activities

Be used without extensive training

Be adaptable to a fast reaction situation

Provide results that have operational significance.

Assessment of human performance is as essential as equipment performance assessment. It is usually impractical to attach measuring instruments directly to the maintenance personnel. However, the VTR provides first-hand data in terms of time, distance, and task difficulty. Data collected is important to other organizations and the valid interpretation of tasks may call for multidisciplinary interpretation. The form of data is important too, for it may facilitate problem understanding and reporting. Beside slowing maintenance effort, interference can cause invalid information. Techniques should not require special maintenance task scheduling which interrupt normal work. Extensive instrumentation of man or equipment cannot be made because of safety, job efficiency, and interference factors. The technique should not call for a very high skill level, or a large amount of prior knowledge. A test is geared to a schedule. Therefore, equipment that requires extensive hook-up time, calibration, and preparation is not desirable. If the technique can identify relationship of the task to turnaround time and operational ready status, it will have served its function.

Test Evaluation Requirements

Historically, human performance evaluation methods have been restricted to one-shot visual observations, direct interviews with participating personnel, checklists, and questionnaires. Such methods are not adequate for evaluating tasks as complex as space shuttle TPS maintenance. The problem here is to provide a technique to accurately measure human performance to the level of detail required to make design/procedural changes later. This implies that evaluation techniques compatible with a VTR system had to be devised, since use of the VTR system is the proposed measurement technique for this study. Typical means of measuring task performance were evaluated, such as the use of stop watches and note taking. These techniques are not adequate for this study since many events occur simultaneously in normal maintenance of a typical TPS.

The technique proposed is use of a miniature event recording system. The adequacy of this system has been demonstrated by MDAC-East under contract to the Air Force Human Resources Laboratory, Wright Patterson Air Force Base, Ohio. The results of this study are reported in AFHRL-TR-69-16. During this study, extensive field evaluation of the technique was accomplished because this was the only way to demonstrate the value of the technique for carrying out its intended purpose, and to probe the limits of its usefulness. Results indicate a real potential of the system as a technique for measuring human performance in a maintenance environment, particularly when used with a VTR system. In this capacity it provides a very good method of extracting relevant data from the video tape. Field experience suggests that the event recorder provides more effective use of manpower and a more methodical and complete evaluation of test elements than do conventional evaluation tools (i.e., stop watch and note taking).

The miniature event recording system is composed of:

event recorder

battery pack

event control box.

The recorder (figure 48) operates without external power and has eight styli that mark on pressure sensitive chart paper. Combining the video tape recorder with the event recorder efficiently and accurately assesses tasks. Event recording charts are simple to analyze with the aid of a chart viewer shown in figure 49. The particular event recorder chosen for this study is a Rustrak, Model 292-8. It records eight channels, weighs little (~ 3 pounds), is small (~ 3 by 5 by 5 inches) and can be operated from a portable battery pack. The event control box consisting of eight pushbutton and toggle switches is wired into the event recorder.

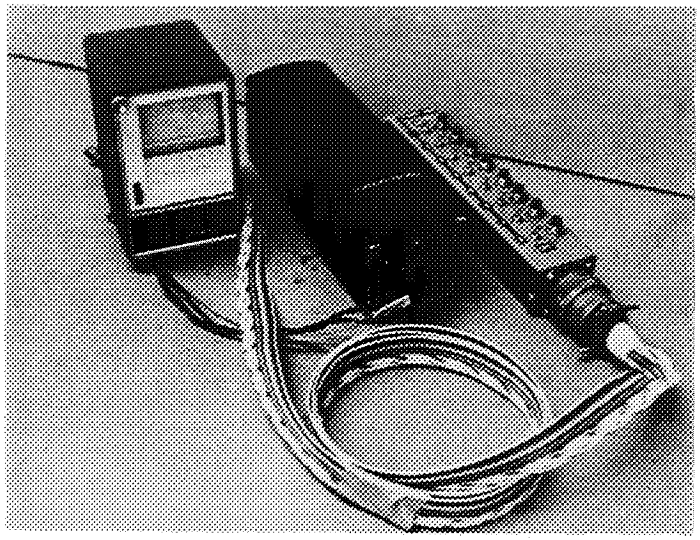


FIGURE 48 EVENT RECORDER

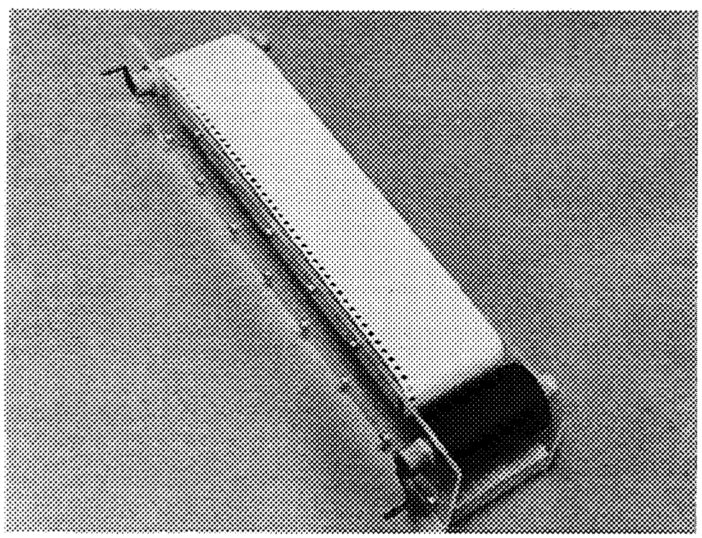


FIGURE 49 CHART VIEWER

When using the event recorder, tasks to be evaluated are divided into several functions. Each function is assigned to one of the eight channels. Some typical task functions might include reading refurbishment procedures, using hand tools, maneuvering support equipment, aligning panels, giving instructions, etc. The event control box is labeled to correspond to functions assigned to the recorder. Actuating the various channels using either the pushbotton or toggle switch on the control box for as long as a particular function is being performed provides a permanent record on the event recorder. Task continuity is preserved by stopping or starting the event recorder only when necessary while viewing the video tape.

When a recording is finished, the chart can be rerolled on the chart viewer and reinserted into the event recorder. The events then can be annotated by lowering the access window and writing notes on the chart since the video tape recording of the maintenance task and the event recorder are on the same time base.

For example, if the special event channel were activated during the initial playback, only a displacement in the line describes what occurred at this point on the chart. One may want to note that this is where an error occurred, or that the appropriate tool was not defined in the procedures, or that the interpretation called for a great deal of skill. The annotation can be the event that is being tested, such as removing fasteners or applying gaskets. If one notes a particularly long period when the technician is gaining access to a piece of equipment, it is important to know what created the delay.

Chart data are summarized in part by mounting the event chart in the viewer and winding it back to the start. Channel 1 is then examined. At each point where the displacement indicates that channel 1 was activated, its duration is measured using the appropriate scale based on gear train and motor speed. The time is noted at the end of the event with a rank order notation. The rank order notation gives a frequency of events on channel 1 at the end of the chart and is repeated for each channel used. Total time per channel is determined easily by adding all events for each channel. Thus, one can derive total time frequency for each channel. With some tasks, it is important to analyze the relationship between or among functions.

Some of the advantages of this system over using a stop watch and taking notes are:

Several tasks functions can be recorded at once.

Observer can direct his full attention to the task.

Recorder has less error potential than a stop watch.

Recordings can be used for time-line, task-loading, and time sharing analyses.

Video tape evaluation in this manner can provide the kind and amount of information to assess the adequacy of TPS concepts and associated maintenance tasks. From a maintenance viewpoint the following problems are typical of those that can be evaluated in depth:

Human error, and design leading to human error

Problems of this type can be fully documented. By backtracking from the error and replaying the tape, conditions that created the error can be identified. These might have been in equipment design, the procedure, tools, or an outgrowth of training or written or spoken orders.

Excessive time

The expenditure of excessive time to accomplish what should be a simple task is often a product of design and procedure problems. This type of problem should be evaluated in terms of expected frequency of the task. Quality engineering offers a medium for obtaining effective changes.

Improper diagnosis of malfunction

Previously, this area has not been effectively evaluated. Determining what caused incorrect identification of a malfunctioning item often requires detailed investigation. Causative factors may be training, procedure, skill, and design. Early solution of this type of problem leads to greater design efficiency.

Ineffective team work

Analyses of task loading and time sharing, communication, and work space could result in an evaluation of group behavior.

Procedure deficiencies

Problems associated with some tasks are the result of inadequate personnel training.

Adequacy of tools

Issued tools are sometimes inadequate. Their design and material may result in injury to personnel, damage to equipment, and improperly adjusted equipment. As men become more acquainted with equipment, they improvise special tools that frequently improve maintenance. Documentation and dissemination of more effective tools should be expedited.

Information derived from this evaluation will be compared to previously estimated manpower and elapsed time requirements for particular maintenance tasks. Based on this comparison, deviations will be noted and assessed. A complete history of events will be documented to NASA-LRC in the form of revised task analyses for those configurations tested on the mockup. In addition, MDAC-East will supply to NASA-LRC all video and event recording tapes for subsequent analyses and disposition. From this evaluation, future cost projections relative to the maintenance operation of various types of TPS configurations can be made more accurately.

Environmental Simulation

A significant factor affecting TPS reuse/refurbishment is its physical change after exposure to ground and flight environments. Such a change may be no more than scorching of the vehicle's surface, requiring minor repair, to complete replacement of a damaged or deformed component part, due to excessive loads. Magnitudes, rates, and periods of exposure of these environments on the TPS could significantly influence the maintenance operation. Thus, a certain amount of environmental testing is required on the mockup in order to create a realistic set of circumstances.

Those environments which, in general, have the most adverse effect on materials are temperature, pressure, and acoustics. The nature of the mockup does not lend itself to adequate or realistic simulation of the pressure and acoustic environments. Therefore, simulation of these environments is not being proposed at this time. As a minimum, however, MDAC-East is proposing simulation of the temperature environment. Insofar as a physical change is concerned, temperature is the predominant contributor. Therefore, a certain amount of temperature simulation should be performed. The intent is to create a maintenance environment which would be representative, at least in part, of that experienced under operational conditions.

A few examples of the type of physical change which might or would occur under a temperature environment are cited to substantiate the need for simulation. One example is the char layer formed on an ablative type heat shield after exposure to entry temperatures. The char formed on elastomers is soft and powdery; over this, a thin layer of silica forms. The depth in the ablator to which the char has penetrated plays a major role in the system refurbishment. Char condition and depth may significantly influence material removal to gain access to substrate mounting bolts.

Another example is the reuseable or removal aspects of coated metallic fasteners after repeated temperature cycling. Experience has shown that in certain cases protective coatings applied to the metallics tend to flow under elevated temperatures making bolt and screw removal more difficult. Likewise, the reuseable life aspects of coated metals after repeated cycling may dictate special handling procedures which could alter normal maintenance operations.

These are but a few of the many problems created by a temperature environment. The significance of these problems as they affect refurbishment can only be assessed under laboratory simulation testing.

It is proposed that a temperature simulation device be constructed similar in concept to that shown in figure 50. This design features a gas flame heater or torch mounted to a variable position tract which can be programmed as desired to create a specified thermal environment anywhere on the test specimen. The exposure area at any given time is 20 by 20 inches. The heater track is mounted on a dolly which provides easy access to other areas of the test specimen. This strip type heater is more than adequate to accomplish the objectives for which it is intended.

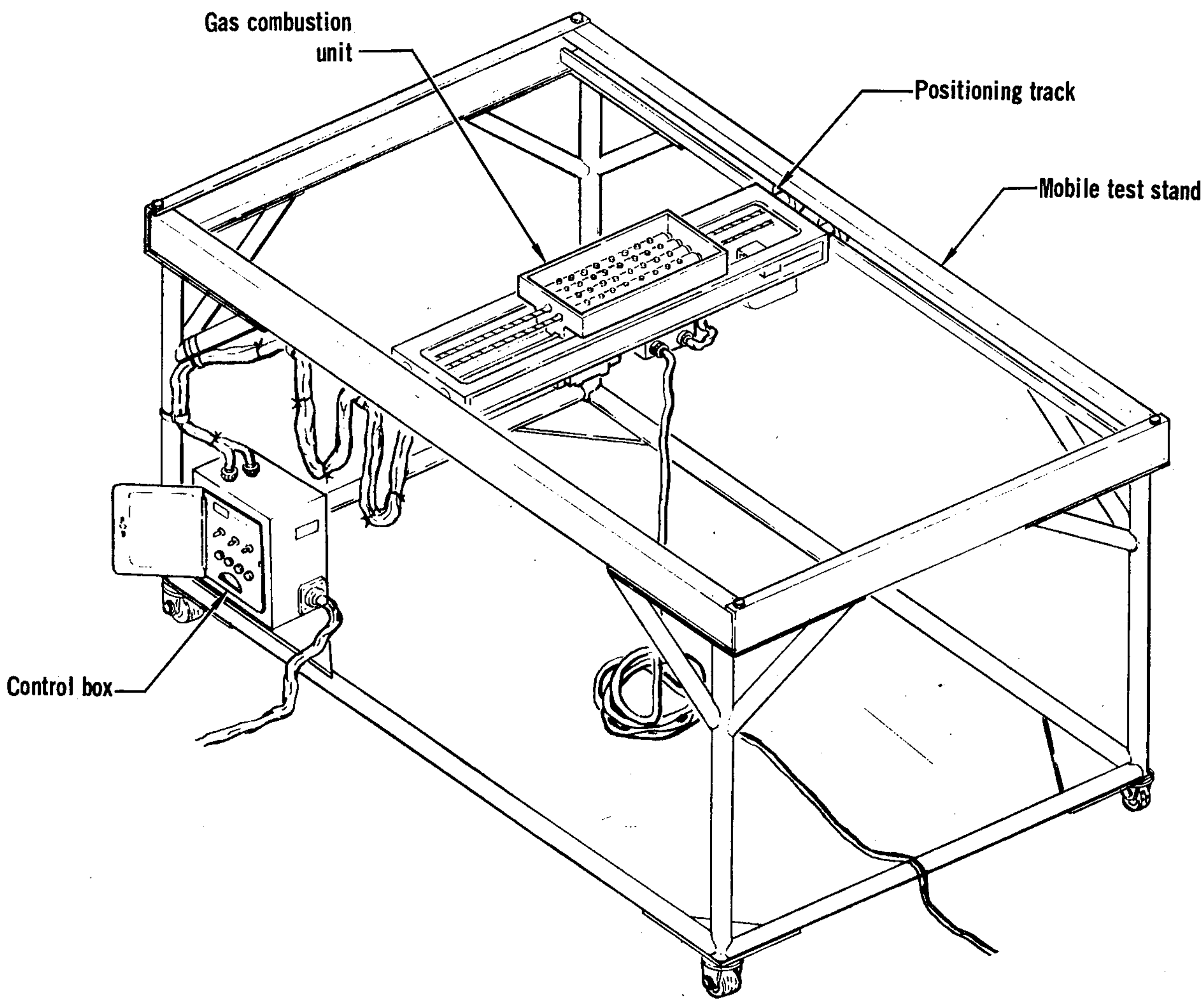


FIGURE 50 ENVIRONMENTAL TEMPERATURE SIMULATOR

The heater unit provides surface temperatures up to 2400°F with an oxidizing environment. The use of excess oxygen in the combustion process will promote full consumption and provide the desired oxidation potential for metallic TPS degradation, ablation processes, and/or fastener degradation. Fuel gas selection will be made on a basis of burning characteristics, availability, and cost.

The combustor is used at preestablished operating flows with heating regulated by controlling the heater spatial position relative to the surface of the test specimen. The heater position is variable in three orthogonal axes.

The axis normal to the heated surface provides heat intensity variations while the axes parallel to the heated surface provide coverage of the entire test area. This is done by slowly sweeping the test area so that the time integral of heating a given location delivers the desired total heat input and maximum desired heat flux conditions. Test input temperature control can be accomplished either by specimen installed thermocouples or calorimeters (located to provide a sweep synchronized response), offset calorimeter mounted on the heater, or by heater operating parameter-position calibration on a calorimetric model.

An alternate to the combustion heater is a quartz lamp heater. If lamps are used, power can be program controlled for heat intensity variations. This requires power regulation equipment in addition to the heater positioning system. For materials which do not discharge particles (i.e., metals) the lamps provide reliable thermal inputs. However, in the case of ablators, which have a gaseous and particle discharge, lamp system reliability is diminished as a result of system contamination. For this reason a combustion type heater is the most reliable and least cost system for long term use.

Personnel Training Requirements

The overall success and effectiveness of the proposed test program lies in the hands of the personnel who will carry it out. Not only will personnel highly qualified within their own areas of competence be assigned to the program, but the program plan ensures that these people will be thoroughly trained in maintenance type operations. Before actual experiments are conducted a training program will be performed in various disciplines enabling personnel to become familiar and proficient in:

- test panel hardware
- mockup installation
- maintenance task procedures
- environmental test equipment operation
- measurement recording techniques
- data evaluation methods
- test conduct.

Initially, all program personnel will examine detail drawings of selected TPS concepts until they become thoroughly familiar with the component parts and assembly thereof. Later during the fabrication cycle, handling and assembly characteristics of these parts will be established for deployment on the mockup. This will be done by letting maintenance personnel assemble parts on a bench operation at the contractors facility.

Before panel installation these personnel will also familiarize themselves with actual mockup installation. At this time, estimated tools and equipment for panel installation will be assessed for adequacy, particularly regarding type and quantity. In addition, the impact of the working area as it effects personnel performance will be assessed by performing a trial installation of panels on the mockup.

During training, personnel will be thoroughly indoctrinated in various maintenance tasks (i.e., replacement, inspection, and repair). Planned test procedures will be reviewed and coordinated with participating test personnel. Special maintenance techniques will be fully documented and studied. The intent is to sufficiently train personnel in realistic environment before actual maintenance operation.

Personnel required to operate the environmental simulation device, video tape recorder, and event recorder will be trained in initial setup, calibration, operation procedure, and individual test requirements. A complete checkout of the equipment will be made at MDAC-East before shipment to NASA-LRC. During this time period, personnel who will eventually operate the equipment at the NASA-LRC facility will have the opportunity to become thoroughly proficient in its operation.

Finally, a dry run of the test conduct will be made to familiarize test personnel with all hardware and procedureal items as a unit. At this time any discrepancies will be determined and changes made as required.

Personnel Requirements

An integral part of the planning activity associated with this task was estimating the type and quantity of manpower to execute the proposed test plan. The goal of this activity was to minimize overall program costs. This implies that personnel skilled in one particular discipline might be called upon to participate in other pertinent assembly and test functions. This approach is considered to be entirely feasible in meeting overall program objectives.

Various disciplines in test plan implementation include management, engineering, product support, manufacturing, and testing. At least one person from each area of competence will be assigned to the program. Depending upon the particular activity being performed, the cognizant team member will be assisted by other study personnel. Specific personnel requirements for phase II are as follows.

Management. - A full time study manger interprets program requirements, determines task assignments and funding, establishes and integrates schedules, monitors and directs test program activities and keeps MDAC-East management and NASA-LRC authorities informed of the program progress.

Engineering. - A full time design engineer and a part time materials process engineer are assigned to the program. During component part fabrication, these personnel ensure product conformance to detail drawings. In particular, the design engineer institutes drawing changes in response to manufacturing or customer requests. The materials engineer, for the most part, assists manufacturing in ablative and HCF heat shield fabrication since many formulations and processes for these materials are not standardized yet. During the testing portion of the program these engineers assist the test director in monitoring maintenance tasks.

Product Support. - A full time maintenance engineer updates existing test procedures and develops new procedures as required. He ensures that these procedures are consistent with design changes that may occur. His primary function is to become proficient with VTR and event recorder system assembly, operation, and maintenance. During the testing portion of the study he assists the test director in monitoring maintenance tasks. After test completion he is chiefly responsible for evaluating test data and updating task analyses. He also assists in final report preparation.

Manufacturing. - When all test hardware is fabricated, several manufacturing personnel will support the experimental tests. The prime function of these personnel is to perform various maintenance tasks called for under each test plan. This includes test hardware replacement, repair, inspection, and overall maintenance. Specifically they are representative of operational maintenace personnel, having had experience with Mercury, Gemini, and ASSET.

Test. - During the testing portion of the study a test engineer conducts environmental temperature simulation tests. He also has responsibility for installing and monitoring all thermocouples and associated test instrumentation.

Test Hardware Requirements

TPS component parts, maintenance tools, test simulation equipment, and measurement devices for the proposed test plans are listed in table 12.

Task Output Data

Output data of this task are detailed drawings of component parts of selected TPS concepts, plans for fabrication and maintenance testing of these parts on a full-scale mockup, and the costs of implementing the plans. Detailed drawings and fabrication requirements of the test hardware have been presented and discussed in previous sections of this report.

TABLE 12 TEST HARDWARE REQUIREMENTS

QTY	NOMENCLATURE OR DESCRIPTION	DRAWING OR SPECIFICATION NO.	NOTES
12	Radiative Panel Assembly	64T020006-3	To be fabricated
8	Attach strap	64T020006-17	To be fabricated
8	Attach strap	64T020006-19	To be fabricated
108	Channel Assembly	G10907-3	To be fabricated
3	Radiative panel assembly	64T020006-1	To be fabricated
4	Attach Strap	64T020006-17	To be fabricated
8	Attach strap	64T020006-21	To be fabricated
80	Shoulder bolt	3M400-3-10-6	To be purchased
12	Radiative panel assembly	64T020005-1	To be fabricated
54	Shoulder bolt	3M400-3-76-6	To be purchased
54	Shim	NAS463X-C10	To be purchased
3	Ablator panel assembly	64T020003-1	To be fabricated
12	Pi-strap assembly	64T020003-5	To be fabricated
60	Plug	64T020003-23	To be fabricated
40	Bolt	AN3-7A	To be purchased
40	Washer	AN960-10L	To be purchased
12	HCF panel assembly	64T020004-1	To be fabricated
4	Spacer assembly	64T020004-3	To be fabricated
6	Bolt	AN3-12A	To be purchased
6	Washer	AN960-10L	To be purchased
8	Plug	64T020004-13	To be fabricated
4	Ablator panel assembly	64T020007-1	To be fabricated
96	Screw	AN509-10R12	To be purchased
240	Bolt	AN3-6A	To be purchased
240	Washer	AN960-10L	To be purchased
240	Plug	64T020007-17	To be fabricated

TABLE 12 (CONCLUDED)

QTY	NOMENCLATURE OR DESCRIPTION	DRAWING OR SPECIFICATION NO.	NOTES
1	Panel installation arrangement	64T020001	To be assembled
1	Panel support assembly	64T020002	To be fabricated
1	Panel dolly		To be supplied by MDAC-East
3	Penumatic wrench		To be supplied by MDAC-East
3	Torque wrench		To be supplied by MDAC-East
3	Flashlight (2 cell)		To be supplied by MDAC-East
3	Inspection mirror		To be supplied by MDAC-East
3 pr	Gloves		To be supplied by MDAC-East
3	High torque screw driver		To be supplied by MDAC-East
1	Panel storage rack		To be supplied by MDAC-East
1	3 inch diameter magnifying glass		To be supplied by MDAC-East
10 oz cartridge	Adhesive	DC3145	To be purchased
1 gal	Adhesive	RTV106	To be purchased
3	Pneumatic drill		To be supplied by MDAC-East
3	Tapered drill		To be supplied by MDAC-East
1	Video tape recording (VTR) system assembly		To be supplied by MDAC-East
1	Event recorder system assembly		To be supplied by MDAC-East
1	Environmental temperature simulator		To be designed and fabricated
176	Thermocouples		To be purchased

Primary outputs of task 5 are experimental test plans whose primary objective is to resolve uncertainties associated with the various maintenance activities involved in replacement, inspection, and repair of representative TPS. The general test setup is shown in figure 51. Six different plans are outlined on succeeding pages which can be performed individually or in combination with each other. Major activities and significant milestones for the overall program plan are shown in figure 52. Each test plan outlines, in chronological order, the type of maintenance tasks performed for a particular TPS concept. Test activities are continuously minitored throughout the program by a VTR system.

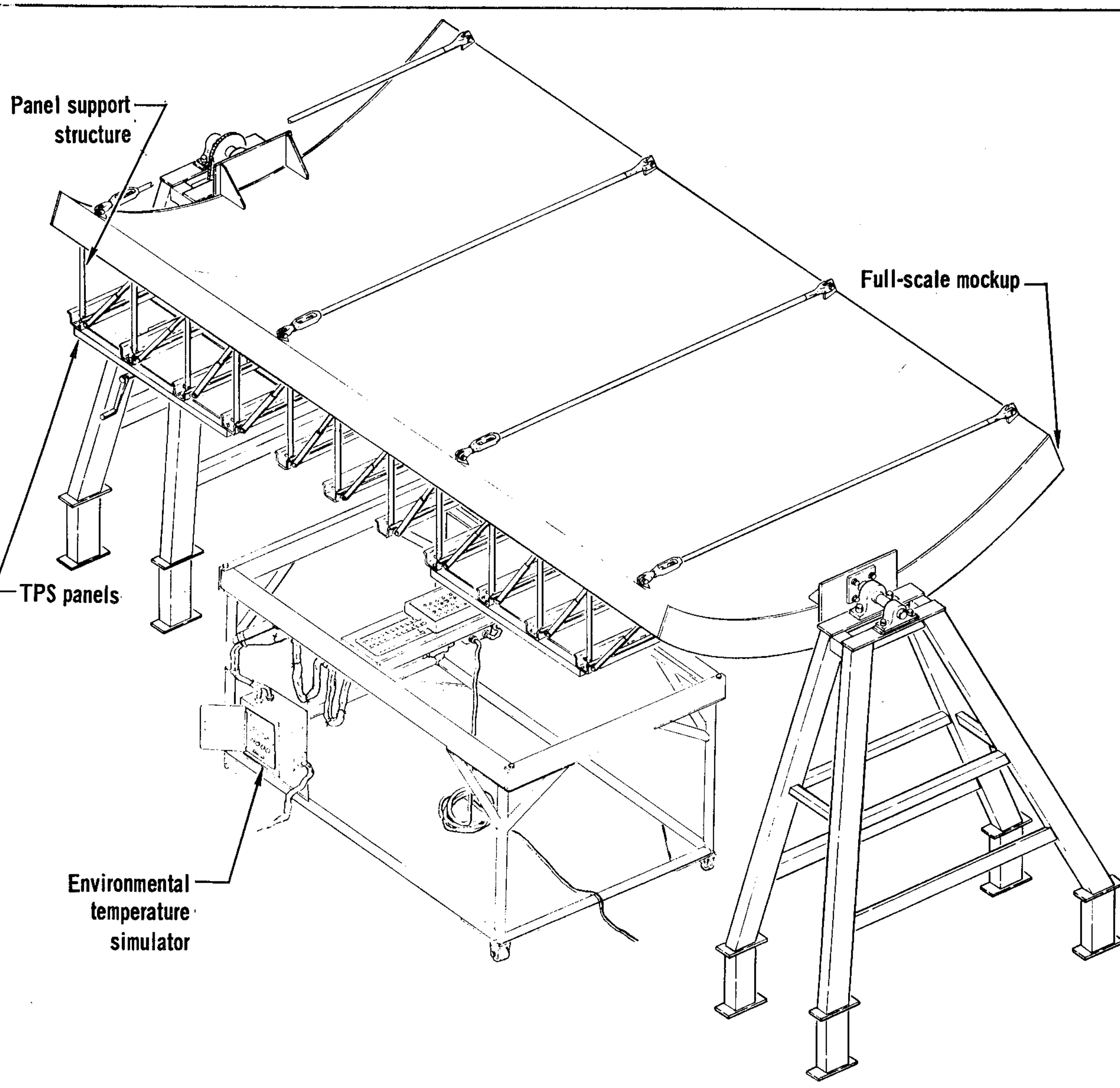


FIGURE 51 EXPERIMENT TEST SETUP

For each maintenance task or simulation test called for, reference is made to a maintenance task schedule. These schedules give details of individual refurbishment activities associated with the particular maintenance function under consideration. In addition, these schedules show elapsed time estimates

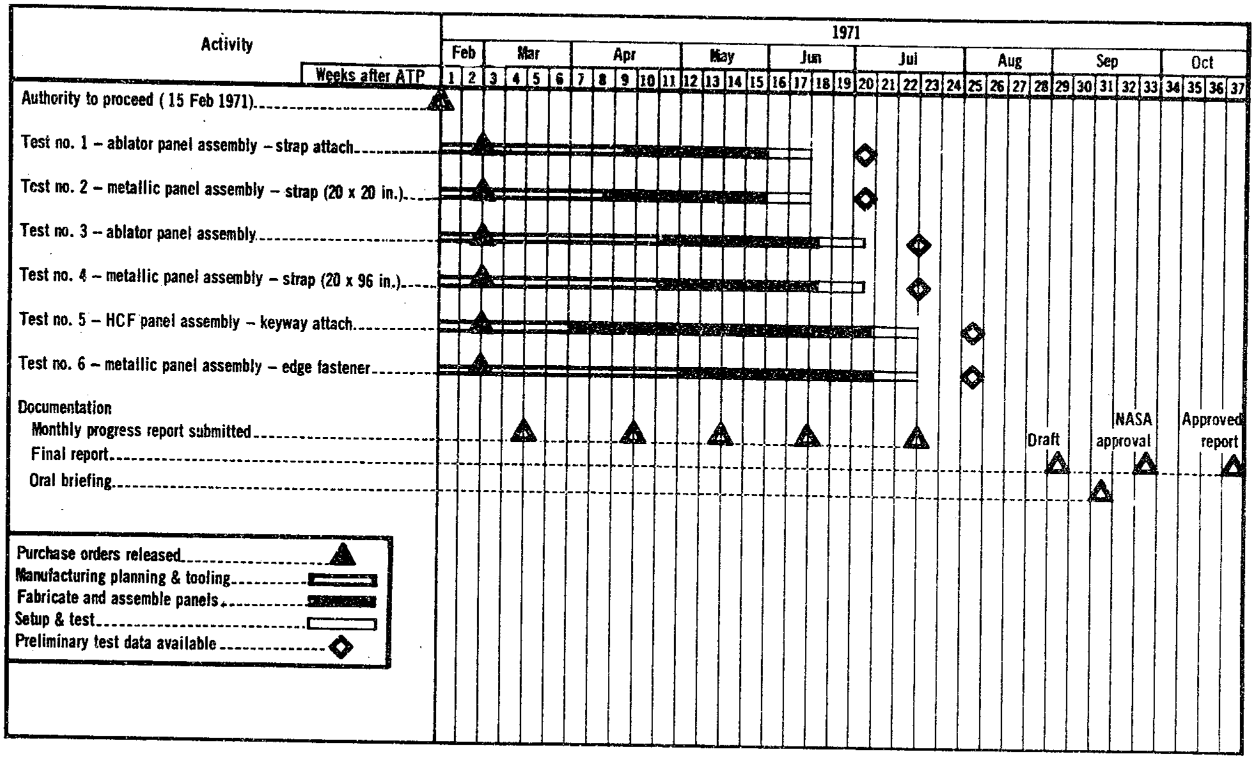


FIGURE 52 MASTER TEST PLAN SCHEDULE

and equipment to perform the particular refurbishment activity. This format of test conduct serves two purposes. It establishes when personnel and equipment are needed, and; it serves as a check list of duties much like that of an operational type maintenance manual. Each test plan also contains provision for test data evaluation, documentation, and a fabrication and test milestone schedule.

Test objectives. - Objectives of individual tests called for under each test plan are referred to in the classification of the particular maintenance task function under consideration. These include initial installation, initial inspection, removal and replacement of a simulated damaged panel, simulated damaged panel repair in place on mockup, environmental testing, and removal and replacement of used or heated TPS panels. Specifically, objectives of each of these maintenance functions are:

Installation: The purpose of this test is to determine and resolve problems which may be involved in the initial and subsequent installation of a TPS panel on the vehicle, particularly with regard to handling, positioning, sealing joints, applying fasteners, etc.

Inspection: The purpose of this test is to establish procedures and equipment requirements for the inspection of the installed TPS panels before flight.

Removal and replacement: Assuming a panel is damaged beyond repair after initial installation and before release of the vehicle to the field, the purpose of this test is to note and resolve the problems involved in removing any randomly located panel on the vehicle and replacing it with a new panel.

Repair: The purpose of this test is to establish procedures and develop techniques for TPS panel repair on the vehicle.

Environmental test: The purpose of this test is to create an operational maintenance environment on the TPS panel exterior surface which would make subsequent panel removal more like those conditions experienced after a normal vehicle entry.

Remove and replace heated panels: The purpose of this test is to examine problems involved in replacing heated or used TPS panels, particularly regarding fastener and seal removal and replacement.

Uncertainties within each of these maintenance functions and objectives are examined in detail under task 4.

Test plans. - Preparation, setup, and test procedures are given below.

(a) Prepare mockup test fixture for TPS panel installation

Check fixture alignment
Verify operation of positioning drive mechanism
Position TPS support structure attachment channels
Drill required attachment holes in mockup support channels

(b) Install TPS panel support structure on mockup in accordance with MDAC drawing 64T020002.

(c) Inspect TPS panel support structure for alignment.

(d) Drill panel attachment holes in mockup support channels and install panel attach hardware (i.e. platenuts) in accordance with MDAC drawing 64T020001.

(e) Check fit and install panels on mockup in accordance with MDAC drawing 64T020001.

(f) Set up and check out VTR system in accordance with established assembly, operation, and maintenance procedures.

(g) Set up and check out event recording system in accordance with established assembly, operation and maintenance procedures.

(h) Set up and check out environmental temperature simulation test equipment in accordance with appropriate assembly and operational procedures. Procedures to be supplied on delivery of hardware at test site.

(i) Remove and instrument test panels and mockup structures with appropriate sensing devices as required to measure temperature and heating input and response data. Thermocouple quantities for each test are contained in appropriate maintenance task schedules.

TEST PLAN 1

(a) INSTALLATION - Install three, 20 by 70 inch, ablator pi-strap panel assemblies (MDAC drawing 64T020003) on the mockup in accordance with MDAC drawing 64T020001, view C, and procedures described in figure 53. Monitor individual maintenance task functions with VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 54- Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 55. Monitor individual maintenance task functions with VTR system.

(d) REPAIR - Repair in place simulated damaged panel on mockup in accordance with figure 56. Monitor individual maintenance task functions with VTR system.

(e) ENVIRONMENTAL TEST - Environmentally temperature test installed panel (MDAC drawing 64T020001) in accordance with figure 57. Monitor test as required with VTR system.

(f) REMOVE HEATED PANELS - Remove charred ablator panels from mockup installation in accordance with figure 58. Monitor individual maintenance task functions with VTR system.

(g) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (f) by use of the VTR system and event recording system.

(h) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 59.

FIGURE 53 MAINTENANCE TASK SCHEDULE A-1

MAINTENANCE TASK SCHEDULE- A-1

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 x 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Installation of Ablative TPS Test Panels			
1. Procure (3) substrate panels size 20" x 70" from storage.	0.20	2	3 panel support - 64T02003-7
2. Procure (3) ablative composites size 20" x 70" with associated attaching nuts, bolts, and washers from storage.	0.40	2	3 ablators 64T020003-3 99 nuts - NAS 679A3W 99 washers - AN960C10L
3. Visually inspect 20" x 70" substrate panels for obvious damage, cleanliness, and deterioration.	0.45		1 flashlight 1 inspection mirror
4. Visually inspect 20" x 70" ablator composites for obvious damage and deterioration.	0.50	1	1 flashlight 1 inspection mirror
5. Align and install an ablative composite to a panel substrate.	0.55	1	1 panel support - 64T020003-7 1 ablator - 64T020003-3
6. Install the (33) nuts and washers to the (33) bolts on the bottom side of the panel substrate.	0.85	3	3/8" sockets and 3 pneumatic wrenches 33 nuts - NAS 679A3W 33 washers - AN960C10L
7. Torque the (33) nuts on the panel substrate.	1.15	3	3/8" socket (3) torque wrenches (3)
8. Visually inspect the completed ablator panel assembly for obvious damage and proper assembly.	1.20	1	1 flashlight 1 inspection mirror 1 ablator panel assy - 64T020003-1

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MAINTENANCE TASK SCHEDULE- A-1

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 x 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
9. Perform Steps 5 through 8 on the remaining 2 ablator test panel assemblies required for this test.			3 ablator panel assy -pi-strap attach-64T020003-1 8 pi-strap assy's. 64T020003-5, 40 bolts AN3-7A 40 washers AN960-106, 40 plugs 64T020003-23
10. Transport ablative TPS test panels and associated hardware from storage to the mockup work area.	1.40	2	
11. Position one of the TPS test panels on the mockup in accordance with configurational arrangement shown in MDAC DWG. 64T020001. Record serial number and location of panel.	1.50	2	1 ablator panel assy - pi-strap attach - 64T020003-1 1 test fixture - 64T020002
12. Align the (4) pi-straps on the ablative TPS test panel.	1.55	1	4 pi-strap assy - 64T020003-5
13. Visually check flexible gaskets (2) for proper alignment.	1.60	1	2 gaskets - 64T020003-13
14. Install the (2) pi-Strap attaching fasteners.	1.75	1	1 socket 1 pneumatic wrench 20 bolts AN3-7A 20 washers AN960-10L
15. Torque the (2) pi-strap attaching fasteners.	1.90	1	1 torque wrench
16. Visually inspect the ablative test panel for obvious damage and proper installation.	1.95	1	1 flashlight 1 inspection mirror
17. Apply a small quantity of DC3145 adhesive to each of the pi-strap attaching fastener plugs (20) with a brush or a spatula to a thickness of 10 to 30 mils over	2.25	2	1" brush or 1 spatula DC3145 adhesive 20 ablator plugs - 64T020003-23

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MAINTENANCE TASK SCHEDULE- A-1

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 x 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
17. (Continued) the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
18. Visually inspect pi-strap attaching fastener ablator plugs for proper installation.	2.35	1	1 flashlight
19. Visually inspect the complete panel installation.	2.40	1	1 flashlight 1 ablator panel assy. pi-strap attach - 64T020003-1
20. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM&P NAPTHA.	2.50	1	
21. Fill spray gun and test for proper function and mixture.	2.60	1	1 spray gun
22. Spray dispersion coating with line pressure at 55 psig to a thickness of 3 to 5 mils. Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches, spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30 minutes if a thickness buildup is desired. Cure the dispersion	2.65	1	

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MAINTENANCE TASK SCHEDULE- A-1

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 x 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
22. (Continued) coating at room temperature for 12 to 18 hours.			
23. Visually inspect coating for proper application.	2.70	1	1 flashlight
24. Perform Steps 11 through 23 for each of the (2) remaining ablative test panels required for this test.			

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FIGURE 54 MAINTENANCE TASK SCHEDULE B-1

MAINTENANCE TASK SCHEDULE- B-1

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 X 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of Ablative TPS Test Panels			
1. Using a flashlight, visually inspect the entire area of the ablative test panel for dents, abrasions, pit marks, erosion and deterioration.	See total at Step 5		1 flashlight 1 inspection mirror
2. Visually inspect ablative test panel dispersion coating for condition, obvious damage and proper coverage.			1 flashlight 1 inspection mirror
3. Visually inspect the ablative test panel pi-strap attaching fastener ablator plugs for proper for proper position and alignment (top of plug should be even with moldline - allowable plug and moldline mismatch tolerance is .030 inches.			1 flashlight 1 inspection mirror
4. Visually inspect pi-straps for proper alignment and installation.			1 flashlight 1 inspection mirror
5. Visually inspect the flexible gaskets on two sides of the test panel for obvious damage. Deterioration, proper alignment and distortion.	0.05	1	1 flashlight

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MAINTENANCE TASK SCHEDULE- B-1

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20 X 70

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. (Continued) NOTE: Any damage of a magnitude affecting the integrity of the fiberglass substrate, will warrant the removal of the ablative panel assembly for further inspection and repair.			
6. Perform Steps 1 thru 5 on the 2 remaining ablative test panels used in this test.			1 flashlight 1 inspection mirror

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FIGURE 55 MAINTENANCE TASK SCHEDULE C-1

MAINTENANCE TASK SCHEDULE-C-1

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Center (Ref. MDAC Dwg. 64T020001) Ablative TPS Test			
1. Drill out the test panel (center) pi-strap attaching fastener (20) ablator plugs.	0.80	2	1 pneumatic drill 1 taper bit 20 ablator plugs 64T020003-23
2. Using a 4 inch wide putty knife, free both sides of the pi-straps from the test panel.	0.95	1	4 inch width putty knife 4 pi-strap assy. - 64T020003-5
3. Using a 4 inch wide putty knife, free the flexible gaskets at the interpanel sealing joint.	1.05	1	4 inch width putty knife gaskets - 64T020003-13 (Ref.)
4. Remove the (20) pi-strap attaching fasteners.	1.20	1	1 socket wrench 20 bolts AN3-7A 20 washers AN960-10L
5. Remove the pi-straps from the test panel (center) as required.	1.25	1	
6. Maneuver test panel (center) free of the test fixture.	1.30	2	1 ablator panel assy. pi-strap attach - 64T020003-1
Inspection of Test Panel			
7. Visually inspect the test panel to determine extent of damage and repair required. Record findings.	1.35	1	1 flashlight 1 inspection mirror
8. Visually inspect pi-straps and attaching fasteners for condition. Record findings.	1.40	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE- C-1

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
9. Transport test panel and associated hardware to the storage area.	1.50	1	1 ablator panel assy. - pi-strap attach - 64T020003-1
10. Inspect support structure on test fixture for condition. Record findings.	1.55	1	1 flashlight 1 inspection mirror 1 test fixture 64T020002
Replacement of Ablator Composite on Panel Substrate			
11. Remove each of the (33) attaching nuts and washers from the backside of ablator panel assembly.	1.85	2	3/8" socket (2) and (2) pneumatic wrenches 33 nuts - NAS 679A3W 33 washers - AN960C10L
12. Remove the simulated damaged ablator composite from the panel support.	1.95	2	1 ablator - 64T020003-3 1 panel support 64T020003-7
13. Visually inspect the panel support for obvious damage and deterioration.	2.00	1	1 flashlight 1 inspection mirror 1 panel support - 64T020003-7
14. Install same ablator composite on the panel support.	2.05	1	1 ablator 64T020003-3
15. Install the (33) nuts and washers on the ablator panel bolts.	2.35	3	3/8" socket (3) pneumatic wrenches (3) 33 - nuts - NAS 679A3W 33 - washers - AN960C10L

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MAINTENANCE TASK SCHEDULE-C-1

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
16. Torque the (33) ablator panel nuts.	2.65	3	3/8" socket (3) and torque wrenches (3) 33 - nuts - NAS 679A3W
17. Transport the ablator panel assembly and associated hardware to the test fixture area.	2.75	2	1 ablator panel assy. - pi-strap attach - 64T020003-1
Replacement of Ablative TPS Test Panel on Test Fixture			
18. Position the test panel (center) on the test fixture.	2.85	2	1 ablator panel assy. - 64T020003-1 1 test fixture - 64T020002
19. Check alignment of the test panel on the mockup support structure. Record findings.	2.90	1	1 ablator panel assy. - 64T020003-1 1 test fixture - 64T020002
20. Position the pi-straps on the test panel for installation.	2.95	1	4 pi-strap assy. - 64T020003-5
21. Check the alignment of the pi-strap attaching fastener holes. Record findings.	3.00	1	
22. Install the (20) pi-strap attaching fasteners on the test panel.	3.15	1	1 socket 1 pneumatic wrench 20 bolts AN3-7A 20 washers AN960-10L
23. Torque the (20) test panel pi-strap attaching fasteners.	3.30	1	1 torque wrench with socket

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MAINTENANCE TASK SCHEDULE-C-1

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
24. Visually inspect the test panel pi-strap attachment installation.	3.35	1	1 flashlight 1 inspection mirror
25. Apply a small quantity of DC 3145 adhesive to each of the pi-strap attaching fastener plugs (20) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours maximum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	3.65	2	1 inch brush or spatula DC 3145 adhesive 20 ablator plugs 64T020003-23
26. Visually inspect pi-strap attaching fastener ablator plugs for proper installation.	3.75	1	1 flashlight
27. Visually inspect the complete panel installation.	3.80	1	1 flashlight
28. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM&P NAPTHA.	3.90	1	
29. Fill spray gun and test for proper function and mixture.	4.00	1	1 spray gun
30. Spray dispersion coating with line pressure at 55 psig Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches, spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30	4.05	1	

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MAINTENANCE TASK SCHEDULE-C-1

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 3	ELAPSED TIME IN HOURS 4	TOOLS AND EQUIPMENT PARTS AND MATERIAL
30. (Continued) minutes if a thickness buildup is desired. Cure the dispersion coating at room temperature for 12 to 18 hours.				
31. Visually inspect coating for proper application.	4.10	☐1		1 flashlight

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FIGURE 56 MAINTENANCE TASK SCHEDULE D-1

MAINTENANCE TASK SCHEDULE- D-1

- TASK FUNCTION REPAIR
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Repair of TPS Panel			
1. Isolate damage to specific panel on the mockup. NOTE: (1) Repairs to damaged panel on mockup shall be limited to area of 1 to 1-1/2 inch in diameter, any damage with a larger area shall warrant panel removal and repair accomplished in a refurbishment area. (2) This task analysis simulates the damage repair on vehicle.	0.05	1	
2. Using a grinding tool, grind away damaged material down to the bondline on the fiberglas facesheet.	0.20	1	1 grinding wheel 1 grinding disk. 1 1/2" wood chisel
3. Remove bonding agent using methyl ethyl ketone, assure area is thoroughly clean and free of any foreign matter.	0.30	1	1 pint methyl ethyl ketone (MEK)
4. Cut a plug of prepared, cured ablative material to appropriate thickness to fit the damaged area.	0.40	1	1 knife
5. Apply primer DC #1203 to the fiberglas facesheet at the panel repair area and the bond side of the cured ablative honeycomb repair plug. A thin film and only one coat is required. Allow	0.50	1	1 pint primer DC #1203 1/2" paint brush

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MAINTENANCE TASK SCHEDULE- D-1

- TASK FUNCTION REPAIR
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. (Continued) primer to dry for a minimum of 1 hour with relative humidity at 50%			
6. Apply a small quantity of RC #3145 adhesive sealant to the fiberglas facesheet bonding surface and sides of the repair area, with a spatula or a brush to a thickness of 10 to 30 mils over the entire contact area. NOTE: It is not necessary to apply adhesive to both surfaces to be bonded.	0.60	1	1 pint RC 3145 adhesive
7. Align and join the ablative honeycomb repair plug immediately (within 10 minutes) after spreading the adhesive. Press the plug firmly into the repair area. NOTE: (1) Plug should not be more than .030 below the mold line of surrounding material. (2) Allow a 24-hour (minimum air cure period before handling or stressing the bonded joint under normal temperature conditions (75°F) & relative humidity above 20%. After 8 hours adhesives are set sufficiently to allow cleanup and trimming.	0.65	1	

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MAINTENANCE TASK SCHEDULE- D-1

- TASK FUNCTION REPAIR
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
8. Remove the excess adhesive and any residue which may have accumulated. Trim as required.	0.75	1	1 knife
Inspection			
9. Visually inspect TPS panel for proper repair.	0.80		1 flashlight
10. Using the x-ray method or micro-wave tester, check the plug repair for voids in the adhesive bond.	1.80	1	1 x-ray unit or 1 microwave tester
11. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM&P NAPTHA.	1.90	1	
12. Fill spray gun and test for proper function and mixture.	2.00	1	1 spray gun
13. Spray dispersion coating with line pressure at 55 psig. Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches, spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30 minutes if a thickness buildup is desired (3 - 5 mils thick). Cure the dispersion coating at room temperature for 12 to 18 hours.	2.05	1	
14. Visually inspect repair for proper installation.	2.10		1 flashlight

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FIGURE 57 MAINTENANCE TASK SCHEDULE E-1

MAINTENANCE TASK SCHEDULE- E-1

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 8 thermocouples
2. Position the mockup so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	1 test fixture
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and mockup	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
Thermal Test Environment			
6. A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to between 2200 and 2400°F in approximately 350 seconds. This surface temperature shall then be maintained for an additional	2.6	2	

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MAINTENANCE TASK SCHEDULE- E-1

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle.			

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FIGURE 58 MAINTENANCE TASK SCHEDULE F-1

MAINTENANCE TASK SCHEDULE- F-1

- TASK FUNCTION REMOVE HEATED PANELS
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 62T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Removal of Heated Test Panels			
1. Remove center heat tested TPS panel. Record serial number and location.	0.05	1	1 ablator panel assy. - pi-strap attach. 64T020003-1
2. Locate the (20) pi-strap attaching fastener ablator plugs on the test panel.	0.10	1	
3. Drill out the (20) pi-strap attaching fastener ablator plugs.	0.90	2	1 pneumatic drive with tapered bit
4. Using a 4 inch wide putty knife, free both sides of the pi-straps from the ablative test panel.	1.05	1	4 inch width putty knife
5. Using a 4 inch wide putty knife, free the flexible gaskets at inter panel sealing joint.	1.15	1	4 inch width putty knife
6. Remove the (20) pi-strap attaching fasteners from the pi-straps.	1.30	1	20 bolts AN 3-7A 20 washers AN 960-10L 1 socket 1 pneumatic wrench
7. Remove the associated pi-straps from the test panel and support structure.	1.35	1	4 pi-strap assy. 64T020003-5
8. Maneuver heated test panel free of the test fixture.	1.40	2	1 ablator panel assy. pi-strap attach 64T020003-1 1 test fixture 64T020002
9. Visually inspect the inside and outside surface of the test panel for condition and record findings.	1.45	1	1 flashlight and inspection mirror

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MAINTENANCE TASK SCHEDULE- F-1

- TASK FUNCTION REMOVE HEATED PANELS
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 62T020003)
- SINGLE PANEL SIZE 20" X 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
10. Visually inspect test panel pi-straps and associated fasteners for condition. Record findings.	1.50	1	1 flashlight and 1 inspection mirror
11. Store the heat tested panel pi-straps and associated attaching fasteners on a storage rack.	1.55	1	1 panel storage rack
12. Visually inspect test panel for condition and record findings.	1.60	1	1 flashlight 1 inspection mirror
13. Visually inspect the test panel support hardware on the mockup for condition. Record findings.	1.65	1	1 flashlgiht 1 inspection mirror
14. Remove each of the (33) ablator attaching nuts and washers from the back side of ablator panel support. Record findings.	1.95	3	3/8" sockets (3) and pneumatic wrenches (3) 33 nuts NAS 679A3W 33 washers AN 960C10L
15. Remove the ablator composite from the panel support.	2.05	2	1 ablator 64T020003-3 1 panel support 64T020003-7
16. Visually inspect ablator composite for obvious damage and deterioration. Record findings.	2.10	1	1 flashlight and 1 inspection mirror
17. Visually inspect the substrate panel for obvious damage and deterioration. Record findings.	2.15	1	1 flashlight 1 inspection mirror
18. Visually inspect the associated hardware for obvious damage and deterioration. Record findings.	2.20	1	1 flashlight 1 inspection mirror
19. Perform Steps 1 thru 18 on the (2) remaining TPS test panels required for this test.			

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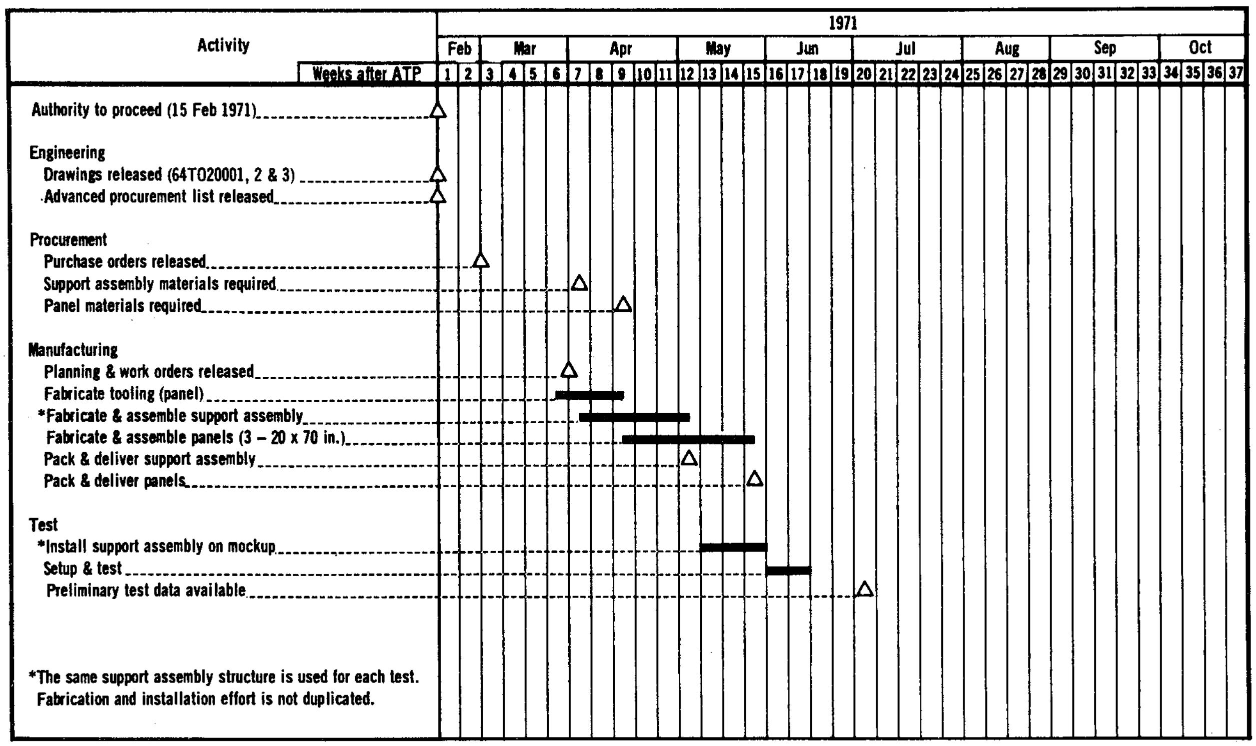

FIGURE 59 TEST PLAN 1 SCHEDULE
(ABLATOR PANEL ASSEMBLY - PI-STRAP ATTACH)

TEST PLAN 2

(a) INSTALLATION - Install nine, 20 by 20 inch, metallic pi-strap panel assemblies (MDAC drawing 64T020006) to the mockup in accordance with MDAC drawing 64T020001, view N, and procedures described in figure 60. Monitor individual maintenance task functions with VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 61. Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 62. Monitor individual maintenance task functions with VTR system.

(d) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 63. Monitor test as required with VTR system.

(e) INSPECTION - Inspect TPS panel installation in accordance with figure 64. Monitor individual maintenance task functions with VTR system.

(f) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) with figure 65. Monitor individual maintenance task functions with VTR system.

(g) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 66. Monitor test as required with VTR system.

(h) INSPECTION - Inspect TPS panel installation in accordance with figure 67. Monitor individual maintenance task functions with VTR system.

(i) REMOVE AND REPLACE - Remove and replace the middle three test panels (MDAC drawing 64 T020001) in accordance with figure 68. Monitor individual maintenance task functions with VTR system.

(j) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (i) with the VTR system and event recording system.

(k) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task function schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 69.

FIGURE 60 MAINTENANCE TASK SCHEDULE A-2

MAINTENANCE TASK SCHEDULE- A-2

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (NUMBER FOLLOWING TIME BAR IS MANLOADING)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Install TPS Test Panels			
1. Transport (9) radiative test panels and associated hardware from storage area to the mockup.	0.10	2	1 panel dolly 9 radiative panel assy - 64T020006-3 8 pi-straps - 64T020006-17 8 pi-straps - 64T020006-19 48 bolts - 3M400-3-10-6
2. Position one of the test panels on the test fixture. Record location and serial number of test panels. NOTE: (1) When adjacent panels are installed, longitudinal panel joints must be aligned. (2) Exercise care to prevent damage to mating surfaces. (3) Due to the use of two different length pi-straps (10 inch and 20 inch) the number of attaching fasteners varies with the location of the TPS test panel on the test fixture.	0.25	1	2 pair gloves
3. Align the appropriate pi-strap combinations on the panel and install attaching fasteners.	0.75	2	1 pneumatic wrench

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MAINTENANCE TASK SCHEDULE- A-2

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (NUMBER FOLLOWING TIME BAR IS MANLOADING)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
4. Perform Steps 2 and 3 on the remaining (8) panels.			
5. Torque test panel attaching fasteners.	1.25	2	1 torque wrench
6. Visually inspect test panel and attaching fastener installation.	1.35	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE-B-2

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspect TPS test panel			
1. Visually inspect entire surface of panels (9) for dents, abrasions, pit marks, erosion, and deterioration.			1 flashlight 1 inspection mirror
2. Visually inspect test panel edges for damage, distortion, and chipped coating.			1 flashlight
3. Visually inspect test panel longitudinal joints for distortion, excessive gapping, chafing, and chipping of coating at the joint.			1 flashlight
4. Check test panel for looseness.			1 pair gloves
5. Visually inspect test panel pi-straps for distortion, deterioration, and proper alignment.			1 flashlight
6. Visually inspect test panel pi-strap attaching fasteners.	0.20 Total	1	1 flashlight

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FIGURE 61 MAINTENANCE TASK SCHEDULE B-2

FIGURE 62 MAINTENANCE TASK SCHEDULE C-2

MAINTENANCE TASK SCHEDULE-C-2

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Simulated Damaged Test Panel NOTE: (1) Exercise care in removing panel fasteners to prevent damage to the coated panel surface. (2) Ensure that all personnel wear gloves while handling metallic test panels.			
1. Remove test panel pi-straps and associated attaching fasteners.	0.05	1	1 pneumatic wrench 1 radiative panel assy - 64T020006-3 1 pair gloves
2. Maneuver the center test panel (Ref MDAC DWG. 64T020001) free at longitudinal joints and remove it from the mockup.	0.10	1	
Inspection of Damaged Test Panel			
3. Visually inspect test panel for condition and record findings.			1 flashlight 1 inspection mirror
4. Visually inspect test panel attaching fasteners for damage			1 flashlight 1 inspection mirror
5. Visually inspect pi-straps for condition and record findings.	0.15	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE-C-2

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. Visually inspect support structure on mockup for condition and record findings.	0.20	1	
Install New Test Panel at Center Location			
7. Position a new test panel in the center location on the test fixture and maneuver to align the longitudinal joints. Check alignment of the attaching fastener holes and record findings.	Totaled at Step 9.		1 radiative panel assy - 64T020006-3
8. Align the pi-straps on the test panel for installation	Totaled at Step 9.		4 pi-straps - 64T020006-19
9. Install the (16) pi-strap attaching fasteners.	0.30	1	1 pneumatic wrench 16 bolts - 3M400-3-10-6
10. Torque the (16) pi-strap attaching fasteners.	0.35	1	1 torque wrench
11. Visually inspect the test panel and pi-strap attaching fastener installation.	0.40	1	1 flashlight 1 inspection mirror

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FIGURE 63 MAINTENANCE TASK SCHEDULE D-2

MAINTENANCE TASK SCHEDULE- D-2

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 18 thermocouples
2. Position the mockup so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and mockup.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
6. Thermal Test Environment: A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of the test specimen, starring at room temperature, to 1800°F in approximately 350 seconds. This surface temperature shall then be maintained for an additional 350 seconds. At the end of this time the gas heater will be shut down	2.3	2	

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MAINTENANCE TASK SCHEDULE- D-2

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required.			

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MAINTENANCE TASK SCHEDULE-E-2

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS		TOOLS AND EQUIPMENT PARTS AND MATERIAL
		1	2	
Inspect TPS Test Panels				
1. Using a flashlight and magnifying glass visually inspect all TPS test panels for evidence of overheat condition and record findings.				1 flashlight 1 3" magnifying glass
2. Visually inspect the test panels for evidence of distortion due to buckling and record findings.				1 flashlight
3. Visually inspect the test panel coating for condition and record findings.				1 flashlight 1 3" magnifying glass
4. Visually inspect the test panel joints for excessive gapping or signs of chafing. Record findings.				1 flashlight 1 inspection mirror
5. Visually inspect test panel attaching fasteners for evidence of overheating and deterioration and record findings.	0.15 Total for 9 panels.	1		1 flashlight

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FIGURE 64 MAINTENANCE TASK SCHEDULE E-2

FIGURE 65 MAINTENANCE TASK SCHEDULE F-2

MAINTENANCE TASK SCHEDULE-F-2

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Heated TPS Test Panel			
1. Remove test panel pi-straps and attaching fasteners.	0.05	1	1 pneumatic wrench
2. Maneuver test panel free of the longitudinal panel joints.	0.10	1	1 radiative panel assy - 64T020006-3 4 pi-straps - 64T020006-19 16 bolts - 3M400-3-10-6 1 pair gloves
3. Remove center test panel from test fixture (Ref. MDAC Dwg. 64T020001) and record it's serial number.	0.15	1	
Inspect Removed Test Panel			
4. Visually inspect test panel for obvious damage, pit marks, abrasions, erosion, and deterioration.			1 flashlight 1 inspection mirror
4a. Visually inspect test panel edges for chipped coating.			
4b. visually inspect the test panel longitudinal joints for distortion, chafing, and chipped coating at the joint.			

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MAINTENANCE TASK SCHEDULE-F-2

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
4c. Visually inspect pi-straps for damage, distortion, and chipped coating.			
4d. Visually inspect test panel attaching fasteners for damage.			
4e. Visually inspect associated support structure on mockup for obvious damage and deterioration.	0.30 Total for 4 through 4E.	1	1 flashlight 1 inspection mirror
Install a New Test Panel			
5. Transport a new test panel to test fixture	0.40	1	1 panel dolly
6. Position new test panel on the test fixture in the same location. Maneuver test panel to align the longitudinal panel joints. Check the alignment of the test panel attaching fastener holes and record findings.	0.45	1	1 radiative panel assy - 64T020006-3
7. Align pi-straps on the test panel and install attaching fasteners.	0.50	1	1 pneumatic wrench 16 bolts - 3M400-3-10-6 4 pi-straps - 64T020006-19
8. Torque pi-strap attaching fasteners.	0.55	1	1 torque wrench
9. Visually inspect the test panel and pi-strap/attaching fastener installation.	0.60	1	1 flashlight 1 inspection mirror

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FIGURE 66 MAINTENANCE TASK SCHEDULE G-2

MAINTENANCE TASK SCHEDULE- G-2

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 18 thermocouples
2. Position the mockup so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and mockup.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
6. Thermal Test Environment: A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to 1800°F in approximately 350 seconds. This surface temperature shall then be maintained for an additional 350 seconds. At the end of this time the gas heater	2.3	2	

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MAINTENANCE TASK SCHEDULE-G-2

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required.			

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MAINTENANCE TASK SCHEDULE- H-2

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64TQ20006)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspect TPS Test Panels			
1. Using a flashlight and magnifying glass visually inspect all (9) TPS test panels for evidence of overheat condition and record findings.	Time totaled at Step 5.		1 flashlight 1 3" magnifying glass
. Visually inspect the test panels for evidence of distortion due to buckling and record findings.			1 flashlight
. Visually inspect the test panel coating for condition and record findings.			1 flashlight 1 3" magnifying glass
4. Visually inspect the test panel joints for excessive gapping or signs of chafing. Record findings.			1 flashlight 1 inspection mirror
5. Visually inspect test panel attaching fasteners for evidence of overheating and deterioration. Record findings.	0.15 Total for all panels.	1	1 flashlight

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FIGURE 67 MAINTENANCE TASK SCHEDULE H-2

FIGURE 68 MAINTENANCE TASK SCHEDULE I-2

MAINTENANCE TASK SCHEDULE- I-2

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove TPS Test Panel			
1. Select three panels that have not been previously removed during the radiative panel testing. Record panel serial numbers and locations.	0.05	1	3 radiative panel assy - 64T020006-3 1 pair gloves
2. Remove the (24) attaching fasteners and pi-straps.	0.10	1	1 pneumatic wrench 24 bolts - 3M400-3-10-6 4 pi-straps - 64T020006-17 4 pi-straps - 64T020006-19
3. Maneuver the test panels free at the longitudinal joints and then remove them from the test fixture. Record findings.	0.15	1	
Inspection of TPS Test Panels			
4. Visually inspect test panels for obvious damage, overheating, deterioration, and distortion, and record findings.	0.20	1	1 flashlight 1 inspection mirror
5. Visually inspect test panels attaching fasteners for condition and record findings.	0.25	1	1 flashlight
6. Visually inspect test panels for condition, and record findings.	0.30	1	1 flashlight 1 inspection mirror
7. Visually inspect the test panel support structure on the test mockup for condition and record findings.	0.35	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE- I-2

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Replace TPS Test Panels			
8. Position (3) same panels on the mockup in their original location. Align longitudinal panel joints. Check alignment of attaching fastener holes. Record findings.	0.40	1	3 radiative panel assy - 64T020006-3
9. Install the (24) test panel attaching fasteners and pi-straps and record findings.	0.45	1	1 pneumatic wrench 24 bolts - 3M400-3-10-6
10. Torque the (24) test panel attaching fasteners.	0.50	1	1 torque wrench
11. Visually inspect the test panel attaching fastener installation.	0.55	1	1 flashlight
12. Visually inspect the test panel installation.	0.60	1	1 flashlight 1 inspection mirror
	Time is for one panel.		

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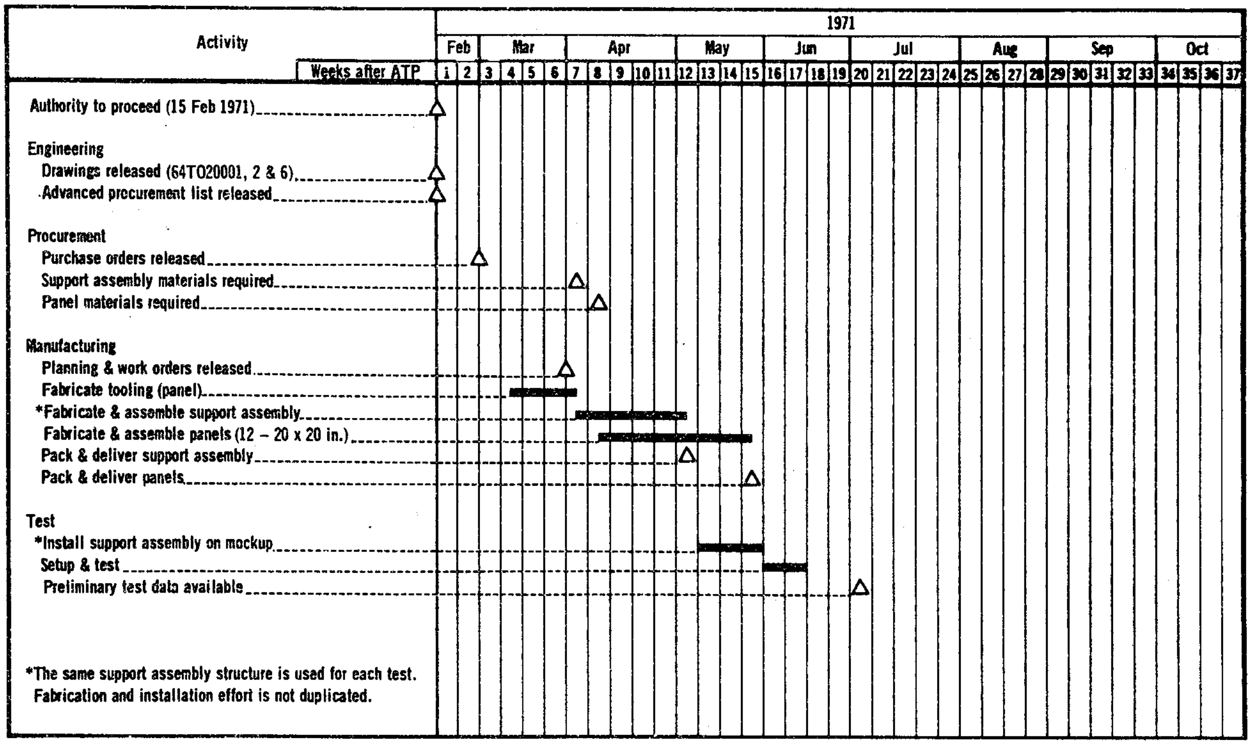

FIGURE 69 TEST PLAN 2 SCHEDULE
(METALLIC PANEL ASSEMBLY - PI-STRAP)

TEST PLAN 3

(a) INSTALLATION - Install three, 40 by 70 inch, ablator multiple fastener panel assemblies (MDAC drawing 64T020007) to the mockup in accordance with MDAC drawing 64T020001 and procedures described in figure 70. Monitor individual maintenance task functions with VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 71. Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 72. Monitor individual maintenance task functions with VTR system.

(d) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 73. Monitor test as required with VTR system.

(e) REMOVE HEATED PANELS - Remove charred ablator panels from mockup in accordance with figure 74. Monitor individual maintenance task function with VTR system.

(f) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (e) by use of the VTR system and event recording system.

(g) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 75.

FIGURE 70 MAINTENANCE TASK SCHEDULE A-3

MAINTENANCE TASK SCHEDULE- A-3

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Installation of Ablative TPS Test Panel			
1. Procure the substrate panels and ablator composites and all associated hardware from storage.	0.40	2	3 ablator panel - 64T020007-5 3 substrate panel - 64T020007-3 180 bolts - AN3-6A 180 washers - AN960-10L 72 screws - AN509-10R12 180 ablator plugs - 64T020007-17
2. Transport the above mentioned components to the mockup work area.	0.60	2	1 panel dolly
3. Visually inspect the ablator composites for obvious damage, deterioration, and erosion.	0.75	1	1 flashlight 1 inspection mirror 1 ablator panel - 64T020007-5
4. Visually inspect the substrate panels for obvious damage and deterioration.	0.90	1	1 flashlight 1 inspection mirror 1 substrate panel - 64T020007-3
5. Visually inspect all associated hardware for obvious damage and deterioration.	1.05	1	180 bolts - AN3-6A 180 washers - AN960-10L 72 screws - AN509-10R12 180 ablator plugs - 64T020007-17

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MAINTENANCE TASK SCHEDULE- A-3

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. Position a substrate panel assy. on the test fixture. Align substrate panel attaching fastener holes and install the (24) attaching fasteners. Record serial number and location.	1.25	2	1 substrate panel - 64T020007-3 24 screws - AN509-10R12 2 pneumatic screwdrivers
7. Torque the (24) substrate panel attaching fasteners (20 - 25 in. lbs.)	1.45	2	2 torque wrenches with screwdriver adapter
8. Visually inspect the substrate panel attaching fastener installation.	1.50	1	1 flashlight 1 inspection mirror
9. Position an ablator composite on the installed substrate panel. Enter panel serial number and location. Then align the ablator composite attaching fastener holes and install (60) bolt and nut combinations (nutplate mounted on bottom of substrate).	2.10	3	1 ablator panel - 64T020007-5 60 bolts - AN3-6A 60 washers - AN960-10L
10. Visually inspect ablator panel flexible gasket for proper alignment.	2.15	1	1 flashlight 1 inspection mirror
11. Torque the (60) attaching bolts to 20 - 25 in. lbs.	2.55	2	3 torque wrenches
12. Visually inspect the attaching bolts for proper installation.	2.60	1	1 flashlight

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MAINTENANCE TASK SCHEDULE-A-3

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
13. Apply a small quantity of DC3145 adhesive to each of the attaching fastener plugs (60) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	4.60	5	DC3145 adhesive 60 ablator plugs - 64T020007-17 1 brush or 1 spatula
14. Visually inspect attaching fastener ablator plugs for proper installation.	4.65	1	1 flashlight
15. Visually inspect the complete panel installation.	4.70		1 flashlight 1 inspection mirror
16. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM&P NAPTHA.	4.90	2	
17. Fill spray gun and test for proper function and mixture.	5.10	1	1 spray gun
18. Spray dispersion coating with line pressure at 55 psig, 3 to 5 mils thick. Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches, spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30 minutes if a	5.20	1	

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MAINTENANCE TASK SCHEDULE-A-3

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
18. (Continued) thickness buildup is desired. Cure the dispersion coating at room temperature for 12 to 18 hours.			
19. Visually inspect panels for proper installation.	5.25	1	
20. Perform Steps 6 thru 19 on the remaining (2) TPS test panels required for this test.			

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FIGURE 71 MAINTENANCE TASK SCHEDULE B-3

MAINTENANCE TASK SCHEDULE-B-3

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
<u>Inspection of Ablative TPS Test Panels</u>			
1. Using a flashlight, visually inspect the entire area of the ablative test panel for dents, abrasions, pit marks, erosion, and deterioration. Record panel serial no. and location.	See Step 4 for total.		1 flashlight 1 inspection mirror 1 ablator panel assy - 64T020007
2. Visually inspect ablative test panel dispersion coating for condition, obvious damage and proper coverage.			1 flashlight
3. Visually inspect the ablative test panel attaching fastener ablator plugs (60) for proper position and alignment (top of plug should be even with mold-line - allowable plug and mold-line mismatch tolerance is .030 inch).			1 flashlight 1 feeler gage
4. Visually inspect the flexible gaskets on two sides of the test panel for obvious damage, deterioration, proper alignment, and distortion. NOTE: Any damage of a magnitude affecting the integrity of the fiberglas substrate will warrant the removal of the ablative panel assembly for further inspection and repair.	0.05	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE-B-3

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" x 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. Perform Steps 1 thru 4 on the 2 remaining ablative TPS test panels used in this test.			

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FIGURE 72 MAINTENANCE TASK SCHEDULE C-3

MAINTENANCE TASK SCHEDULE-C-3

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC 64T020007)
- SINGLE PANEL SIZE 40" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Ablative TPS (Center) Test Panel			
1. Drill out the test panel (center) ablator to substrate attaching ablator plugs (60).	3.00	5	5 pneumatic drills with tapered bits
2. Using a 4 inch wide putty knife free the flexible gasket at the interpanel sealing space.	3.20	2	2 four inch wide putty knife
3. Remove the (60) ablator to substrate attaching fasteners.	3.60	4	4 pneumatic wrenches 60 bolts AN3-6A
4. Maneuver the ablator composite free of the substrate and the mockup.	3.70	2	1 ablator panel - 64T020007-5
Inspection of Ablator Panel			
5. Visually inspect ablator panel to determine extent of damage and the repair required. Record findings.	3.75	1	1 flashlight 1 inspection mirror
6. Position the ablator panel on the panel dolly.	3.85	2	1 panel dolly
7. Visually inspect the ablator panel attaching fasteners. Record findings.	3.90	1	1 flashlight
8. Visually inspect the substrate panel on the mockup for obvious damage and deterioration.	3.95	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE-C-3

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC 64T020007)
- SINGLE PANEL SIZE 40" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Replacement of Ablator Panel on Mockup			
9. Remove ablator composite from panel dolly and position on substrate on the mockup. Check alignment of ablator composite and attaching fastener holes. Record findings.	4.05	2	1 ablator panel 64T020007-5 1 panel dolly
10. Install the (60) ablator panel attaching fasteners.	4.45	4	4 pneumatic wrench 60 bolts AN3-6A
11. Torque the (60) ablator panel attaching fastener to 20-25 in. lbs.	4.75	3	3 torque wrench
12. Visually inspect the ablator panel attaching fastener installation.	4.80	1	1 flashlight
13. Apply a small quantity of DC 3145 adhesive to each of the attaching fastener plugs (60) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	5.80	5	DC 3145 adhesive 60 ablator plugs - 64T020007-17 1 brush (1 inch width) or 1 spatula

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MAINTENANCE TASK SCHEDULE- C-3

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC 64T020007)
- SINGLE PANEL SIZE 40" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
14. Visually inspect attaching fastener ablator plugs for proper installation.	5.85	1	1 flashlight 1 inspection mirror
15. Visually inspect the complete panel installation.	5.90	1	1 flashlight 1 inspection mirror
16. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM&P NAPTHA.	6.10	2	
17. Fill spray gun and test for proper function and mixture.	6.30	1	
18. Spray dispersion coating with line pressure at 55 psig. Spray 3 to 5 mils thick. Cure the dispersion coating at room temperature for 12 to 18 hours.	6.40	1	
19. Visually inspect panels for proper installation.	6.45	1	

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FIGURE 73 MAINTENANCE TASK SCHEDULE D-3

MAINTENANCE TASK SCHEDULE- D-3

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER
- SINGLE PANEL SIZE 40" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 16 thermocouples
2. Position the test fixture so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	1 test fixture
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and mockup.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
Thermal Test Environment			
6. A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to between 2200 and 2400°F in approximately 350 seconds. This surface temperature shall then be maintained for an additional	5.4	3 4 2	

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MAINTENANCE TASK SCHEDULE- D-3

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER
- SINGLE PANEL SIZE 40" X 70"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle.			

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FIGURE 74 MAINTENANCE TASK SCHEDULE E-3

MAINTENANCE TASK SCHEDULE-E-3

- TASK FUNCTION REMOVE HEATED PANEL
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" X 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove TPS Test Panel From Mockup			
1. Record serial number and the location of the center TPS test panel.	0.05	1	
2. Locate the (60) ablator attaching fastener plugs on the test panel.	0.15	1	1 flashlight
3. Drill out the (60) ablator panel attaching fastener plugs.	3.15	5	5 pneumatic drills with tapered bit
4. Remove the (60) ablator panel attaching fasteners. Free flexible gasket with putty knife.	3.55	4	60 bolts AN3-6A 4 3/8" socket 4 pneumatic wrench
5. Maneuver the ablator composite free of the substrate panel on the mockup.	3.65	2	1 ablator panel assy. - 64T020007-5
Inspect TPS Test Panel			
6. Visually inspect the ablator panel for obvious damage, overheating, erosion and deterioration. Record findings.	3.70	1	1 flashlight 1 inspection mirror
7. Visually inspect the associated hardware for condition and record findings.	3.75	1	1 flashlight 1 inspection mirror
8. Place ablator panel and associated hardware on a panel dolly.	3.85	2	1 panel dolly
9. Visually inspect the substrate panel on the mockup for obvious damage, over heating and deterioration. Record findings.	3.90	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE-E-3

- TASK FUNCTION REMOVE HEATED PANEL
- HEAT SHIELD TYPE ABLATIVE
- ATTACH CONCEPT MULTIPLE FASTENER (MDAC DWG. 64T020007)
- SINGLE PANEL SIZE 40" X 70"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
10. Remove the (24) substrate panel attaching screws on the mockup.	4.10	2	2 pneumatic screwdrivers 24 screws - AN509-10R12
11. Remove the substrate panel from the mockup.	4.20	2	1 substrate assy. - 64T020007-3
12. Visually inspect backside of substrate panel for condition and record findings.	4.25	1	1 flashlight 1 inspection mirror
13. Place substrate panel on panel dolly.	4.35	2	1 panel dolly
14. Visually inspect the mockup for condition and record findings.	4.40	1	1 flashlight 1 inspection mirror
15. Inspect the support hardware on the mockup and record findings.	4.45	1	1 flashlight 1 inspection mirror
16. Perform steps 1 through 15 on the remaining (2) TPS test panels required for this test.			

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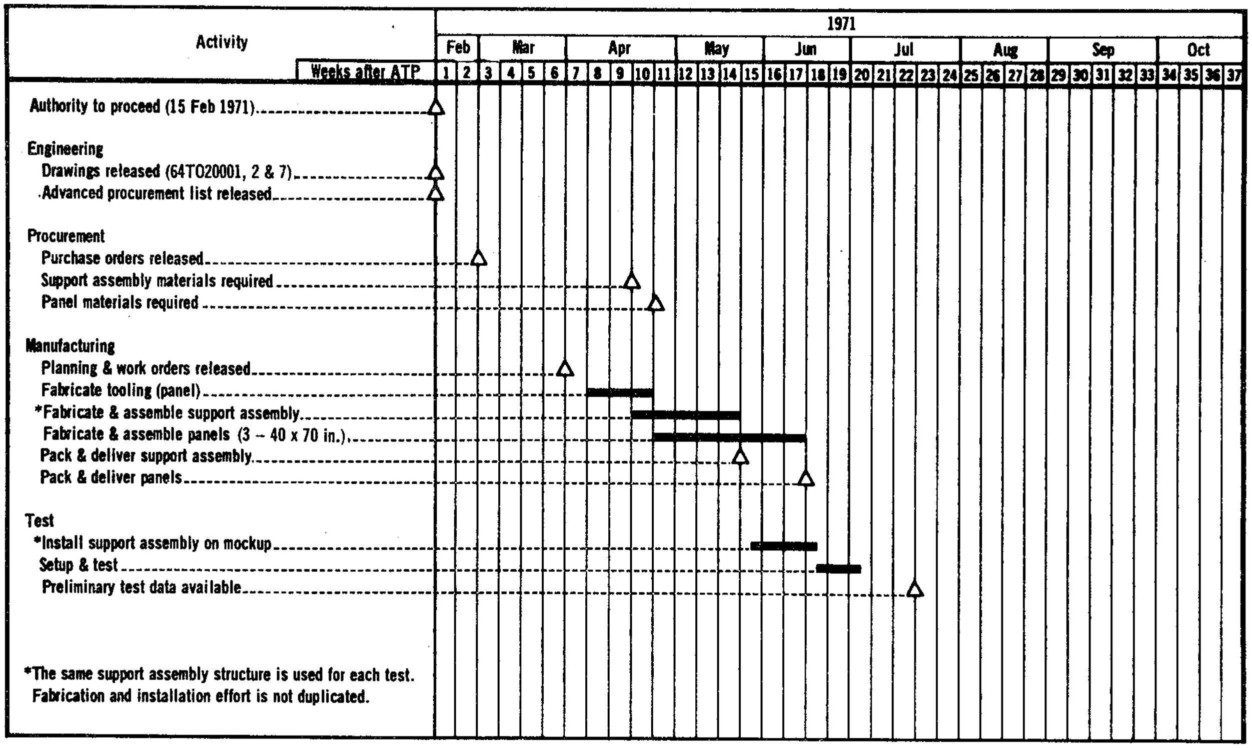

FIGURE 75 TEST PLAN 3 SCHEDULE
(ABLATOR PANEL ASSEMBLY)

TEST PLAN 4

(a) INSTALLATION - Install three, 20 by 96 inch, metallic pi-strap panel assemblies (MDAC drawing 64T020006) on the mockup in accordance with MDAC drawing 64T020001 and procedures described in figure 76. Monitor individual maintenance task functions with the VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 77. Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 78. Monitor individual maintenance task functions with VTR system.

(d) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 79. Monitor test as required with VTR system.

(e) INSPECTION - Inspect TPS panel installation in accordance with figure 80. Monitor individual maintenance task functions with VTR system.

(f) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 81. Monitor individual maintenance task functions with VTR system.

(g) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 82. Monitor test as required with VTR system.

(h) INSPECTION - Inspect TPS panel installation in accordance with figure 83. Monitor individual maintenance task functions with VTR system.

(i) REMOVE AND REPLACE - Remove and replace one test panel (center panel, MDAC drawing 64T020001) in accordance with figure 84. Monitor individual maintenance task functions with VTR system.

(j) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (i) with the VTR system and event recording system.

(k) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task function schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 85.

MAINTENANCE TASK SCHEDULE- A-4

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" X 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Install TPS Test Panels			
1. Transport (3) radiative test panels and associated hardware from storage area to the mockup.	0.10	2	1 panel dolly 3 radiative panel assy 64T020006-1 8 pi-straps 64T020006-21 80 shoulder bolts - 3M400-3-10-6
2. Position one of the test panels on the test fixture. Record its location and serial number. NOTE: 1. When adjacent panels are installed, longitudinal panel joints must be aligned. 2. Exericse care to prevent damage to mating surfaces.	0.40	6	4 pi-straps 64T020006-17 6 pair gloves
3. Align the appropriate pi-strap combinations on the panels and install attaching fasteners.	1.00	3	3 pneumatic wrenches 80 bolts-3M400-3-10-6
4. Torque test panel attaching fasteners.	1.30	3	3 torque wrenches
5. Visually inspect test panel and attaching fastener installation.	1.35	1	1 flashlight 1 inspection mirror
6. Perform Steps 2 thru 5 on the remaining (2) test panels. Record location and serial nos.			

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FIGURE 76 MAINTENANCE TASK SCHEDULE A-4

MAINTENANCE TASK SCHEDULE- B-4

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" X 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspect TPS Test Panels			
1. Visually inspect the test panels for dents, pit marks, abrasions, erosion and deterioration.			1 flashlight 1 inspection mirror
2. Visually inspect test panel edges for damage and distortion.			1 flashlight
3. Visually inspect test panel longitudinal joints for distortion, gapping and chafing.			1 flashlight 1 inspection mirror
4. Check test panels for looseness.			
5. Visually inspect test panel pi-straps for distortion, deterioration and alignment.			1 flashlight
6. Visually inspect pi-strap attaching fasteners for obvious damage and burring of the tool slots.	Total for all panels. 0.25	1	1 flashlight

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FIGURE 77 MAINTENANCE TASK SCHEDULE B- 4

FIGURE 78 MAINTENANCE TASK SCHEDULE C-4

MAINTENANCE TASK SCHEDULE- C-4

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" X 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Simulated Damaged TPS Test Panel			
NOTE: 1. Exercise care in removing panel fasteners to prevent damage to panel surface. 2. When removing center panel, support outside panels if sagging is indicated, with pi-straps.			
1. Remove the center test panel attaching fasteners and associated pi-straps.	0.30	3	3 pneumatic wrenches 1 radiative panel assy 64T020006-1 4 pi-strap 64T020006-21 36 shoulder bolts 3M400-3-10-6 3 pair gloves
2. Maneuver the center test panel (ref. MDAC DWG. 64T020001) free at the longitudinal joints and remove it from mockup.	0.45	3	
Inspection			
3. Visually inspect test panel for condition and record findings.			1 flashlight 1 inspection mirror
4. Visually inspect test panel attaching fasteners for condition and record findings.			
5. Visually inspect test panel pi-straps for condition and record findings. Place test panel and associated hardware on a storage rack.			1 storage rack

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MAINTENANCE TASK SCHEDULE- C-4

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. Visually inspect support structure on the test fixture for condition and record findings.	0.55 Total for Steps 3 thru 6.	1	
Reinstall Same TPS Test Panel			
7. Remove same panel from storage rack and position it in the center location on the test fixture. Maneuver panel to align the longitudinal joints. Check alignment of the attaching fastener holes and record findings.	0.70	3	1 storage rack
8. Align pi-straps on the test panel for installation. Install attaching fasteners and torque.	1.15	3	1 torque wrench
9. Visually inspect the panel and pi-strap/attaching fastener installation.	1.20	1	1 flashlight 1 inspection mirror

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FIGURE 79 MAINTENANCE TASK SCHEDULE D-4

MAINTENANCE TASK SCHEDULE- D-4

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 30 thermocouples
2. Position the mockup so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and test fixture.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
6. Thermal Test Environment: A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to $1800^{\circ}F$ in approximately 350 seconds. This surface temperature shall then be maintained for an additional 350 seconds. At the	2.9	2	

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MAINTENANCE TASK SCHEDULE- D-4

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle.			

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FIGURE 80 MAINTENANCE TASK SCHEDULE E-4

MAINTENANCE TASK SCHEDULE-E-4

- TASK FUNCTION: INSPECTION
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC 64T020006)
- SINGLE PANEL SIZE: 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 1 2	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of Heated TPS Test Panels			
1. Visually inspect heated test panels for obvious damage, overheating, erosion, and deterioration. Record findings.	0.10	1	1 flashlight 1 inspection mirror
2. Visually inspect the longitudinal panel joints for distortion, buckling, excessive gapping, and chafing, and record findings.	0.15	1	1 flashlight 1 inspection mirror
3. Visually inspect pi-straps for condition and record findings.	0.20	1	1 flashlight
4. Visually inspect attaching fasteners for condition and record findings.	0.25	1	1 flashlight

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FIGURE 81 MAINTENANCE TASK SCHEDULE F-4

MAINTENANCE TASK SCHEDULE- F-4

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove One Heated TPS Test Panel			
1. Remove the center test panel attaching fasteners and associated pi-straps.	0.30	2	2 pneumatic wrenches 1 radiative panel assy - 64T020006-1 36 shoulder bolts - 3M400-3-10-6 4 pi-straps - 64T020006-21 3 pair gloves
2. Maneuver center test panel (MDAC Dwg. 64T020001) free of the longitudinal joints and remove it from test fixture. Place test panel on storage rack.	0.45	3	
3. Visually inspect associated support structure on mockup for obvious damage and deterioration.	0.50	1	1 flashlight 1 inspection mirror
Reinstall Same TPS Test Panel			
4. Position the same test panel on the mockup in the center position. Maneuver test panel to align the longitudinal joints. Check the alignment of the attaching fastener holes and record findings.			
5. Align pi-straps on the test panel and install the attaching fasteners and then torque.	1.00	2	2 pneumatic wrenches 2 torque wrenches 1 radiative panel assy - 64T020006-1 36 shoulder bolts - 3M400-3-10-6

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MAINTENANCE TASK SCHEDULE- F-4

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. (Continued)			4 pi-straps - 64T020006-21
6. Visually inspect the test panel and attaching fastener installation.	1.05	1	1 flashlight 1 inspection mirror

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FIGURE 82 MAINTENANCE TASK SCHEDULE G-4

MAINTENANCE TASK SCHEDULE- G-4

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 30 thermocouples
2. Position the mockup so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and test fixture.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
6. Thermal Test Environment: A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to	2.90	2	

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MAINTENANCE TASK SCHEDULE- G-4

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) 1800°F in approximately 350 seconds. This surface temperature shall then be maintained for an additional 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required.			

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MAINTENANCE TASK SCHEDULE-H-4

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE 20" x 96"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of Heated TPS Test Panels			
1. Visually inspect test panels for obvious damage, overheating, erosion, and deterioration. Record findings.	0.10	1	1 flashlight 1 inspection mirror
2. Visually inspect the longitudinal panel joints for distortion, buckling, excessive gapping, and chafing, and record findings.	0.15	1	1 flashlight 1 inspection mirror
	0.20	1	
3. Visually inspect pi-straps for condition and record findings.			1 flashlight
4. Visually inspect attaching fasteners for condition and record findings.	0.25	1	1 flashlight

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FIGURE 83 MAINTENANCE TASK SCHEDULE H-4

FIGURE 84 MAINTENANCE TASK SCHEDULE I-4

MAINTENANCE TASK SCHEDULE- I-4

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (MANLOADING)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Three Heated TPS Test Panels			
1. Remove the (3) center test panels attaching fasteners (72) and associated pi-straps (8).	0.60	2	2 pneumatic wrenches 3 radiative panel assy. - 64T020006-1 72 shoulder bolts - 3M400-3-10-6 8 pi-straps - 64T020006-21 3 pair gloves
2. Maneuver test panels free of the longitudinal joints and remove from test fixture. Place test panels (3) on storage rack.	0.75	3	
3. Visually inspect associated support structure on mockup for obvious damage and deterioration.	0.85	1	1 flashlight 1 inspection mirror
Install Same (3) TPS Test Panels			
4. Position TPS test panels on the mockup in the center position. Maneuver test panels to align the longitudinal joints. Check the alignment of the attaching fastener holes and record findings.	1.00	3	
5. Align pi-straps (8) on the test panels and install the attaching fasteners and torque.	1.60	3	2 pneumatic wrenches 2 torque wrenches 3 radiative panel assy - 64T020006-1 72 shoulder bolts 3M400-3-10-6 8 pi-straps -64T020006-21

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MAINTENANCE TASK SCHEDULE- I-4

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: PI-STRAP (MDAC DWG. 64T020006)
- SINGLE PANEL SIZE: 20" x 96"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (MANLOADING)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. Visually inspect the test panels and attaching fastener installation.	1.70	1	1 flashlight 1 inspection mirror

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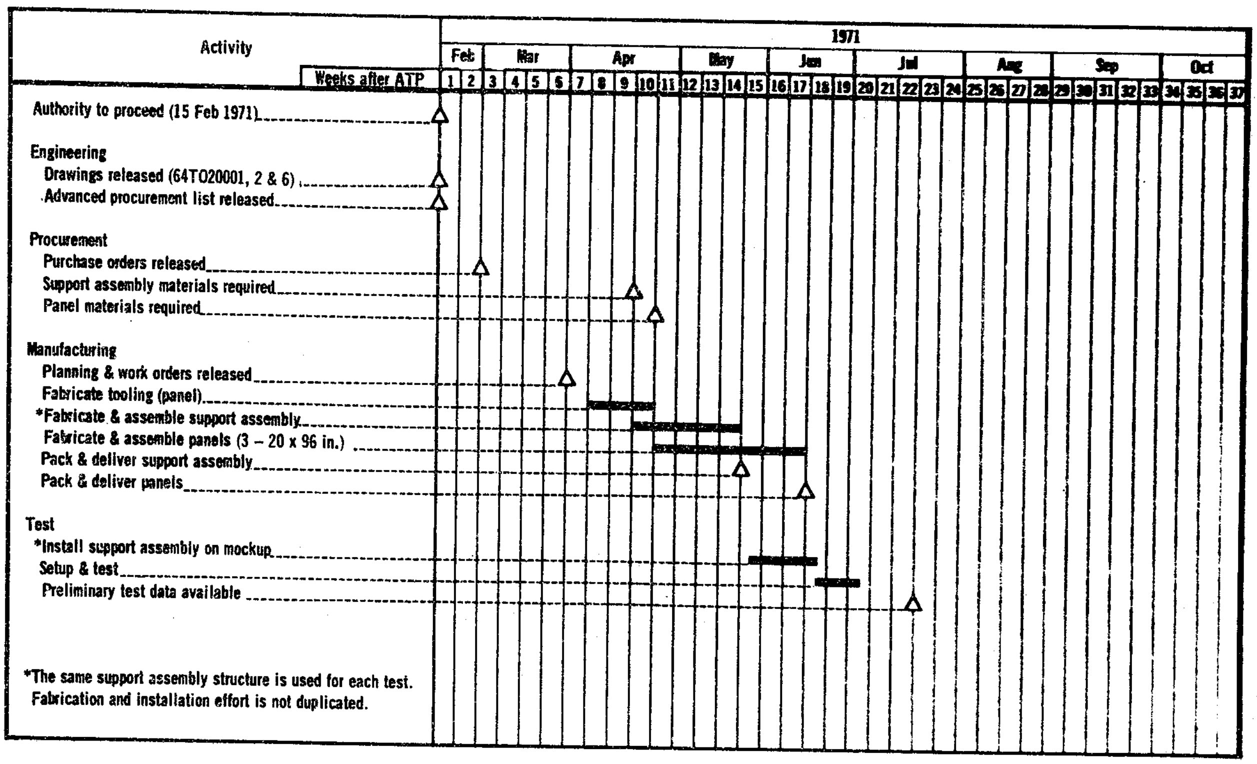

FIGURE 85 TEST PLAN 4 SCHEDULE
(METALLIC PANEL ASSEMBLY - PI-STRAP)

TEST PLAN 5

(a) INSTALLATION - Install nine, 20 by 20 inch, HCF keyway panel assemblies (MDAC drawing 64T020004) to the mockup in accordance with MDAC drawing 64T020001, view B, and procedures described in figure 86. Monitor individual maintenance task functions with VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 87. Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace a simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 88. Monitor individual maintenance task functions with VTR system.

(d) REPAIR - Repair in place simulated damaged panel on mockup in accordance with figure 89. Monitor individual maintenance task functions with VTR system.

(e) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 90. Monitor test as required with VTR system.

(f) REMOVE AND REPLACE HEATED PANELS - Remove and replace middle row of HCF panels from mockup in accordance with figure 91. Monitor individual maintenance task functions with VTR system.

(g) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (f) with the VTR system and event recording system.

(h) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task function schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 92.

FIGURE 86 MAINTENANCE TASK SCHEDULE A-5

MAINTENANCE TASK SCHEDULE- A-5

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Install TPS Test Panels NOTE: Exercise care in handling of HCF TPS test panels to prevent damage.			
1. Procure (9) HCF test panels and associated hardware from storage. Transport HCF test panels to the mockup area.	0.15	3	9 HCF panel assy - 64T020004-1 3 Spacer Assy - 64T020004-3 6 bolts - 3M400-3-180-6 1 panel dolly
2. Install one row of HCF test panels (3) and position the panels on the mockup in accordance with configuration arrangement found in MDAC Dwg. 64T020001. Match up keyways for installation. Move panel approximately .75 inch or until spring loaded plunger engages the panel positioning slot. Record serial numbers and location of panels.	0.25	1	
3. Position and align the test panel spacer assy. Install 2 spacer assy attaching fasteners. NOTE: Exercise care to prevent damage to HCF panel during installation and torqueing of the attaching fasteners.	0.30	1	1 spacer assy - 64T020004-3 2 bolts 3M400-3-180-6 1 pneumatic wrench

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MAINTENANCE TASK SCHEDULE- A-5

- TASK FUNCTION: INSTALLATION
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
4. Interlock interface between HCF panel/spacer by turning locking mechanism (located in center of spacer assy) 90 degrees.	0.35	1	1 Allen head wrench
5. Torque the (2) spacer assy attaching fasteners.	0.40	1	1 torque wrench
6. Perform Steps 2 through 5 on the remaining HCF test panels.			
7. Visually inspect the HCF spacer assy attaching fastener installation.	0.45	1	1 flashlight
8. Visually inspect the complete panel installation.	0.50	1	1 flashlight

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MAINTENANCE TASK SCHEDULE- B-5

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of HCF TPS Test Panels			
1. Using a flashlight, visually inspect the entire area of the HCF TPS test panel for dents, abrasions, pit marks, erosion, and deterioration. Record panel serial number and location.	0.05	1	1 HCF panel assy - 64T020004 -1 1 flashlight 1 inspection mirror
2. Visually inspect HCF test panel coating for condition, obvious damage, and proper coverage.	0.10	1	1 flashlight 1 inspection mirror
3. Visually inspect the spacer assy for damage, proper alignment and installation.	0.15	1	1 flashlight 1 inspection mirror
4. Visually inspect HCF test panel edges for obvious damage, deterioration, proper alignment, and distortion. NOTE: Any damage of a magnitude affecting the integrity of the substrate panel will warrant the removal of the HCF TPS test panel assembly for further inspection and repair.	0.20	1	1 flashlight 1 inspection mirror

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FIGURE 87 MAINTENANCE TASK SCHEDULE B-5

FIGURE 88 MAINTENANCE TASK SCHEDULE C-5

MAINTENANCE TASK SCHEDULE- C-5

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove HCF Test Panel (Center)			
1. Disengage HCF panel/spacer interface interlock by turning locking mechanism (located in center of spacer assy) 90 degrees.	0.05	1	1 allen head wrench
2. Remove the spacer assy attaching fasteners.	0.15	1	2 bolts - 3M400-3-180-6 1 pneumatic wrench
3. Remove the spacer assy.	0.20	1	
4. Depress the spring loaded plunger and maneuver test panel approximately .75 inch to clear attaching keyway. Move test panel free of the test fixture.	0.25	1	1 HCF panel assy - 64T020004-1
Inspection			
5. Visually inspect the test panel to determine extent of damage and repair required. Record findings.	0.30	1	1 flashlight 1 inspection mirror
6. Place test panel on a panel storage rack.	0.35	1	1 storage rack
7. Visually inspect spacer assy for condition and record findings.	0.40	1	1 flashlight

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MAINTENANCE TASK SCHEDULE- C-5

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
8. Visually inspect spacer assy associated hardware for condition and record findings.	0.45	1	1 flashlight
9. Visually inspect support structure on the mockup for condition and record findings.	0.50	1	1 flashlight
10. Replace HCF test panel in the center location on the support structure. Matchup keyways for installation. Move test panel approximately .75 inch or until spring loaded plunger engages the panel positioning slot and record findings.	0.55	1	
11. Position and align spacer assy on test panel and install attaching fasteners and record findings.	0.60	1	2 bolts - 3M400-3-180-6 1 pneumatic wrench
12. Interlock interface between HCF panel/spacer by turning locking mechanism (located in center of spacer assy) 90 degrees.	0.65	1	1 allen head wrench
NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.			

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MAINTENANCE TASK SCHEDULE- C-5

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
13. Torque the (2) spacer assy attaching fasteners.	0.70	1	1 torque wrench
14. Visually inspect the spacer assy attaching fastener installation.	0.75	1	1 flashlight
15. Visually inspect the complete panel installation.	0.80	1	1 flashlight 1 inspection mirror

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FIGURE 89 MAINTENANCE TASK SCHEDULE D-5

MAINTENANCE TASK SCHEDULE- D-5

- TASK FUNCTION REPAIR
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
1. Locate simulated damaged HCF test panel.	0.10	1	1 flashlight
2. Using a grinding wheel, grinding disc and a sharp putty knife, remove the HCF material from the test panel down to the fiberglass panel support bond line.	1.10	2	1 wheel grinder 1 disc grinder 1 putty knife
3. Clean the bonding agent from the fiberglass panel support using methyl, ethyl ketone. After panel support is clean and free of any foreign material, cover panel support with clean cloth to prevent contamination.	1.25	1	
4. Procure a serviceable HCF plug, sized to fit damaged area.	1.30	1	
5. Remove cloth cover from the panel support. Apply primer DC #1203 to the panel support and the bond side of the HCF plug. A thin film and only one coat is required. Allow primer to dry for a minimum of 1 hour with relative humidity at 50%.	1.40	1	
6. Apply a small quantity of DC #3145 adhesive sealant to the fiberglass panel support bonding surface and spread with a spatula or brush to a thickness of 10 to 30 mils over the entire contact area. NOTE: It is not necessary to apply adhesive to both surfaces to be bonded.	1.55	1	

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MAINTENANCE TASK SCHEDULE- D-5

- TASK FUNCTION REPAIR
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
7. Align and join the HCF plug to the fiberglass panel support immediately (within 10 minutes) after spreading the adhesive. Press the parts firmly together with finger pressure using a progressive action starting at one end so air will be excluded from the joint. NOTE: Allow a 24 hour (minimum) air cure period before handling or stressing the bonded joint. Under normal conditions of temperature (75°F) relative humidity above 20% the bonded parts will cure to handle in 24 hours. Full cure will develop in 2 to 3 days.	1.60	1	
8. Remove the excess adhesive and any residue which may have accumulated.	1.65	1	
9. Visually inspect HCF plug for proper installation.	1.70	1	1 flashlight
10. Using x-ray method or microwave tester procedure check the HCF plug installation for voids in the adhesive bond.	2.70	2	1 x-ray unit or 1 microwave tester

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FIGURE 90 MAINTENANCE TASK SCHEDULE E-5

MAINTENANCE TASK SCHEDULE- E-5

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
<u>Environmental Simulation Test</u>			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 18 thermocouples
2. Position the test fixture so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	1 test fixture
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and test fixture.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
<u>Thermal Test Environment</u>			
6. A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to between 2200 and 2400°F in approximately 350 seconds. This surface temperature shall then be maintained for an	2.3	2	

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MAINTENANCE TASK SCHEDULE- E-5

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
additional 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required.			

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FIGURE 91 MAINTENANCE TASK SCHEDULE F-5

MAINTENANCE TASK SCHEDULE- F-5

- TASK FUNCTION: REMOVE HEATED PANELS
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Heated TPS Test Panel			
1. Disengage HCF panel/spacer interface interlock by turning locking mechanism (located in center of spacer assy) 90 degrees.	0.05	1	1 allen head wrench
2. Remove the (2) spacer assy attaching fasteners.	0.15	1	2 bolts - 3M400-3-180-6 1 pneumatic wrench
3. Remove the spacer assy.	0.20	1	
4. Depress the spring loaded plunger and maneuver center test panel approximately .75 inch to clear attaching keyway. Move test panel free of the test fixture.	0.25	1	1 HCF panel assy - 64T020004-1
5. Place heated test panel and associated hardware on a storage rack.	0.30	1	1 storage rack
Inspection			
6. Visually inspect panel support structure and record findings.	0.35	1	1 flashlight 1 inspection mirror

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MAINTENANCE TASK SCHEDULE- F-5

- TASK FUNCTION: REMOVE HEATED PANELS
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Install New TPS Test Panel			
7. Transport a new HCF test panel and associated hardware from storage area to the test fixture	0.40	1	1 HCF panel assy - 64T020004-1
8. Visually inspect new test panel and associated hardware for condition and record findings.	0.45	1	1 flashlight 1 inspection mirror
9. Place the HCF test panel in the center location on the test fixture. Matchup keyways on the test fixture and test panel. Move test panel approximately .75 inch or until spring loaded plunger engages the panel positioning slot and record findings.	0.50	1	1 HCF panel assy - 64T020004-1
10. Position and align spacer assy on test panel and install attaching fasteners (2). Record findings.	0.55	1	1 spacer support - 64T020004-3 2 bolts - 3M400-3-180-16 1 pneumatic wrench
11. Interlock interface between HCF panel/spacer by turning locking mechanism (located in center of spacer assy) 90 degrees.	0.60	1	1 allen head wrench
NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.			

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MAINTENANCE TASK SCHEDULE- F-5

- TASK FUNCTION REMOVE HEATED PANELS
- HEAT SHIELD TYPE HCF
- ATTACH CONCEPT KEY/KEYWAY ASSEMBLIES (MDAC DWG. 64T020004)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 … 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
12. Torque the (2) spacer assy attaching fasteners.	0.65	1	1 torque wrench
13. Visually inspect the spacer assy attaching fastener installation.	0.70	1	1 flashlight 1 inspection mirror
14. Visually inspect the complete panel installation.	0.75	1	1 flashlight 1 inspection mirror

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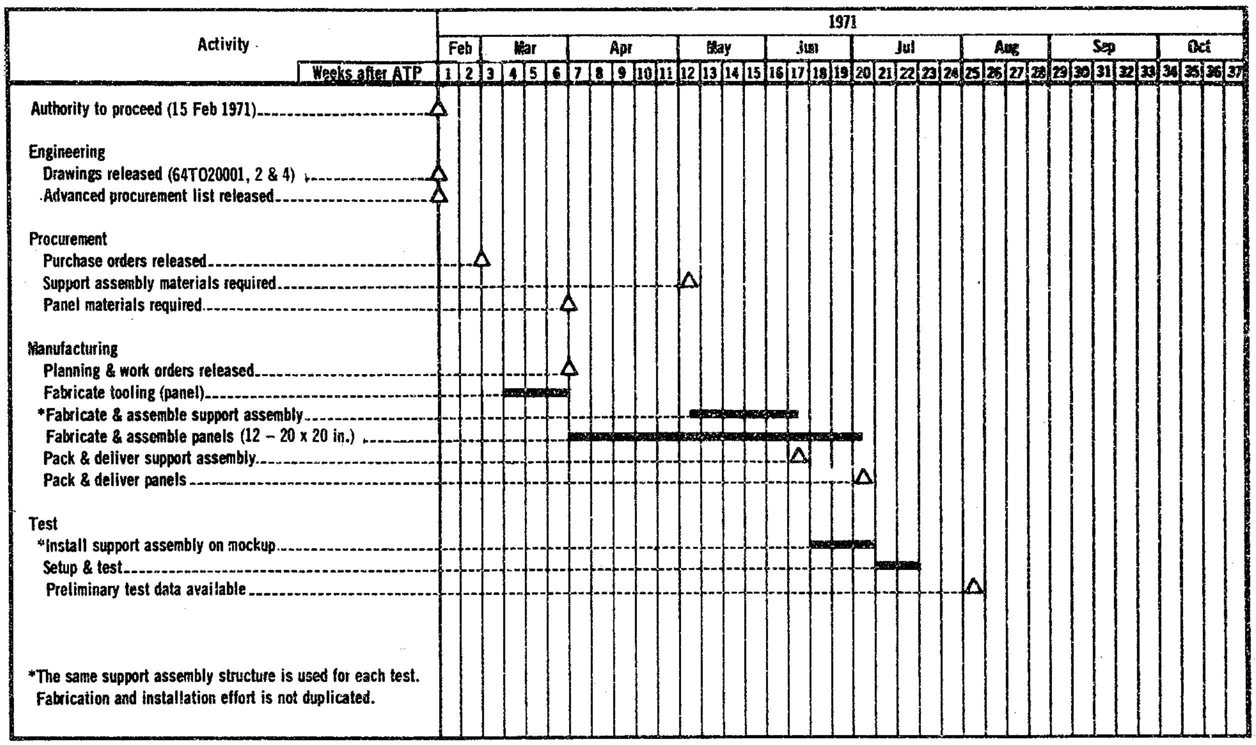

FIGURE 92 TEST PLAN 5 SCHEDULE
(HCF PANEL ASSEMBLY - KEYWAY ATTACH)

TEST PLAN 6

(a) INSTALLATION - Install nine, 20 by 20 inch, metallic edge fastener panel assemblies (MDAC drawing 64T020005) to the mockup in accordance with MDAC drawing 64T020001, view G, and procedures described in figure 93. Monitor individual maintenance task functions with VTR system.

(b) INSPECTION - Inspect TPS panel installation in accordance with figure 94. Monitor individual maintenance task functions with VTR system.

(c) REMOVE AND REPLACE - Remove and replace simulated damaged panel (center panel, MDAC drawing 64T020001) in accordance with figure 95. Monitor individual maintenance task functions with VTR system.

(d) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 96. Monitor test as required with VTR system.

(e) INSPECTION - Inspect TPS panel installation in accordance with figure 97. Monitor individual maintenance task functions with VTR system.

(f) REMOVE AND REPLACE - Remove and replace center heated test panel in accordance with figure 98. Monitor individual maintenance task function with VTR system.

(g) ENVIRONMENTAL TEST - Environmentally temperature test installed panels (MDAC drawing 64T020001) in accordance with figure 99. Monitor test as required with VTR system.

(h) INSPECTION - Inspect TPS panel installation in accordance with figure 100. Monitor individual maintenance task functions with VTR system.

(i) REMOVE AND REPLACE - Remove and replace middle row of test panels (MDAC drawing 64T020001) in accordance with figure 101. Monitor individual maintenance task functions with VTR system.

(j) TEST DATA EVALUATION - Evaluate test data obtained in steps (a) through (i) with VTR system and event recording system.

(k) DOCUMENTATION - Compare test data with previously estimated manpower and elapsed time requirements given in appropriate maintenance task function schedules. Note and assess deviations. Transmit a complete history of events to NASA-LRC in the form of revised task analyses for those configurations tested on mockup.

Time-phased activities and milestone events for this experimental plan are shown in figure 102.

MAINTENANCE TASK SCHEDULE-A-6

- TASK FUNCTION INSTALLATION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Install TPS Test Panels			
1. Transport (9) radiative test panels and associated hardware from the storage area to the mockup area.	0.10	2	9 radiative panel assy. - 64T020005-1 54 shoulder bolts - 3M400-3-76-6 54 washers- 69T020005-19
2. Position one of the test panels on the test fixture. Record location and serial number of test panels. NOTE: Exercise care during installation to prevent damage to panel joints.	0.15	1	
3. Install (6) test panel attaching fasteners. NOTE: Perform steps 2 thru 3 on the remaining 8 TPS test panels.	0.20	1	1 high torque screwdriver
4. Torque (54) test panel attaching fasteners.	0.65	1	1 torque wrench with high torque screwdriver adapter
5. Visually inspect test panel and attaching fastener installation.	0.75	1	1 flashlight 1 inspection mirror

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FIGURE 93 MAINTENANCE TASK SCHEDULE A-6

MAINTENANCE TASK SCHEDULE- B-6

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 · 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of TPS Test Panels			
1. Using a flashlight and mirror, visually inspect entire area of the radiative test panels for dents, abrasions, pit marks, erosion, and deterioration. Record test panel serial number and location.	0.05	1	1 flashlight 1 inspection mirror
2. Visually inspect panel edges for damage and distortion.	0.10	1	1 flashlight 1 inspection mirror
3. Visually inspect test panel longitudinal panel joints for distortion, excessive gapping, and chafing.	0.15	1	1 flashlight 1 inspection mirror
4. Check test panel for looseness and clearance under shims.	0.20	1	1 pair gloves 1 feeler gage
5. Visually inspect test panel attaching fasteners for burring of the tool slots.	0.25	1	1 flashlight 1 inspection mirror

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FIGURE 94 MAINTENANCE TASK SCHEDULE B-6

FIGURE 95 MAINTENANCE TASK SCHEDULE C-6

MAINTENANCE TASK SCHEDULE-C-6

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: EDGE FASTENER (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 … 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove Simulated Damaged Test Panel			
NOTE: Exercise care in removing panel fasteners to prevent damage to the coated panel surface.			
1. Remove the (6) attaching fasteners from center panel. (Ref. MDAC DWG. 64T020001)	0.05	1	1 high torque screwdriver 6 shoulder bolts - 3M400-3-76-6 6 washers 64T020005-19
2. Maneuver the center test panel free from the longitudinal joints and remove test panel from support structure.	0.10	1	1 radiative panel assy - 64T020005-1
Inspection			
3. Visually inspect the test panel and record findings.	0.15	1	1 flashlight 1 inspection mirror
4. Visually inspect test panel attaching fasteners and record findings.	0.20	1	1 flashlight
Reinstall Center TPS Test Panel			
5. Position test panel into the center location on the test fixture and maneuver test panel to align the longitudinal panel	0.50	1	1 test fixture 64T020002

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MAINTENANCE TASK SCHEDULE- C-6

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: HCF
- ATTACH CONCEPT: EDGE FASTENER (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 … 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. (Continued) joints. Check alignment of the attaching fastener holes and record findings.			
6. Install the (6) test panel attaching fasteners.	0.55	1	1 high torque screwdriver 6 shoulder bolts - 3M400-3-76-6 6 washers - 64T020005-19
7. Torque the (6) test panel attaching fasteners.	0.60	1	1 torque wrench with high torque screwdriver adapter
8. Visually inspect the test panel and fastener installation.	0.65	1	1 flashlight 1 inspection mirror

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FIGURE 96 MAINTENANCE TASK SCHEDULE D-6

MAINTENANCE TASK SCHEDULE- D-6

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY. (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 2 thermocouples
2. Position the test fixture so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	1 test fixture
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and test fixture.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50		
Thermal Test Environment			
6. A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to 1800°F in approximately 350 seconds. This surface temperature shall then be maintained for an	2.3	2	

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MAINTENANCE TASK SCHEDULE- D-6

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY. - (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) additional 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required. Repeat mission cycle TBD times.			

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MAINTENANCE TASK SCHEDULE- E-6

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENERS ASSY (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS,	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Inspection of TPS Test Panel			
1. Using a flashlight visually inspect the heated radiative panels for obvious damage, erosion and deterioration. Record findings.	0.05	1	1 flashlight
2. Visually inspect test panels for evidence of distortion, overheating, dents, scratches and abrasions. Record findings.	0.10	1	1 flashlight
3. Visually inspect the attaching fasteners (shoulder bolts) and shims for evidence of overheating and burring of the tool slots on the bolts. Record findings.	0.10	1	1 flashlight
4. Visually inspect the panel joints for distortion, excessive gapping and chafing. Record findings.	0.15	1	1 flashlight
5. Check test panels for excessive looseness and record findings.	0.20	1	1 flashlight

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FIGURE 97 MAINTENANCE TASK SCHEDULE E-6

FIGURE 97 MAINTENANCE TASK SCHEDULE E-6

FIGURE 98 MAINTENANCE TASK SCHEDULE F-6

MAINTENANCE TASK SCHEDULE- F-6

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY - (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove One Heated TPS Test Panel			
1. Record serial number and location of the TPS test panel to be removed.	0.05	1	
2. Remove the (6) attaching fasteners on the test panel selected.	0.10	1	1 high torque screwdriver 6 shoulder bolts 3M400-3-76-6 6 washers - 64T020005-19
3. Maneuver the test panel free of the longitudinal panel joints and remove test panel from its location on the test fixture. Record findings.	0.15	1	1 radiative panel assy - 64T020005-1
Inspection of Heated TPS Test Panel			
4. Visually inspect test panel for obvious damage, overheating, deterioration and distortion. Record findings.	0.20	1	1 flashlight 1 inspection mirror
5. Visually inspect test panel attaching fasteners for condition and record findings.	0.30	1	1 flashlight
6. Visually inspect the test panel support structure on the mockup for condition and record findings.	0.35	1	1 flashlight 1 inspection mirror
Replace Heat Tested TPS Test Panel			
7. Position test panel on the test fixture. Align longitudinal panel joints. Check alignment of attaching fastener holes and record findings.	0.40	1	1 radiative panel assy - 64T020005-1

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MAINTENANCE TASK SCHEDULE- F-6

- TASK FUNCTION REMOVE AND REPLACE
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY - (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
8. Install the (6) test panel attaching fasteners and record findings.	0.45	1	1 high torque screwdriver 6 shoulder bolts 3M400-3-76-6 6 washers - 64T020005-19
9. Torque the (6) test panel attaching fasteners.	0.50	1	1 torque wrench with a high torque screwdriver adapter
10. Visually inspect the test panel attaching fastener installation.	0.55	1	1 flashlight
11. Visually inspect TPS test panel installation.	0.60	1	1 flashlight 1 inspection mirror

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FIGURE 99 MAINTENANCE TASK SCHEDULE G-6

MAINTENANCE TASK SCHEDULE-G-6

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY. (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Environmental Simulation Test			
1. Assure that all required environmental simulation test equipment is operational and available in the test area.	0.15	1	1 mobile temperature simulator unit (gas) 8 thermocouples
2. Position the test fixture so that the test panels are in the right attitude for environmental simulation testing.	0.20	1	1 test fixture
3. Maneuver the mobile temperature simulator unit (gas) into the proper position for testing. Lock brakes to maintain position.	0.25	1	
4. Install the required thermocouples on test panels and test fixture.	0.45	1	
5. Activate the mobile temperature simulator unit (gas) for testing.	0.50	1	
Thermal Test Environment			
6. A representative entry temperature environment will be simulated on the external surface of the test panel by use of a gas heater device described in Task 5, Part I, of this report. The temperature profile shall consist of raising the external surface temperature of the test specimen, starting at room temperature, to 1800°F in approximately 350 seconds. This surface temperature shall then be maintained for an	2.3	2	

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MAINTENANCE TASK SCHEDULE- G-6

- TASK FUNCTION ENVIRONMENTAL TEST
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY. (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. (Continued) additional 350 seconds. At the end of this time the gas heater will be shut down and natural cooling of the panel allowed to take place. This temperature profile represents one entry mission cycle. This mission cycle will be repeated until periodic inspection reveals a degradation or until refurbishment maintenance would be required. Repeat mission cycle TBD times.			

NUMBER FOLLOWING TIME BAR IS MANLOADING

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MAINTENANCE TASK SCHEDULE- H-6

- TASK FUNCTION INSPECTION
- HEAT SHIELD TYPE METALLIC
- ATTACH CONCEPT EDGE FASTENER ASSY. (MDAC 64T020005)
- SINGLE PANEL SIZE 20" X 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
<u>Inspect TPS Test Panels</u>			
1. Select a heat tested test panel for inspection. Record test panel serial number and location.	Time Totaled at Step 6		1 radiative panel assy. - 64T020005-1
2. Using a flashlight and magnifying glass visually inspect the entire panel area for evidence of over heat condition and record findings.			1 flashlight 1 3" magnifying glass
3. Visually inspect the test panel for evidence of distortion due to buckling. Record findings.			1 flashlight
4. Visually inspect the test panel coating for condition and record findings.			1 flashlight 1 three inch magnifying glass
5. Visually inspect the test panel joints for excessive gapping or signs of chafing and record findings.			1 flashlight 1 inspection mirror
6. Visually inspect test panel attaching fasteners for evidence of overheating and deterioration and record findings.	0.05 Total Per Panel	1	1 flashlight

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FIGURE 100 MAINTENANCE TASK SCHEDULE H-6

FIGURE 101 MAINTENANCE TASK SCHEDULE I-6

MAINTENANCE TASK SCHEDULE- I-6

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: EDGE FASTENER ASSY. (MDAC 64T020005)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
Remove TPS Test Panel			
1. Select three panels that have not been previously removed during the radiative panel testing. Record panel serial numbers and locations.	0.05	1	3 radiative panel assy - 64T020005-1
2. Remove the (6) attaching fasteners on one of the test panels selected.	0.10	1	1 high torque screwdriver 18 shoulder bolts - 3M400-3-76-6 18 washers - 64T020005-19
3. Maneuver the TPS test panel free of the longitudinal panel joints and remove test panel from its location on the test fixture. Record findings.	0.15	1	
Inspection of TPS Test Panel			
4. Visually inspect test panels for obvious damage, overheating, deterioration, and distortion and record findings.	0.20	1	1 flashlight 1 inspection mirror
5. Visually inspect test panel attaching fasteners for condition and record findings.	0.25	1	1 flashlight
6. Visually inspect test panel associated insulation for condition and record findings.	0.30	1	1 flashlight 1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

MAINTENANCE TASK SCHEDULE- I-6

- TASK FUNCTION: REMOVE AND REPLACE
- HEAT SHIELD TYPE: METALLIC
- ATTACH CONCEPT: EDGE FASTENER ASSY (MDAC DWG. 64T020005)
- SINGLE PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
7. Visually inspect the test panel support structure on the test fixture for condition and record findings.	0.35	1	1 flashlight 1 inspection mirror
Replace TPS Test Panel			
8. Position a new test panel on the test fixture. Align longitudinal panel joints. Check alignment of attaching fastener holes and record findings.	0.40	1	3 radiative panel assy - 64T020005-1
9. Install the (6) test panel attaching fasteners on one panel and record findings.	0.45	1	1 pneumatic screwdriver 6 shoulder bolts - 3M400-3-76-6 6 washers --64T020005-19
10. Torque the (6) test panel attaching fasteners. NOTE: Repeat Steps 2 thru 10 for the other (2) panels.	0.50	1	1 torque wrench with high torque screwdriver adapter.
11. Visually inspect the test panel and attaching fastener installation.	0.60	1	1 flashlight

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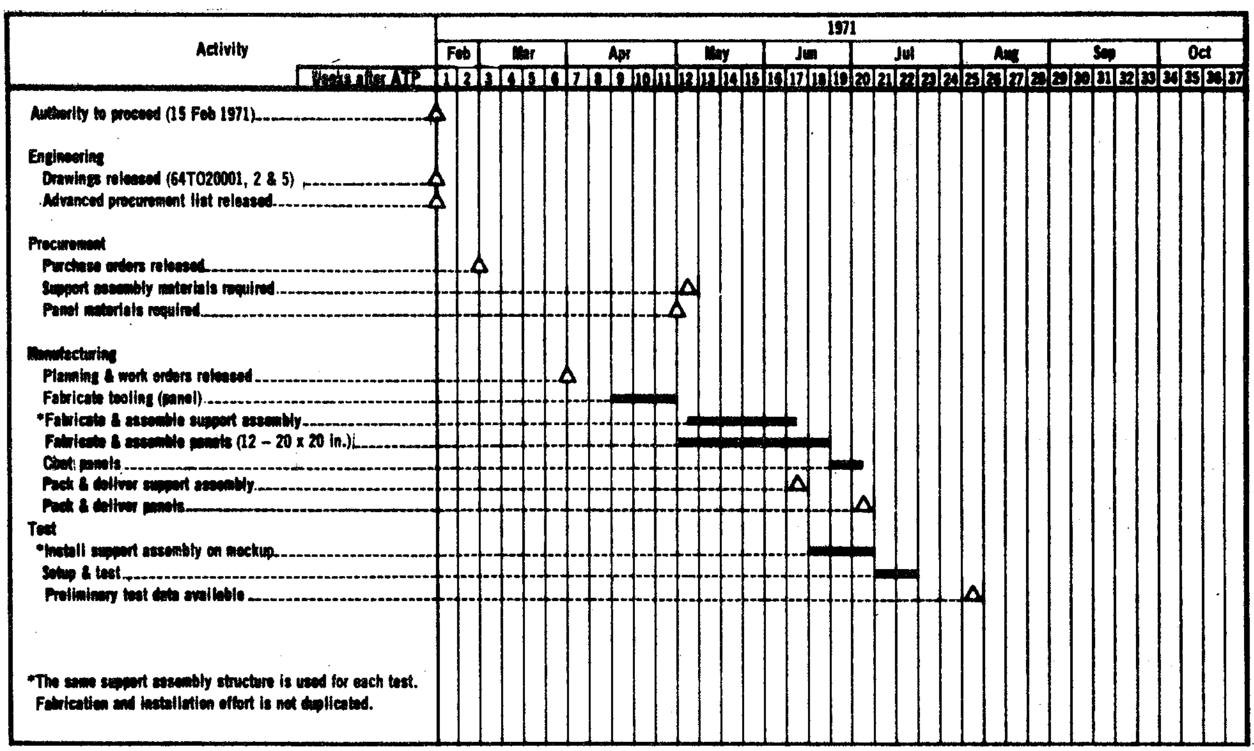

FIGURE 102 TEST PLAN 6 SCHEDULE
(METALLIC PANEL ASSEMBLY - EDGE FASTENER)

CONCLUSIONS

Several significant conclusions may be drawn from this study. These are summarized below.

1. Minimum weight considerations favor integral tanks; however, tank simplicity, replaceability, and maintenance considerations suggest nonintegral tanks.

2. Primary structure can be described as either endoskeletal (those arrangements where primary structural elements are at some distance inside of the outer body contour) or exoskeletal (those elements which follow closely the outer moldline of the vehicle). The exoskeletal structure representative of current aircraft design has been studied for many years; however, little is known about the maintenance operations associated with an endoskeletal structure, thus, characteristic refurbishment data is needed in this area.

3. In the hot structure approach, where the primary structure skin also serves as a heat sink, titanium is the most likely material for construction.

4. For the cold structure approach, wherein the structure is thermally protected, aluminum is the most likely candidate material for construction.

5. Inherent and critical in the refurbishment concept is an attachment method which allows easy access to internal subsystems so as to minimize removal, repair, and inspection times of various components.

6. Attachment concepts chosen for analysis had one or more of the following attributes: simplicity, accessibility, reliability, technological currency, interchangeability, and easy replacement, inspection, and repair.

7. Ablative heat shield attachment techniques lend themselves readily to adhesive bonding, mechanical fasteners, or combinations thereof. Techniques considered included bonded attach, mechanical fastener attach, pi-strap attach, multiple mechanical fastener attach, and key/keyway attach.

8. Unlike ablative heat shields, metallic heat shields rely primarily on the use of some sort of mechanical fastener. Flush fastener attach and pi-strap attach techniques were considered.

9. Primary attachment techniques for hardened compacted fibers (HCF) favor bonding although most ablative heat shield attachment techniques are applicable to HCF heat shield systems.

10. Either of the three types of heat shield panel systems considered (i.e., ablative, metallic, and nonablative-nonmetallic) can be removed and replaced without seriously affecting refurbishment of the other.

11. Optimum panel length for all materials under minimum weight considerations is approximately 20 inches. Practical panel widths range from 20 to 120 inches.

12. In general, attachment techniques specified for basic heat shield systems may be applied in specialized areas of the vehicle such as body nose tip, fuselage chines, and horizontal control surface leading edges.

13. Removal and replacement cost estimates indicate that manpower requirements decrease as panel size increases whereas elapsed time increases as panel size increases.

14. In the case of the removal and replacement of the ablative and HCF heat shield systems there is little cost advantage in refurbishment of panels greater than 20 square feet. In the case of metallic heat shield systems the breakeven point is between 40 and 60 square feet.

15. Although the removal and replacement requirements for the so-called special areas (chines and leading edges) are relatively small, on a unit basis, they could have a significant influence on overall vehicle refurbishment cost when considered for a specific configuration and program definition.

16. Operational maintenance labor costs are very much dependent on the type of heat shield system and attachment concept used. Variations up to $8 million for a 100 flight life can be realized depending on the concept considered.

17. Design and cost uncertainties are best defined under the following categories: concept feasibility, material effects, fastener removal and installation, size limitations, tool and equipment configurations, and repair procedures.

18. All of the questions raised concerning design and cost uncertainties can be answered by implimentation of the experimental test program as outlined.

19. A limited amount of environmental temperature simulations is required to create a realistic maintenance environment.

20. The use of video tape and event recording systems provide the most efficient method of recording and analyzing various types of maintenance functions.

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APPENDIX A

COST ESTIMATE TASK ANALYSES

TASK ANALYSIS NO. 1

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative - ULD

PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1

PANEL LOCATION: Bottom

PANEL SIZE: Small: 20 x 20 inches

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Ablative Material from Vehicle NOTE: Due to the extensive grinding and cutting operation required to remove the ablative material from the double face honeycomb on the vehicle, the use of goggles/eye shields, breathing mask and vacuum cleaner is mandatory safety equipment.			
1. Using grinding wheel, sanding disc and a suitable knife like cutting tool, remove the ablative material from the structural double face honeycomb on the vehicle, down to the bond line.	1.00	1	1 grinding wheel 1 sanding disc 1 cutting device 2 goggles/face shield 2 respirator masks 1 vacuum cleaner
2. Clean the structural double face honeycomb with methyl ethyl ketone (MEK) to remove debris from the surface.	1.20	1	1 gal. methyl ethyl ketone (MEK)
o Inspection			
3. Visually inspect surface of structural honeycomb for damage resulting from ablative material removal.	1.25	1	1 flashlight 1 inspection mirror
4. Cover the cleaned surface with anti-tarnish tissue	1.30	1	1 box anti-tarnish tissues

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TASK ANALYSIS NO. 1

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative - ULD

PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1

PANEL LOCATION: Bottom

PANEL SIZE: Small: 20 x 20 inches

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle			
5. Transport ablative material segment to the vehicle.	1.40	1	
6. Thoroughly clean all surfaces to be bonded by wiping with a clean cloth dampened with cleaning solvent. Wipe dry with a clean, dry cloth before evaporation of the solvent. Always clean an area wider than the width of the finally applied adhesive. It is essential that clean cloths and clean solvent be used in the cleaning operation. Do not use contaminated materials. Repeat cleaning operations until a clean, oil free surface is assured. Cleaned surfaces shall be allowed to dry 3 to 5 minutes before the application of any bonding material. Adhesive should be applied as soon as possible after cleaning. Do not allow handling or storage between the cleaning and bonding operations.	1.45	1	1 gal. methyl ethyl ketone

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TASK ANALYSIS NO. 1

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle			
7. Before applying adhesive apply a single uniform thin brush-coat of SS-4004 Silicone Primer to clean mating surfaces. Apply primer to cover an area wider than the width of the finally applied adhesive. Allow primer to air dry a minimum of 30 minutes at ambient temperature prior to applying adhesive. A longer dry time shall be allowed if there are wet spots evident in the primer coat. Remove the primer and repeat the priming procedure whenever the primer becomes contaminated or when the RTV silicone adhesive is not applied within 72 hours after priming. Use applicable cleaning procedure to remove primer.	1.65	1 1	1 gal. silicone primer SS-4004
8. Mix RTV-90 in the weight ratio of 1 per cent Silicure L-24 Catalyst to weight of base compound. It is imperative that the accelerators be thoroughly dispersed throughout the base compounds. Stirring and folding in the accelerator must be done	1.80	1	RTV-90 silicure, L-24 catalyst

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 1

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle (Cont.)			
slowly to avoid excessive air entrapment. Approximately 5 to 7 minutes of hand mixing or blending with a spatula is normally required to obtain uniformity.			
9. Apply adhesive to one of the mating surfaces using a sealant gun. Cover entire surface to be bonded with a layer of material approximately 25 mils thick.	1.95	1	
Place the surfaces to be bonded together and effect the bond using even contact pressure and squeezing out any excess adhesive. Care should be taken to insure that no air is trapped between the mating surfaces. The adhesive has sufficient substance to support the bonded surface during cure but if a vertical bond or similar condition is to be made tooling should be used to hold the bond together until the adhesive is tack-free.			1 air bag 1 air bag support stand
The adhesive shall be cured to tack-free, firm, rubbery condition prior to trimming (8 hrs.) Remove the excess adhesive by scraping with a plastic scraper.			1 plastic scraper

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (11 – 12)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle (Cont.)			
9. (Cont.) Apply adhesive to one of the mating surfaces using a sealant gun. Cover entire surface to be bonded with a layer of material approximately 25 mils thick.	2.00	1	RTV 90 adhesive silicure, L-24 catalyst
Place the surfaces to be bonded together and effect the bond using even contact pressure and squeezing out any excess adhesive. Care should be taken to insure that no air is trapped between the mating surfaces. The adhesive has sufficient substance to support the bonded surface during cure but if a vertical bond or similar condition is to be made tooling should be used to hold the bond together until the adhesive is tack-free.			1 air bag 1 air bag support stand
The adhesive shall be cured to tack-free, firm, rubbery condition prior to trimming (8 hrs.) Remove the excess adhesive by scraping with a plastic scraper.			1 plastic scraper
o Inspection			
10. Visually inspect ablative material for proper installation	2.05	1	1 flashlight
11. Set up microwave tester	2.55	1	1 microwave tester
12. Microwave test panel for bondline integrity	3.05	1	1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: 2Small: 20 x 20 inches

TASK ANALYSIS NO. 1

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (12 – 20)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle (Cont.)			
13. Using sealant gun, fill in void on the perimeter of panel	3.25	1	1 sealant gun elastomeric adhesive (DC #3145)
14. Place platen over the repair and support with sufficient pressure to compress adhesive smoothly. Allow supported platen to remain in place for 8 hours to allow adhesive to cure.	3.35	1	1 platen 1 air bag 1 air bag support
15. After curing, use sharp edge knife to trim surface of adhesive section flush with surrounding panel.	3.50	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS 21	33	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replace Ablative Material on Vehicle (Cont.)				
16. Apply dispersion coating to adhesive. Allow to cure for 12 hours.	3.60	1		Dispersion coating 1 brush or 1 spray gun
17. Inspect panel sealing operation for proper installation	3.65		1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS HCF Material From Vehicle			
Note: Due to the Extensive grinding and cutting operation required to remove the HCF material from the structural double face honeycomb on the vehicle, the use of goggles/eyeshields, breathing masks and vacuum cleaner is mandatory safety equipment.			1 grinding wheel 1 sanding disc 1 cutting device 2 goggles/face shield 2 respirator masks 1 vacuum cleaner
1. Using a grinding wheel, sanding disc and a suitable knife like cutting tool, remove the HCF material from the structural double face honeycomb on the vehicle, down to the bond line.	1.00	1	1 grind wheel 1 sanding disc 1 cutting device
2. Clean the surface of the structural double face honeycomb with methyl ethyl ketone (MEK) to remove the debris.	1.20	1	1 gal. methyl ethyl ketone (MEK)
3. Cover the cleaned surface with anti-tarnish tissue after cleaning procedure.	1.25	1	1 box anti-tre
o Inspection 4. Inspect the structural double face honeycomb surface for damage deterioration overheating and cleanliness.	1.30	1	1 flashlight 1 insp mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. Recover the structural double face honeycomb surface with the anti-tarnish tissue.	1.35	1	1 box anti-tarnish tissue
o Replacement of HCF Segment on Vehicle			
6. Transport a new HCF segment from the storage area to the vehicle. NOTE: Exercise care in handling the HCF segment (20" x 20" tile) to prevent damage to the exterior coating applied to each tile.	1.45	1	
7. Remove the anti-tarnish tissue from the structural double face honey comb surface of the vehicle.	1.50	1	
8. Make visual check to assure that the structural double face honey comb surface is still clean and free of any foreign matter.	1.55	1	1 flash light
9. Apply a single uniform coat of #1203 silicone primer to the structural double face honeycomb surface and the inside surface of the HCF tile.	1.70	1	1 gal. silicone primer #1203

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small 20" x 20"

TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of HCF Segment on Vehicle - cont'd.			
10. Apply a uniform coat of DC# 3145 approximately 0.010-0.030 inch thick to the bonding surface of the structural double face honey comb surface on the vehicle.	1.80	1	1 gal. adhesive DC#3145
11. Position and align the HCF tile on the vehicle in a manner to prevent as much entrapment of air bubbles as possible.	1.90	1	
12. Roll the outside tile surface with a rubber roller to insure intimate contact at the bond-line and to squeeze out excess adhesive. Work from the center of the tile to the four sides. Allow the assembly to cure at room temperature (65°F to 100°F) for 24 hours before handling. The #3145 will be full cured in 5 to 7 days.	2.00		1 rubber roller

NUMBER FOLLOWING TIME BAR IS MANLOADING

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HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (27 – 28)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of HCF Segment on Vehicle (cont.)			
13. Remove excess cure #3145 with a plastic scraper (45° cutting edge). Exercise care to prevent damage to the HCF tile coating.	2.05	1	1 plastic scraper (45° cutting edge)
14. Visually inspect HCF tile for proper installation.	2.10	1	1 flash light 1 insp. mirror
15. Set up microwave tester	2.60	1	1 microwave tester
16. Microwave test panel for bond-line integrity.	3.10	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (28 – 36)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of HCF Segment on Vehicle (cont)			
17. Using sealant gun, fill in void on the perimeter of panel	3.30	1	1 sealant gun elastomeric adhesive (DC#3145)
18. Place platen over the repair and support with sufficient pressure to compress adhesive smoothly. Allow support platen to remain in place for 8 hours to allow adhesive to cure.	3.40	1	1 platen 1 air bag 1 air bag support
19. After curing, use sharp edge knife to trim surface of adhesive flush with surrounding panel.	3.50	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 2

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (37 – 49)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of HCF Segment on Vehicle (cont)			
20. Apply dispersion coating to adhesive. Allow to cure for 12 hours.	3.60	1	Dispersion coating 1 brush or 1 spray gun
21. Inspect panel sealing operation for proper installation.	3.65	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 3

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (6) panel attaching fastener plugs.	0.05	1	
2. Drill out (6) panel attaching fastener plugs.	0.55	1	1 drill
3. Using a prescribed tool, free panel edges from adjacent panels.	0.60	1	1 edge freeing tool
4. Remove (6) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	0.70	1	1 socket wrench
5. Maneuver the panel free of the vehicle.	0.75	1	1 edge freeing tool
6. Transport panel to storage area for disposition.	0.85	1	
7. Store panel on the prescribed storage rack.	0.90	1	1 panel storage rack
o Inspection			
8. Visually inspect fiberous insulation for damage. Deterioration and signs of overheating.	0.95	1	1 flashlight 1 inspection mirror
9. Remove, replace or repair insulation as required (see task analysis no. 29)			
10. Visually inspect the support hardware for damage deterioration and overheating.	1.00	1	1 flashlight 1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 3

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection/(Cont.)			
11. Visually inspect attaching fasteners for damage, deterioration and overheating.	1.05	1	1 flashlight 1 inspection mirror
o Replacement of TPS Panel			
12. Transport a new panel from storage area to the vehicle.	1.15	1	
13. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	1.20	1	
14. Install the (6) panel attaching fasteners.	1.30	1	1 socket wrench
15. Torque the (6) panel attaching fasteners.	1.35	1	1 torque wrench
16. Visually inspect the panel attaching fastener for proper installation.	1.40	1	1 flashlight 1 inspection mirror
17. Apply a small quantity of RVT 106 adhesive to each of the (6) panel attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs in plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure	1.50	1	RVT 160 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 3

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
Time before handling or stressing joint. Full cure will develop in 2 or 3 days.			
18. Visually inspect attaching fastener plugs for proper installation.	1.55	1	1 flashlight 1 inspection mirror
19. Visually inspect the complete panel installation.	1.60	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 4

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1–2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (26) panel attaching fastener plugs.	0.10	2	
2. Drill out (26) panel attaching fastener plugs.	2.10	4	4 drills
3. Using a prescribed tool, free panel edges from adjacent panels.	2.50	4	4 edge freeing tools
4. Position panel dolly for the panel removal.	2.70	4	1 panel dolly
5. Elevate dolly platform for panel retrieval.	2.90	4	1 panel dolly
6. Lock brakes on the dolly.	3.00	2	1 panel dolly
7. Remove the (24) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	3.40	4	4 socket wrenches
8. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	3.60	4	4 edge freeing tool 1 panel dolly
9. Lower panel dolly platform with panel from the elevated position to the transport position.	3.80	4	
10. Unlock panel dolly brakes.	3.90	2	1 panel dolly
11. Transport panel to the storage area to await disposition.	4.30	4	1 panel dolly
12. Store panel on a prescribed storage rack.	4.50	4	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 4

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2–3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
13. Visually inspect the fibrous insulation for damage, deterioration and signs of overheating.	4.60	2	2 flashlights 2 inspection mirrors
14. Remove, replace or repair insulation as required (see Task Analysis No. 29).			
15. Visually inspect the support hardware for damage, deterioration and overheating.	4.70	2	
16. Visually inspect the attaching fasteners for damage, deterioration and overheating.	4.80	2	
o Replacement of TPS Panel			
17. Load a new panel onto the panel dolly and transport panel to the vehicle.	5.40	4	1 panel dolly
18. Position panel dolly for panel installation.	5.60	4	
19. Elevate panel dolly platform with panel to the install position.	5.80	4	
20. Lock panel dolly brakes	5.90	2	1 panel dolly
21. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	6.10	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical
Fastener Attach Concept #2
PANEL LOCATION Bottom

PANEL SIZE: Medium: 20 x 120 inches

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
22. Install the (26) panel attaching fasteners.	6.50	4	4 socket wrenches
23. Lower the panel dolly. platform to transport position.	6.70	4	1 panel dolly
24. Release panel dolly brakes.	6.80	2	
25. Remove panel dolly from the work area.	7.00	4	
26. Torque the (26) panel attaching fasteners.	7.20	2	2 torque wrenches
27. Visually inspect the panel attaching fasteners for proper installation.	7.40	2	2 flashlights 2 inspection mirrors
28. Apply a small quantity of RTV 106 adhesive to each of the (26) panel attaching fastener plugs with a brush or spatula to a thickness of 10-30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	7.80	4	RTV 160 adhesive
29. Visually inspect plugs for proper operation.	8.00	2	
30. Visually inspect the complete panel installation.	8.20	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 5

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (62) panel attaching fastener plugs.	0.20	4	
2. Drill out (62) panel attaching fastener plugs.	5.20	4	4 drills
3. Using a prescribed tool, free the panel edges from adjacent panel.	6.00	8	8 edge freeing tools
4. Position a panel dolly for the panel removal.	6.40	8	1 panel dolly
5. Elevate dolly platform for panel removal.	6.80	8	
6. Lock brakes on the dolly.	6.90	2	
7. Remove the (62) panel attaching fasteners NOTE: The panel is bonded directly to the fiberglass honyecomb substrate and are removed or replaced as one unit.	8.10	8	8 socket wrenches
8. Maneuver the panel free of the vehicle.and lower panel onto panel dolly.	8.90	8	8 edge freeing tool 1 panel dolly
9. Lower panel dolly platform from the elevated position to the transport position.	9.30	8	1 panel dolly
10. Unlock panel dolly brakes.	9.40	2	
11. Transport panel to the storage area to await disposition.	10.20	8	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 5

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3, 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel (Cont.)			
12. Store panel on a prescribed storage rack.	10.60	8	1 panel storage rack
o Inspection			
13. Visually inspect the fiberous insulation for damage, deterioration and signs of overheating.	11.00	4	4 flashlights 4 inspection mirrors
14. Remove, replace ore repair insulation as required (see Task Analysis No. 29).			
15. Visually inspect the support hardware for damage, deterioration and overheating.	11.40	4	
16. Visually inspect the attach-fasteners for damage, deterioration and overheating.	11.80	4	
o Replacement of TPS Panel			
17. Load a new panel onto the panel dolly and transport panel to the vehicle.	13.00	8	1 panel dolly
18. Position panel dolly for panel installation.	13.40	8	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 5

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
19. Elevate panel dolly platform with panel to the install position.	13.80	8	1 panel dolly
20. Lock panel dolly brakes.	13.90	2	
21. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	14.30	8	
22. Install the (60) panel attaching fasteners.	15.50	8	8 socket wrenches
23. Lower the panel dolly flatform to transport position.	15.90	8	1 panel dolly
24. Release panel dolly brakes.	16.00	2	
25. Remove panel dolly from the work area.	16.40	8	
26. Torque the (60) panel attaching fasteners.	17.00	4	4 torque wrenches
27. Visually inspect the panel attaching fasteners for proper installation.	17.60	4	4 flashlights 4 inspection mirrors
28. Apply a small quantity of RTV 106 adhesive to each of the (60) panel attaching fastener plugs, with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area.	18.80	8	RTV 160 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 5

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
29. Visually inspect plugs for proper operation.	19.20	4	
30. Visually inspect the complete panel installation.	19.60	4	4 flashlights 4 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 6

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o **Removal of TPS Panel**			
1. Locate the (10) pi-strap attaching fastener plugs.	0.05	1	
2. Drill out the (10) pi-strap attaching fastener plugs.	0.75	1	1 drill
3. Using a prescribed tool, free panel edges and pi-strap edges from adjacent panels.	0.85	1	1 edge freeing tool
4. Remove the (10) pi-strap attaching fasteners.	0.95	1	1 socket wrench
5. Remove the associated pi-straps.	1.00	1	1 edge freeing tool
6. Maneuver panel free of vehicle. NOTE: Panel is bonded directly to a fiberglass honeycomb substrate, therefore are removed as a single unit.	1.05	1	
7. Transport panel and associated pi-straps to the storage area to await disposition.	1.15	1	
8. Store panel on prescribed storage rack.	1.20	1	1 panel storage rack
o **Inspection**			
9. Visually inspect fiberglass insulation for damage, overheating and deterioration.	1.25	1	1 flashlight 1 inspection mirror
10. Remove, replace, and repair insulation (as required (See Task Analysis No. 29))			

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 6

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o **Inspection**			
11. Visually inspect all support hardware for damage, deterioration and overheating.	1.30	1	
12. Visually inspect attaching fasteners for damage, deterioration and signs of overheating.	1.35	1	
o **Replacement of TPS Panel**			
13. Transport a new panel with associated pi-straps to the vehicle.	1.45	1	
14. Position panel on the vehicle and align for installation.	1.50	1	
15. Align pi-straps on panel for fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.	1.55	1	
16. Install the (10) pi-strap attaching fasteners.	1.65	1	1 socket wrench
17. Torque the (10) pi-strap attaching fasteners.	1.70	1	1 torque wrench
18. Visually inspect pi-strap attaching fasteners for proper installation.	1.75	1	1 flashlight 1 inspection mirror
19. Apply a small quantity of RTV 106 adhesive to each of the (10) pi-strap attaching fastener plugs with a brush or spatula to a	1.90	1	1 RTV 106 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 6

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
20. Visually inspect pi-strap attaching fastener plugs for proper installation.	1.95	1	1 flashlight 1 inspection mirror
21. Visually inspect the complete panel installation.	2.00	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 7

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate the (28) pi-strap attaching fastener plugs	0.10	2	
2. Drill out the (28) pi-strap attaching fastener plugs	2.10	4	4 drills
3. Using a prescribed tool, free panel edges and pi-strap edges from adjacent panels	2.70	4	4 edge freeing tools
4. Position a panel dolly for the panel removal	2.90	4	1 panel dolly
5. Elevate panel dolly platform for panel removal	3.10	4	
6. Lock brakes on panel dolly	3.20	2	
7. Remove the (28) panel attaching fasteners	3.60	4	4 socket wrenches
8. Remove the associated pi-straps	4.00	4	
9. Maneuver the panel free of the vehicle and lower panel onto panel dolly	4.20	4	4 edge freeing tools 1 panel dolly
10. Lower panel dolly platform with panel from the installed position to the transport position	4.40	4	1 panel dolly
11. Unlock panel dolly brakes	4.50	2	
12. Transport panel with associated pi-straps to a storage area to await disposition	4.90	4	
13. Store panel on a storage rack	5.10	4	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 7

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
14. Visually inspect fibrous insulation for damage, deterioration and overheating	5.20	2	2 flashlights 2 inspection mirrors
15. Remove, replace or repair insulation (see task analysis no. 29)			
16. Visually inspect all support hardware for damage, deterioration and overheating	5.30	2	
17. Visually inspect attaching fasteners for damage, deterioration and overheating	5.40	2	
o Replacement of TPS Panel			
18. Load a new panel and associated pi-straps, on the panel dolly	5.60	4	1 panel dolly
19. Transport panel on dolly to the vehicle	6.00	4	
20. Position panel dolly for panel installation	6.20	4	1 panel dolly
21. Elevate panel dolly platform with panel to installed position	6.40	4	
22. Lock panel dolly brakes	6.50	2	
23. Position the new panel on the vehicle and align for installation NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	6.70	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative/HCF

PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3

PANEL LOCATION: Bottom

PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 7

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
24. Align the pi-straps for the attaching fastener installation	6.90	4	
25. Install the (28) pi-strap attaching fasteners	7.30	4	4 socket wrenches
26. Lower platform of the panel dolly from the installed position to the transport position	7.50	4	1 panel dolly
27. Release panel dolly brakes	7.60	2	
28. Remove panel dolly from the work area	7.80	4	
29. Torque the (28) pi-strap attaching fasteners	8.00	2	2 torque wrenches
30. Visually inspect the pi-strap attaching fasteners for damage and proper installation	8.20	2	2 flashlights 2 inspection mirrors
31. Apply a small quantity of RTV 106 adhesive to the pi-strap attaching fastener plugs (28) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 or 3 days.	8.60	4	RTV 160 adhesive
32. Visually inspect plugs for proper operation.	8.80	2	2 flashlights 2 inspection mirrors
33. Visually inspect the complete panel installation	9.00	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 8

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate the (62) pi-strap attaching fastener plugs	0.20	4	
2. Drill out the (62) pi-strap attaching fastener plugs	5.20	4	4 drills
3. Using a prescribed tool, free panel edges and pi-strap edges from adjacent panels	6.00	8	8 edge freeing tools
4. Position a panel dolly for the panel removal	6.40	8	1 panel dolly
5. Elevate panel dolly platform for panel removal	6.80	8	
6. Lock brakes on panel dolly	6.90	2	
7. Remove the (62) panel attaching fasteners	8.10	8	8 socket wrenches
8. Remove the associated pi-straps	8.90	8	8 edge freeing tools
9. Maneuver the panel free of the vehicle and lower panel onto panel dolly	9.70	8	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 8

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel (Cont.)			
10. Lower panel dolly platform with panel to the transport position	10.10	8	1 panel dolly
11. Unlock panel dolly brakes	10.20	2	
12. Transport panel with associated pi-straps to a storage area to await disposition	11.00	8	
13. Store panel on a storage rack	11.40	8	1 panel storage rack
o Inspection			
14. Visually inspect fibrous insulation for damage, deterioration and overheating	11.80	4	4 flashlights 4 inspection mirrors
15. Remove, replace or repair insulation as required (see task analysis no. 29)			
16. Visually inspect all support hardware for damage, deterioration and overheating	12.20	4	
17. Visually inspect attaching fasteners for damage, deterioration and overheating	12.60	4	
o Replacement of TPS Panel			
18. Load a new panel and associated pi-straps, on the panel dolly	13.00	8	1 panel dolly
19. Transport panel on dolly to the vehicle	13.80	8	
20. Position panel dolly for panel installation	14.20	8	1 panel dolly
21. Elevate panel dolly platform with panel to install position	14.60	8	
22. Lock panel dolly brakes	14.70	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
23. Position the new panel on the vehicle and align for installation NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	15.10	8	
24. Align the pi-straps for the attaching fastener installation	15.50	8	
25. Install the (62) pi-strap attaching fasteners	16.70	8	8 socket wrenches
26. Lower platform of the panel dolly from the install position to the transport position	17.10	8	1 panel dolly
27. Release panel dolly brakes	17.20	2	
28. Remove panel dolly from the work area	17.60	8	
29. Torque the (62) pi-strap attaching fasteners	18.20	4	4 torque wrenches
30. Visually inspect the pi-straps attaching fasteners for damage and proper installation	18.80	4	4 flashlights 4 inspection mirrors
31. Apply a small quantity of RTV 160 adhesive to the pi-strap attaching fastener plugs (62) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint.	20.00	8	RTV 160 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.) Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 or 3 days.			
32. Visually inspect plugs for proper operation.	20.40	4	4 flashlights 4 inspection mirrors
33. Visually inspect the complete panel installation	20.80	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 9

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (6) pi-strap attaching fastener ablator plugs.	0.05	1	
2. Drill out (6) pi-strap attaching fastener ablator plugs.	0.75	1	1 drill
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	0.80	1	1 edge freeing tool
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	0.85	1	
5. Remove (6) pi-strap attaching fasteners.	0.95	1	1 socket wrench
6. Remove associated pi-straps.	1.00	1	1 edge freeing tool
7. Maneuver ablator panel assy. (includes ablator panel attached to honeycomb substrate panel) free of vehicle. NOTE: (1) Ablator panel and honeycomb substrate panel are removed as an assembly. (2) Disassembly of panels (16 studs) to be accomplished in the refurbishment area and disposition of subassemblies determined.	1.05	1	
8. Transport ablator panel assembly and associated pi-straps to refurbishment area.	1.15	1	
9. Store panel on storage rack.	1.20	1	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 9

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
10. Visually inspect the fiberous insulation for damage, overheating and deterioration.	1.25	1	1 flashlight 1 inspection mirror
11. Remove, replace or repair insulation as required (see Task Analysis No. 29).			
12. Visually inspect all support hardware for damage, deterioration and overheating.	1.30	1	
13. Visually inspect attaching fasteners for damage, deterioration, and signs of overheating.	1.35	1	
o Replacement of TPS Panel			
14. Transport a new ablator panel assembly and associated pi-straps to the vehicle.	1.45	1	
15. Position the new ablator panel assembly on the vehicle for installation.	1.50	1	
16. Position the pi-straps on the ablator panel for installation.	1.55	1	
17. Install the (6) pi-strap attaching fasteners.	1.65	1	1 socket wrench
18. Torque the (8) attaching fasteners.	1.70	1	1 torque wrench
19. Visually inspect the pi-strap attaching installation.	1.75	1	1 flashlight 1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

TASK ANALYSIS NO. 9

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple
Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom

PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
20. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure period before handling. Full cure will develop in 2 to 3 days.	1.90	1	RTV 106 adhesive
21. Visually inspect pi-strap attaching fastener plug installation.	1.95	1	1 flashlight 1 inspection mirror
22. Visually inspect the complete panel installation.	2.00	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 3

TASK ANALYSIS NO. 10

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (26) pi-strap attach-fastener ablator plugs.	0.10	2	
2. Drill out (26) pi-strap attaching fastener ablator plugs.	2.10	4	4 drills
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	2.50	4	4 edge freeing tools
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	2.70	4	2 edge freeing tools
5. Position panel dolly for ablator panel assembly removal.	2.90	4	1 panel dolly
6. Elevate dolly platform for panel assembly removal.	3.10	4	
7. Lock brakes on dolly	3.20	2	
8. Remove (26) pi-strap attaching fasteners.	3.60	4	4 socket wrenches
9. Remove associated pi-straps	4.00	4	4 edge freeing tools
10. Maneuver ablator panel assy (comprised of ablator panel attached to the honeycomb substrate panel) free of vehicle. NOTE: (1) Ablator panel and honeycomb substrate panel are removed as an assembly. (2) Disassembly of panel (72 stubs) to be accomplished in the	4.20	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 10

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel (Cont.)			
in the refurbishment area and disposition of subassemblies determined.			
11. Lower panel dolly with panel from installed position to transport position.	4.40	4	1 panel dolly
12. Unlock panel dolly brakes	4.50	2	
13. Transport ablator panel assy. and associated pi straps to the refurbishment area.	4.90	4	
14. Unload ablator panel assy. from panel dolly and store on prescribed storage rack.	5.10	4	1 panel storage rack
o Inspection			
15. Visually inspect the fiberous insulation for damage overheating and deterioration.	5.20	2	2 flashlights 2 inspection mirrors
16. Visually inspect all support hardware for damage, deterioration and overheating.	5.30	2	
17. Visually inspect attaching fasteners for damage, deterioration and overheating.	5.40	2	
o Replacement of TPS Panel			
18. Load a new ablator panel assembly and associated pi-straps on the panel dolly and transport to the vehicle.	6.00	4	1 panel dolly
19. Position panel dolly for ablator panel assembly installation.	6.20	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 10

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 ... 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
20. Elevate ablator panel assy. to installation position.	6.40	4	1 panel dolly
21. Lock the panel dolly brakes.	6.50	2	
22. Position the new ablator panel assembly on the vehicle and align for installation.	6.70	4	
23. Position pi-straps on panel and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.	6.90	4	
24. Install the (26) pi-strap attaching fasteners.	7.30	4	4 socket wrenches
25. Lower the panel dolly platform.	7.50	4	1 panel dolly
26. Release panel dolly brakes.	7.60	2	
27. Remove panel dolly from work area.	7.80	4	
28. Torque the (26) pi-strap attaching fasteners.	8.00	2	2 torque wrenches
29. Visually inspect the pi-strap fasteners for proper installation.	8.20	2	2 flashlights 2 inspection mirrors
30. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs (26) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area.	8.60	4	RTV 160 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 10

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 ... 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
31. Visually inspect pi-strap attaching fastener ablator plugs for proper installation.	8.80	2	2 flashlights 2 inspection mirrors
32. Visually inspect the complete panel installation.	9.00	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (62) pi-strap attaching fastener ablator plugs.	0.20	4	
2. Drill out (62) pi-strap attaching fastener ablator plugs.	5.20	4	4 drills
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	6.00	8	8 edge freeing tools
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	6.10	2	2 edge freeing tools
5. Position panel dolly for ablator panel assembly removal.	6.50	8	1 panel dolly
6. Elevate dolly platform for panel assembly removal.	6.90	8	
7. Lock brakes on dolly.	7.00	2	
8. Remove (62) pi-strap attaching fasteners.	8.20	8	8 socket wrenches

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel (Cont.)			
9. Remove associated pi-straps.	9.00	8	8 edge freeing tools
10. Maneuver ablator panel assy. (Comprised of ablator panel attached to the honeycomb substrate panel) free of vehicle. NOTE: (1) Ablator panel and honeycomb substrate are removed as an assembly. (2) Disassembly of panel (184 stubs) to be accomplished in the refurbishment area and disposition of subassemblies determined.	9.80	8	
11. Lower panel dolly with panel from installed position to transport position.	10.20	8	1 panel dolly
12. Unlock panel dolly brakes.	10.30	2	
13. Transport ablator panel assy. and associated pi-straps to the refurbishment area.	11.10	8	
14. Unload ablator panel assy. from panel dolly and store on prescribed storage rack.	11.50	8	1 panel storage rack
o Inspection			
15. Visually inspect the fiberous insulation for damage, overheating and deterioration.	11.90	4	4 flashlights 4 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 11

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection (Cont.)			
16. Remove, replace or repair insulation as required (see Task Analysis No. 29).			
17. Visually inspect all support hardware for damage, deterioration and overheating.	12.30	4	
18. Visually inspect attaching fasteners for damage, deterioration, and overheating.	12.70	4	
o Replacement of TPS Panel			
19. Load a new ablator panel assembly and associated pi-straps on the panel dolly and transport to the vehicle.	13.90	8	1 panel dolly
20. Position panel dolly for ablator panel assembly installation.	14.30	8	
21. Elevate ablator panel assy. to installation position.	14.70	8	
22. Lock the panel dolly brakes.	14.80	2	
23. Position the new ablator panel assembly on the vehicle and align for installation.	15.20	8	
24. Position pi-straps on panel and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.	15.60	8	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 11

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
25. Install the (62) pi-strap attaching fasteners.	16.80	8	8 socket wrenches
26. Lower the panel dolly platform.	17.20	8	1 panel dolly
27. Release panel dolly brakes.	17.30	2	
28. Remove panel dolly from work area.	17.70	8	
29. Torque the (62) pi-strap attaching fasteners.	18.30	4	4 torque wrenches
30. Visually inspect the pi-strap fasteners for proper installation.	18.90	4	4 flashlights 4 inspection mirrors
31. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs (62) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	20.10	8	RTV 160 adhesive
32. Visually inspect pi-strap attaching fastener ablator plugs for proper installation.	20.50	4	4 flashlights 4 inspection mirrors
33. Visually inspect the complete panel installation.	20.90	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 12

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Small 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (16) ablator panel attaching fastener ablator plugs.	0.05	1	
2. Drill out the (16) attaching fastener ablator plugs.	1.55	2	2 Drills
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the inter panel sealing space.	1.65	1	1 Edge Freeing Tool
4. Remove the (16) ablator panel attaching fasteners.	1.95	2	2 Socket Wrenches
5. Maneuver the panel free of the fiberglass honeycomb substrate panel on the vehicle.	2.00	1	1 Edge Freeing Tool
6. Transport ablator panel to the storage area to await disposition	2.10	1	
o Inspection			
7. Visually inspect the fiberglass honeycomb substrate panel for damage, deterioration and overheating.	2.15	1	1 Flashlight 1 Inspection Mirror
8. Visually inspect the associated hardware for damage and overheating.	2.20	1	
9. Visually inspect attaching fasteners for damage, deterioration and signs of overheating.	2.25	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 12

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Small 20" x 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel			
10. Transport a new ablator panel to the vehicle.	2.35	1	
11. Position the new ablator panel on the vehicle for installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.	2.40	1	
12. Install the (16) attaching fasteners.	2.70	2	2 Socket Wrenches
13. Torque the (16) attaching fasteners.	2.80	1	1 Torque Wrench
14. Visually inspect attaching fasteners for proper installation	2.85	1	1 Flashlight 1 Inspection Mirror
15. Apply a small quantity of RTV 106 adhesive to each of the attaching fastener ablator plugs with a brush or spatula to a thickness of of 10 to 30 mils over the entire contact area. Insert plugs in plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time, before handling or stressing joint. Full cure will develop in 2 to 3 days.	3.15	2	RTV 106 Adhesive
16. Visually inspect the attaching fastener plugs for proper installation.	3.20	1	1 Flashlight 1 Inspection Mirror
17. Visually inspect the complete panel installation.	3.25	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 13

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: **Ablative**
PRINCIPAL ATTACH CONCEPT: **Multiple Mechanical Fastener Concept #4B**
PANEL LOCATION **Bottom**
PANEL SIZE: **Medium 20" x 120"**

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o **Removal of TPS Panel**			
1. Locate (72) ablator panel attaching fastener ablator plugs.	0.20	4	
2. Drill out the (72) attaching fastener ablator plugs.	6.20	4	4 Drills
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the inter panel sealing space.	6.60	4	4 Edge Freeing Tools
4. Position a panel dolly for the ablator panel removal.	6.80	4	1 Panel Dolly
5. Elevate dolly platform for ablator panel removal.	7.00	4	
6. Lock brakes on dolly	7.10	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 13

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: **Ablative**
PRINCIPAL ATTACH CONCEPT: **Multiple Mechanical Fastener Concept 4B**
PANEL LOCATION **Bottom**
PANEL SIZE: **Small 20" x 120"**

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
7. Remove the (72) ablator panel attaching fasteners	8.30	4	4 Socket Wrenches
8. Maneuver ablator panel free of the fiberglass honecomb substrate panel on the vehicle and lower plane onto panel dolly.	8.50	4	4 Edge Freeing Tools
9. Lower panel dolly with panel from installed position to transport position.	8.70	4	1 Panel Dolly
10. Unlock panel dolly brakes	8.80	2	
11. Transport ablator panel to the storage area to await disposition	9.20	4	
12. Store ablator panel on a prescribed storage rack.	9.40	4	1 Panel Storage Rack
o Inspection			
13. Visually inspect the fiberglass honey comb substrate panel for damage deterioration and overheating.	9.50	2	2 Flashlights 2 Inspection Mirrors
14. Visually inspect the associated hardware for damage and overheating.	9.60	2	
15. Visually inspect attaching fasteners for damage, deterioration, and signs of overheating.	9.70	2	
o Replacement of TPS Panel			
16. Transport a new ablator panel to the vehicle.	10.10	4	1 Panel Dolly
17. Position panel dolly for ablator panel installation	10.30	4	
18. Elevate ablator panel to installation position.	10.50	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 13

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept 4B
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
19. Lock panel dolly brakes.	10.60	2	1 Panel Dolly
20. Position the new ablator panel on the vehicle and align for installation. **NOTE:** Exercise care to prevent damage during installation and torqueing of the ablator panel attaching fasteners.	10.80	4	
21. Install the (72) ablator panel attaching fasteners.	12.00	4	4 Socket Wrenches
22. Lower panel dolly platform.	12.20	4	1 Panel Dolly
23. Release panel dolly brakes.	12.30	2	
24. Remove panel dolly from work area.	12.50	4	1 Panel Dolly
25. Torque the (72) ablator panel attaching fasteners.	13.30	4	4 Torque Wrenches
26. Visually inspect the ablator panel attaching fasteners for proper installation.	13.90	4	4 Flashlights 4 Inspection Mirrors
27. Apply a small quantity of RTV 106 adhesive to each of the (72) attaching fastener ablator plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	15.10	14	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 13

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (4 – 5)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
28. Visually inspect ablator plugs for proper installation.	15.50	4	4 Flashlights 4 Inspection Mirrors
29. Visually inspect the complete panel installation.	15.90	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 14

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1–2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate (176) ablator panel attaching fastener ablator plugs	6.40	8	
2. Drill out the (176) attaching fastener ablator plugs	15.60	8	8 drills

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 5

TASK ANALYSIS NO. 14

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2–3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the inter panel sealing space	16.40	8	8 edge freeing tools
4. Position a panel dolly for the ablator panel removal	16.80	8	1 panel dolly
5. Elevate dolly platform for ablator panel removal	17.20	8	
6. Lock brakes on dolly	17.30	2	
7. Remove the (176) ablator panel attaching fasteners	20.50	8	8 socket wrenches
8. Maneuver ablator panel free of the fiberglass honeycomb substrate panel on the vehicle and lower panel onto panel dolly	21.30	8	8 edge freeing tools
9. Lower panel dolly with panel from installed position to transport position	21.70	8	1 panel dolly
10. Unlock panel dolly brakes	21.80	2	
11. Transport ablator panel to the storage area to await disposition	22.60	8	
12. Store ablator panel in a prescribed storage rack	23.00	8	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 5

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
13. Visually inspect the fiber-glass honeycomb substrate panel for damage, deterioration and overheating	23.40	4	4 flashlights 4 inspection mirrors
14. Visually inspect the associated hardware for damage and over-heating	23.80	4	
15. Visually inspect attaching fasteners for damage, deter-ioration, and overheating	24.29	4	
o Replacement of TPS Panel (Cont.)			
16. Transport a new ablator panel to the vehicle	25.00	8	1 panel dolly
17. Positon panel dolly for ablator panel installation	25.40	8	
18. Elevate ablator panel to installation position	25.80	8	
19. Lock panel dolly brakes	25.90	2	
20. Position the new ablator panel on the vehicle and align for installation NOTE: Exercise care to prevent damage during installation and torqueing of the ablator panel attaching fasteners	26.30	8	
21. Install the (176) ablator panel attaching fasteners	29.50	8	8 socket wrenches

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 5

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (4 – 5)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
22. Lower panel dolly platform	29.90	8	1 panel dolly
23. Release panel dolly brakes	30.00	2	1 panel dolly
24. Remove panel dolly from work area	30.40	8	
25. Torque the (176) ablator panel attaching fasteners	32.00	4	4 torque wrenches
26. Visually inspect the ablator panel attaching fasteners for proper installation	33.20	4	4 flashlights 4 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 4 OF 5

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (5, 6)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
28. Apply a small quantity of RTV 106 adhesive to each of the (176) attaching fastener ablator plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	36.40	8	RVT 106 adhesive
29. Visually inspect ablator plugs for proper installation.	37.60	4	4 flashlights 4 inspection mirrors
30. Visually inspect the complete panel installation.	38.00	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 15

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate each (3) pi strap attaching fastener ablator plugs. NOTE: One pi-strap is used to secure every 3 panels. This study deals with panel nearest the pi-strap.	0.05	1	
2. Drill out (3) pi-strap attaching fastener ablator plugs.	0.30	1	1 drill
3. Remove pi-strap attaching fasteners (3).	0.35	1	1 socket wrench
4. Using a prescribed tool free pi-strap of panels.	0.40	1	1 edge freeing tool
5. Using a prescribed tool free flexible gasket at interpanel sealing space.	0.45	1	
6. Maneuver ablator panel approximately .75 inches to unlock panel attaching keyway and pull panel free of vehicle.	0.50	1	
7. Transport ablator panel and associated pi-strap to the storage area to await disposition.	0.60	1	
8. Store panel on storage rack.	0.65	1	
o Inspection			
9. Visually inspect ablator panel attaching fasteners for damage, Deterioration and overheating.	0.70	1	1 flashlight 1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 15

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
10. Visually inspect insulation and associated hardware for damage. Deterioration and overheating.	0.75	1	1 flashlight 1 inspection mirror
11. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Replacement of TPS Panel			
11. Transport the new ablator panel and pi-strap to the vehicle.	0.85	1	
12. Position the new ablator panel on vehicle, matchup keyway and align for installation.	0.90	1	
13. Check the flexible gaskets on two sides of the panel for position and alignment.	0.95	1	
14. Install the new pi-strap and align for fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.	1.00	1	
15. Install the (3) pi-strap attaching fasteners.	1.05	1	1 socket wrench
16. Torque the (3) pi-strap attaching fasteners.	1.10	1	1 torque wrench
17. Visually inspect pi-strap attaching fastener installation.	1.15	1	1 flashlight 1 inspection mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

TASK ANALYSIS NO. 15

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
18. Apply a small quantity of RVT 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area - insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure period before handling or stressing joint. Full cure will develop in 2 to 3 days.	1.20	1	RVT 106 adhesive
19. Visually inspect the pi-strap attaching fastener plug installation.	1.25	1	
20. Visually inspect the complete panel installation.	1.30	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 16

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate each (3) pi-strap attaching fastener ablator plugs.	0.05	1	
2. Drill out (3) pi-strap attaching fastener ablator plugs.	0.30	1	1 drill
3. Remove (3) pi-strap attaching fasteners.	0.35	1	1 socket wrench
4. Using a prescribed tool, free pi strap of panels.	0.40	1	1 edge freeing tool
5. Using a prescribed tool, free flexible gasket at inter panel sealing space.	0.80	4	4 edge freeing tools
6. Position panel dolly for ablator panel removal.	1.00	4	1 panel dolly
7. Elevate panel dolly platform for ablator panel removal.	1.20	4	
8. Lock brakes on panel dolly.	1.30	2	
9. Maneuver ablator panel approximately .75 inches to unlock panel attaching keyway, pull panel free of vehicle and place on panel dolly.	1.50	4	4 edge free tools
10. Lower panel dolly with panel from install to transport position.	1.70	4	1 panel dolly
11. Transport ablator panel and associated pi-straps to the refurbishment area to await disposition.	2.10	4	
12. Unload panel and pi-straps and store the panel on a prescribed storage rack.	2.30	4	1 panel dolly

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 16

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
13. Visually inspect ablator panel attaching fasteners for damage, deterioration and overheating.	2.40	2	2 flashlights 2 inspection mirrors
14. Visually inspect insulation and associated hardware for damage, deterioration, and overheating.	2.50	2	
15. Remove, replace or repair insulation as required (see task analysis no.			
o Replacement of TPS Panel			
16. Load the new ablator panel and associated pi-straps on the panel dolly and transport to the vehicle.	3.10	4	1 panel dolly
17. Position panel dolly for ablator panel installation.	3.30	4	
18. Elevate ablator panel to install position.	3.50	4	
19. Lock the panel dolly brakes.	3.60	2	
20. Position the new ablator panel on the vehicle matchup keyway and align for installation.	4.00	4	
21. Check the flexible gaskets on two sides of the panel for position and alignment.	4.20	4	
22. Install the new pi-strap and align for attaching fastener installation.	4.25	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 16

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.) NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.			
23. Install the (3) pi-strap attaching fasteners.	4.30	1	1 socket wrench
24. Lower panel dolly platform	4.50	4	1 panel dolly
25. Release panel dolly brakes.	4.60	2	
26. Remove panel dolly from work area.	4.80	4	
27. Torque the (3) pi-strap attaching fasteners.	4.85	1	1 torque wrench
28. Visually inspect pi-strap fasteners for proper installation.	4.90	1	1 flashlight 1 inspection mirror
29. Apply a small quantity of RVT 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure period before handling or stressing joint-full cure will develop in 2 or 3 days.	4.95	1	1 RVT 106 adhesive
30. Visually inspect the pi-strap attaching fastener plug installation.	5.00	1	1 flashlight 1 inspection mirror
31. Visually inspect the complete panel installation.	5.20	2	2 flashlights 2 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 17

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Locate each (6) pi-strap attaching fastener ablator plugs.	0.10	2	
2. Drill out (6) pi-strap attaching fastener ablator plugs.	0.60	2	2 drills
3. Remove (6) pi-strap attaching fasteners.	0.70	2	2 socket wrenches
4. Using a prescribed tool, free pi-straps of panels.	0.80	2	2 edge freeing tools
5. Using a prescribed tool, free flexible gasket at inter panel sealing space.	1.60	8	8 edge freeing tools
6. Position panel dolly for ablator panel removal.	2.00	8	1 panel dolly
7. Elevate panel dolly platform for ablator panel removal.	2.40	8	
8. Lock brakes on panel dolly	2.50	2	
9. Maneuver ablator panel approximately .75 inches to unlock panel attaching keyway, pull panel free of vehicle and place on panel dolly.	3.30	8	
10. Lower panel dolly with panel from install to transport position.	3.70	8	
11. Transport ablator panel and associated pi-straps to the refurbishment area to await disposition.	4.50	8	
12. Unload panel and pi-straps and store the panel on a prescribed storage rack.	4.90	8	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 17

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
13. Visually inspect ablator panel attaching fasteners for damage, deterioration and overheating.	5.30	4	4 flashlights 4 inspection mirrors
14. Visually inspect insulation and associated hardware for damage, deterioration, and overheating.	5.70	4	
15. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Replacement of TPS Panel			
16. Load the new ablator panel and associated pi-straps on the panel dolly and transport to the vehicle.	6.90	8	1 panel dolly
17. Position panel dolly for ablator panel installation.	7.30	8	
18. Elevate ablator panel to install position.	7.70	8	
19. Lock the panel dolly brakes.	7.80	2	
20. Position the new ablator panel on the vehicle, match up keyway and align for installation.	8.60	8	
21. Check the flexible gaskets on two sides of the panel for position and alignment.	9.00	8	
22. Install the new pi-strap and align for attaching fastener installation.	9.10	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 17

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Large. 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.			
23. Install the (6) pi-strap attaching fasteners.	9.20	2	2 socket wrenches
24. Lower panel dolly platform.	9.60	8	1 panel dolly
25. Release panel dolly brakes.	9.70	2	
26. Remove panel dolly from work area.	10.10	8	
27. Torque the (6) pi strap attaching fasteners.	10.20	2	2 torque wrenches
28. Visually inspect pi-strap fasteners for proper installation.	10.30	2	2 flashlights 2 inspection mirrors
29. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure period before handling or stressing joint-full cure will develop in 2 or 3 days.	10.40	2	RTV 160 adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 4

TASK ANALYSIS NO. 17

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
30. Visually inspect the pi-strap attaching fastener plug installation.	10.50	2	2 flashlights 2 inspection mirrors
31. Visually inspect the complete panel installation.	10.90	4	4 flashlights 4 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 4 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners - No Intermediate Support #6A
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 18

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Install panel removal handling tools on panel	0.05	1	2 panel removal tools
2. Remove (6) panel attaching fasteners.	0.15	1	1 pneumatic screwdriver
3. Using panel removal tools maneuver panel free of panel joints.	0.25	1	2 panel removal tools
o Inspection			
4. Visually inspect panel for damage and deterioration. NOTE: Pay particular attention to mating surfaces.	0.30	1	1 flashlight 1 inspection mirror
5. Visually inspect fasteners (6) for serviceability.	0.35	1	
6. Visually inspect panel support hardware.	0.40	1	
7. Visually inspect insulation and associated hardware	0.45	1	
8. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area	0.55	1	2 panel removal tools
10. Store panel on storage rack. NOTE: Panels to be individually packed to prevent damage to panel surface.	0.60	1	1 panel storage rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners - No Intermediate Support #6A
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 18

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel (Cont.)			
11. Remove panel removal handling tools.	0.65	1	2 panel removal tools
12. Place protective cover over panel on storage rack.	0.70	1	1 protective cover
o Replacement of TPS Panel			
13. Remove cover from panel on storage rack.	0.75	1	1 protective cover
14. Install panel removal handling tools	0.80	1	2 panel removal tools
15. Transport panel to vehicle for installation	0.85	1	
16. Position panel on vehicle and align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	0.95	1	
17. Install (6) panel attaching fasteners.	1.05	1	1 pneumatic screwdriver
18. Remove panel removal handling tools	1.10	1	2 panel removal tools
19. Torque fasteners (6)	1.20	1	1 torque wrench
20. Visually inspect fastener installation.	1.25	1	1 flashlight 1 inspection mirror
21. Visually inspect panel installation	1.30	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 19

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners Attachment, Concept #6B
PANEL LOCATION: Bottom
PANEL SIZE: Small (40" x 40")

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Install panel removal handling tools on panel	0.10	2	4 panel removal tools
2. Remove the (18) panel attaching fasteners	0.30	2	1 pneumatic screw driver 1 screw driver
3. Using the handling tools maneuver panel free of longitudinal panel joints and vehicle	0.50	2	4 panel removal tools
o Inspection			
4. Visually inspect panel for damage and deterioration NOTE: Pay particular attention to mating surfaces	0.60	1	1 flashlight 1 inspection mirror
5. Visually inspect fasteners (15) for serviceability	0.70	1	
6. Visually inspect panel support hardware	0.80	1	
7. Visually inspect insulation and associated hardware			
8. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area	1.10	2	4 panel removal tools
10. Store panel on storage rack	1.20	2	1 panel storage rack
11. Remove panel removal handling tools (5) NOTE: Panels to be individually racked to prevent damage	1.30	2	4 panel removal tools
12. Place protective cover over panel on storage rack	1.40	2	1 protective cover

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 19

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners Attachment, Concept #6B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 Inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel			
13. Remove cover from panel on storage rack	1.50	2	1 protective cover
14. Install panel removal handling tools	1.60	2	4 panel removal tools
15. Transport panel to vehicle for installation	1.80	2	
16. Position panel on vehicle and shift in two directions to achieve proper overlap and alignment of the longitudinal panel joint NOTE: Exercise extreme care to prevent damage to the mating surfaces	2.00	2	
17. Install the (18) panel attaching fasteners NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin	2.20	2	1 pneumatic screw driver 1 screw driver
18. Remove the panel removal handling tools	2.30	2	4 panel handling tools
19. Torque the (18) panel attaching fasteners	2.40	1	1 torque wrench
20. Visually inspect the (18) panel attaching fastener installation for damage	2.50	1	1 flashlight 1 insp-mirror
21. Visually inspect the completed panel installation	2.60	1	1 flashlight 1 insp-mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap
Attaching Concept #7A
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 20

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Install panel removal handling tools on panel	0.05	1	2 panel removal tools
2. Remove pi-strap fasteners (6) and pi-strap from panel NOTE: Exercise extreme care to prevent damage to the panel coated surface	0.15	1	1 pneumatic crew driver
3. Using panel removal handling tools, maneuver panel free of panel joints	0.25	1	2 panel removal tools
o Inspection			
4. Visually inspect panel and pi-straps for damage and deterioration NOTE: Pay particular attention to mating surfaces	0.30	1	1 flashlight 1 inspection mirror
5. Visually inspect pi-straps fasteners (6) for serviceability	0.35	1	
6. Visually inspect panel support hardware	0.40	1	
7. Visually inspect insulation and associated hardware			
8. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area	0.55	1	2 panel removal tools

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap
Attaching Concept #7A
PANEL LOCATION Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 20

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
10. Store panel on panel storage rack NOTE: Panels to be individually racked to prevent damage to panel surface	0.60	1	1 panel storage rack
11. Remove panel removal handling tools	0.65	1	2 panel removal tools
12. Place protective cover over panel on storage rack	0.70	1	1 protective cover
c Replacement of TPS Panel			
13. Remove cover from panel on storage rack	0.75	1	1 protective cover
14. Install panel removal handling tools	0.80	1	2 panel removal tools
15. Transport panel to vehicle for installation	0.90	1	
16. Position panel on vehicle and align panel joints NOTE: Exercise extreme care to prevent damage to the mating surfaces	1.00	1	
17. Install pi-straps and pi-strap fasteners (6)	1.10	1	1 pneumatic screw driver
18. Remove panel removal handling tools (2)	1.15	1	2 panel removal tools
19. Torque pi-strap fasteners (6)	1.25	1	1 torque wrench
20. Visually inspect pi-strap fasteners (6) installation	1.30	1	1 flashlight 1 inspection mirror
21. Visually inspect TPS panel installation	1.35	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panels			
1. Install panel removal handling tools on panel.	0.20	4	8 Panel Handling Tools
2. Position and elevate panel dolly for panel removal.	0.60	4	1 Panel Dolly
3. Lock brakes on panel dolly.	0.70	2	
4. Remove Pi-strap attaching fasteners (26) and Pi-straps from panel. NOTE: Exercise care to prevent damage to panel surface and panel fastener head slots.	1.10	4	2 Pneumatic Screw Drivers 2 Screw Drivers
5. Using the panel removal handling tools maneuver panel free of panel joints and vehicle. Lower panel onto panel dolly and lower dolly platform.	1.50	4	8 Panel Handling Tools
o Inspection			
6. Visually inspect panel and Pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces and fastener holes.	1.70	2	2 Flashlights 2 Inspection Mirrors
7. Visually inspect Pi-strap fasteners (26) for serviceability	1.90	2	
8. Visually inspect panel support hardware.	2.10	2	
9. Visually inspect insulation and associated hardware. Remove, replace or repair insulation, as	2.30	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection (Cont.)			
required (See Task Analysis No. 29).			
10. Transport panel with dolly to storage area.	2.70	4	1 Panel Dolly
11. Store panel on prescribed panel storage rack. NOTE: Panels to be individually racked to prevent damage.	2.90	4	1 Panel Storage Rack
12. Remove panel removal handling tools.	3.10	4	8 Panel Removal Tools
13. Install protective cover over panel on strorage rack.	3.30	4	1 Panel Protective Cover
o Replacement of TPS Panels			
14. Remove protective cover from panel on storage rack.	3.50	4	1 Panel Protective Cover
15. Install panel removal handling tools.	3.70	4	8 Panel Removal Tools
16. Remove panel from panel storage rack and place on panel dolly.	3.90	4	1 Panel Storage Rack
17. Transport panel and dolly from storage area to vehicle.	4.30	4	1 Panel Dolly
18. Position and elevate dolly for panel installation on vehicle.	4.70	4	1 Panel Dolly
19. Lock brakes on panel dolly.	4.80	2	1 Panel Dolly
20. Raise panel from dolly and position on vehicle. Align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	5.20	4	1 Panel Dolly

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel			
21. Install (26) Pi-strap attaching fasteners. NOTE: Exercise care during installation to prevent damage to the fastener heads and surrounding panel skin.	5.60	4	2 Pneumatic Screw Drivers 2 Screw Drivers
22. Remove the panel removal handling tools.	5.80	4	8 Panel Removal Tools
23. Unlock brake on panel dolly.	5.90	2	1 Panel Dolly
24. Remove panel dolly from work area.	6.30	4	1 Panel Dolly
25. Torque the (26) Pi-strap attaching fasteners.	6.50	2	2 Torque Wrenches
26. Visually inspect the (26) Pi-strap attaching fastener installation for damage.	6.70	2	2 Flashlights 2 Inspection Mirrors
27. Visually inspect the completed panel installation	6.90	2	2 Flashlights 2 Inspection Mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 22

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large 20" x 300"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panels			
1. Install panel removal handling tools on panel.	0.40	8	16 Panel Removal Tools
2. Position and elevate panel dolly for panel removal.	1.20	8	1 Panel Dolly
3. Lock brakes on panel dolly.	1.30	2	1 Panel Dolly
4. Remove Pi-strap attaching fasteners (58) and Pi-straps from panel. NOTE: Exercise care to prevent damage to panel coated surface and panel fastener head slots.	2.10	4	2 Penumatic Screw Drivers 2 Screw Drivers
5. Using the panel removal handling tools (16), Maneuver panel free of panel joints and vehicle. Lower panel onto panel dolly and lower dolly platform.	2.90	8	16 Panel Removal Tools
o Inspection			
6. Visually inspect panel and Pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces and fastener holes.	3.10	4	4 Flashlights 4 Inspection Mirrors
7. Visually inspect Pi-strap fasteners (58) for serviceability	3.50	4	
8. Visually inspect panel support hardware.	3.90	4	
9. Visually inspect insulation and associated hardware. Remove, replace or repair insulation, as	4.30	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 22

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large 20" x 300"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
required (See Task Analysis No. 29)			
10. Transport panel with dolly to to storage area.	5.10	8	1 Panel Dolly
11. Store panel on prescribed panel storage rack. NOTE: Panels to be individually racked to prevent damage.	5.50	8	1 Panel Storage Rack
12. Remove panel removal handling tools.	5.90	8	16 Panel Removal Tools
13. Install protective cover over panel on storage rack.	6.30	8	1 Panel Protective Cover
o Replacement of TPS Panels			
14. Remove protective cover from panel on storage rack.	6.70	8	1 Panel Protective Cover
15. Install panel removal handling tools (16).	7.10	8	16 Panel Removal Tools
16. Remove panel from panel storage rack and place on panel dolly.	7.50	8	1 Panel Storage Rack
17. Transport panel and dolly from storage area to vehicle.	8.30	8	1 Panel Dolly
18. Position and elevate dolly for panel installation on vehicle.	9.10	8	1 Panel Dolly
19. Lock brakes on panel dolly.	9.20	2	1 Panel Dolly
20. Raise panel from dolly and position on vehicle. Align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	10.00	8	1 Panel Dolly

NUMBER FOLLOWING TIME BAR IS MANLOADING

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large 20" x 300"

TASK ANALYSIS NO. 22

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (manloading)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel - Cont.			
21. Install (58) Pi-strap attaching fasteners. NOTE: Exercise care during installation to prevent damage to the fastener heads and surrounding panel skin.	10.80	8	4 Pneumatic Screw Drivers 4 Screw Drivers
22. Remove the panel removal handling tools.	11.20	8	16 Panel Removal Tools
23. Unlock brake on panel dolly.	11.30	2	1 Panel Dolly
Remove panel dolly from work area.	11.70	4	1 Panel Dolly
24. Torque the (58) Pi-strap attaching fasteners.	12.10	4	4 Torque Wrenches
25. Visually inspect the (58) Pi-strap attaching fastener installation for damage	12.50	4	4 Flashlights 4 Inspection Mirrors
26. Visually inspect the completed panel installation.	12.90	4	4 Flashlights 4 Inspection Mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 23

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Remove body chine on one side of the panel (See task analysis no. 27)	1.25	1	
2. Install panel removal handling tools on panel	1.35	2	4 panel removal tools
3. Remove (2) indexing screws from panel	1.40	1	1 pneumatic screwdriver
4. Remove (14) pi-strap fasteners and pi-strap from panel NOTE: Exercise care to prevent damage to panel coated surface and pi-straps.	1.60	2	
5. Using panel removal handling tools, maneuver panel toward side with removed chines, to release the panel from mid panel support, and panel joints	1.80	2	4 panel removal tools
o Inspection			
6. Visually inspect panel and pi-straps for damage and deterioration NOTE: Pay particular attention to mating surfaces	1.90	1	1 flashlight inspection mirror
7. Visually inspect pi-strap fasteners (14) for serviceability	2.00	1	
8. Visually inspect panel support hardware	2.10	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 23

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection (Cont.)			
9. Visually inspect insulation and associated hardware	2.20	1	1 flashlight 1 inspection mirror
10. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
11. Transport panel to storage area	2.40	2	4 panel removal tools
12. Store panel on storage rack NOTE: Panels to be individually racked to prevent damage	2.50	2	1 panel storage rack
13. Remove panel removal handling tools	2.60	2	4 panel removal tools
14. Install protective cover over panel on storage rack NOTE: Repeat preceding steps to remove each panel in sequence to reach the specific panel desired		2	1 panel protective cover
o Replacement of TPS Panel			
15. Remove protective cover from panel on storage rack	2.80	2	
16. Install panel removal handling tools	2.90	2	4 panel removal tools
17. Transport panel from storage rack to vehicle	3.10	2	
18. Using handling tools, position panel on vehicle and slide panel in panel support channel to its prescribed location and align indexing screw holes	3.30	2	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 23

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of TPS Panel (Cont.)			
NOTE: Exercise care to prevent damage to mating surfaces			
19. Install indexing screw(2)	3.35	1	1 pneumatic screwdriver
20. Install pi-straps and pi-strap fasteners (14) NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin	3.55	2	1 screwdriver
21. Remove the panel removal handling tools	3.65	2	4 panel removal tools
22. Torque pi-strap fasteners (14) and indexing screws(2) NOTE: Repeat preceding steps to replace each panel in sequence to install the specific panel desired.	3.75	1	1 torque wrench
23. Visually inspect pi-strap fastener installation on panels installed	3.85	1	1 flashlight 1 inspection mirror
24. Visually inspect panel installations of panels affected	3.95	1	
25. Install body chine (See task Analysis No. 27)	4.60	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 24

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Remove body chine on one side of the panel (see Task Analysis No. 27)	1.25	1	
2. Instal panel removal handling tools on panel	1.45	4	8 panel removal tools
3. Position and elevate panel dolly for panel removal	1.85	4	1 panel dolly
4. Remove (2) indexing screws from panel	1.90	1	1 pneumatic screw driver
5. Remove (28) pi-strap fasteners and pi-straps from panel NOTE: Exercise care to prevent damage to panel coated surface and panel fastener head slots	2.30	4	2 pneumatic screw driver 2 screw drivers
6. Using the panel removal handling tools, maneuver panel toward side with removed chines, to release the panel from mid panel support, and panel joints. Lower panel on to panel dolly and dolly platform	2.70	4	8 panel removal tools
o Inspection			
7. Visually inspect panel and pi-straps for damage and deterioration NOTE: Pay particular attention to mating surfaces and indexing screw holes	2.90	2	2 flashlights 2 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 24

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
8. Visually inspect pi-strap fasteners (28) for serviceability	3.10	2	2 flashlights 2 inspection mirrors
9. Visually inspect panel support hardware	3.30	2	
10. Visually inspect insulation and associated hardware	3.50	2	
11. Remove, replace or repair insulation as required (see task analysis no. 29)			
12. Transport panel with panel dolly to storage	3.90	4	1 panel dolly
13. Store panel on prescribed panel storage rack NOTE: Panel to be individually racked to prevent damage	4.10	4	1 panel storage rack
14. Remove panel removal handling tools	4.30	4	8 panel removal tools
15. Install protective cover over panel on storage rack NOTE: Repeat preceding steps to remove each panel in sequence to reach the specific panel desired			1 protective cover
o Replacement of TPS Panel			
16. Remove protective cover from panel on storage rack	4.50	4	1 protective cover
17. Install panel removal handling tools	4.70	4	8 panel removal tools
18. Remove panel from rack and place on panel dolly	4.90	4	1 panel dolly

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 24

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
19. Transport panel on dolly from storage to vehicle	5.30	4	
20. Position and elevate dolly for panel installation on vehicle	5.70	4	
21. Using panel handling tools position panel on vehicle and slide panel in panel support channel to its prescribed location and align indexing screw holes NOTE: Exercise care to prevent damage to mating surfaces	6.10	4	8 panel removal tools
22. Install indexing screws (2)	6.15	1	1 pneumatic screw driver
23. Install pi-straps and (28) pi-strap fasteners NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin	6.55	4	2 pneumatic screw drivers 2 screw drivers
24. Remove the panel handling tools	6.75	4	8 panel removal tools
25. Remove panel dolly from work area	7.15	4	1 panel dolly
26. Torque (28) pi-strap fasteners and (2) indexing screws NOTE: Repeat preceding steps to replace each panel in sequence to install the specific panel desired	7.35	2	2 torque wrenches
27. Visually inspect pi-strap fastener installation on panels installed	7.55	2	2 flashlights 2 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 4

TASK ANALYSIS NO. 24

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3 – 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
28. Visually inspect panel installation of panels affected	7.75	2	
29. Install body chine (see Task Analysis No. 27)	8.40	/	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 25

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1–2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of TPS Panel			
1. Remove body chine on one side of panel (see Task Analysis no. 27)	1.25	1	
2. Install panel removal handling tools on panel	1.65	8	16 panel removal tools
3. Position and elevate panel dolly for panel removal	2.45	8	1 panel dolly
4. Remove (2) indexing screws from panel	2.50	1	1 pneumatic screw driver
5. Remove (62) pi-strap fasteners and pi-straps from panel NOTE: Exercise care to prevent damage to panel coated	3.30	4	2 pneumatic screw driver 2 screw drivers
6. Using the panel removal handling tools maneuver panel toward side with removed chines, to release the panel from mid panel support and panel joints. Lower panel on panel dolly and lower dolly platform	4.10	8	16 panel removal tools
o Inspection			
7. Visually inspect panel and pi-straps for damage and deterioration NOTE: Pay particular attention to mating surfaces and indexing screw holes	4.50	4	4 flashlights 4 inspection mirrors
8. Visually inspect pi-strap fasteners (62) for serviceability.	4.90	4	4 flashlights 4 inspection mirrors

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 25

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2–3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
9. Visually inspect panel support hardware	5.30	4	
10. Visually inspect insulation and associated hardware	5.70	4	
11. Remove, replace or repair insulation as required (see Task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
12. Transport panel on panel dolly to storage	6.50	8	1 panel dolly
13. Store panel on prescribed panel storage rack NOTE: Panel to be individually racked to prevent damage	6.90	8	1 panel storage rack
14. Remove panel removal handling tools	7.30	8	16 panel removal tools
15. Install protective cover over panel on storage rack	7.70	8	
o Replacement of TPS Panel			
16. Remove protective cover from panel on storage rack	8.10	8	1 protective cover
17. Install panel removal handling tools	8.50	8	16 panel removal tools
18. Remove panel from rack and place on panel dolly	8.90	8	1 panel dolly
19. Transport panel on dolly from storage to vehicle	9.70	8	
20. Position and elevate dolly for panel installation on vehicle	10.50	8	1 panel dolly

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION Bottom
PANEL SIZE: Large: 40 x 300 inches

TASK ANALYSIS NO. 25

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3, 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
21. Using panel handling tools, position panel on vehicle and slide panel in panel support channel to its prescribed location and align indexing screw holes NOTE: Exercise care to prevent damage to mating surfaces	11.30	8	16 panel removal tools
22. Install indexing screws (2)	11.35	1	1 pneumatic screw driver
23. Install pi-straps and (62) pi-strap fasteners NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin	12.95	8	2 pneumatic screw drivers 2 screw drivers
24. Remove the panel handling tools	13.35	8	16 panel removal tools
25. Remove panel dolly from work area	13.75	4	1 panel dolly
26. Torque (62) pi-strap fasteners and (2) indexing screws	14.15	4	4 torque wrenches
27. Visually inspect pi-strap fastener installation	14.55	4	4 flashlights
28. Visually inspect panel installation	14.95	4	4 inspection mirrors
29. Install body chine (see Task Analysis no. 27)	15.60	/	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 26

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION: Bottom
PANEL SIZE: 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of Leading Edge Segment			
1. Remove the (14) screws from the access door adjacent to the leading edge panel segment to be removed.	0.20	1	1 Screw Driver
2. Using a socket wrench turn the hex shaft, protruding from the backside of the main wing spar, in the counter clockwise direction to retract the (4) spring loaded locking pins. (Support the leading edge segment during this operation.)	0.30	2	1 Socket Wrench
3. With the (4) leading edge spring loaded locking pins retracted, pull the leading edge segment straight forward and free of the vehicle wing. NOTE: (1) Each leading edge segment which is accessible thru the access door on the top of the wing, overlaps the leading edge segment to the right and left of this specific segment. (2) Therefore, any right hand or left hand segment requires the removal of two overlap segments.	0.35	1	
4. Transport leading edge segment to the storage area to await disposition.	0.45	1	
5. Store leading edge segment on a prescribed storage rack.	0.50	1	1 Storage Rack

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 26

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION: Bottom
PANEL SIZE: 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
6. Visually inspect wing spar forward area and attaching points, for damage, deterioration and overheat conditions.	0.55	1	1 Flashlight 1 Inspection Mirror
7. Visually inspect backside of main wing spar thru the wing access door for damage, deterioration and an overheat condition	0.60	1	
8. Visually inspect main wing spar forward insulation for damage, deterioration and overheat condition	0.65	1	
o Replacement of Leading Edge Segment			
9. Transport a new leading edge segment to the vehicle.	0.75	1	
10. Position and align the leading edge segment in the appropriate place on the forward side of the main wing spar. NOTE: As previously noted, any right hand or left hand leading edge segment replacement involves two other segments due to the overlap principle.	0.85	1	
11. Using the socket wrench, turn the hex shaft protruding from the backside of the main wing spar, in the clockwise direction to extend the spring loaded locking pins. (Pull forward on	0.95	2	1 Socket Wrench

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

TASK ANALYSIS NO. 26

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION Bottom
PANEL SIZE: 20"

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (number following time bar)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of Leading Edge Segment (Cont.) leading edge segment to assure locking pins are in full lock position.)			
12. Replace the access door with (14) screws, adjacent to the leading edge segment that was replaced.	1.15	1	1 Screw Driver
13. Torque the access door (14) attaching screws.	1.25	1	1 Torque Wrench
14. Visually inspect access door for proper installation.	1.30	1	1 Flashlight 1 Inspection Mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 27

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION: Chine Area
PANEL SIZE: 40" Segment

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of Chine Segment			
1. Locate the 8 chine attaching fastener plugs.	0.05	1	
2. Drill out the (8) chine attaching fastener ablative plugs.	0.75	1	1 Drill
3. Using a prescribed tool, free the chine segment from the adjacent chine segments, from the metallic spring seal and at metallic lip seal.	0.85	1	1 Edge Freeing Tool
4. Remove the (8) chine segment attaching fasteners.	0.95	1	1 Socket Wrench
5. Maneuver the chine segment free of the vehicle.	1.00	1	
6. Transport chine segment to the storage area to await disposition	1.10	1	
7. Store chine segment on a prescribed storage rack.	1.15	1	1 Chine Storage Rack
o Inspection			
8. Visually inspect the chine supports for damage, deterioration and signs of overheating.	1.20	1	1 Flashlight 1 Inspection Mirror
9. Visually inspect the attaching hardware for damage, deterioration and signs of overheating.	1.25	1	
o Replacement of Chine Segment			
10. Transport a new chine segment to the vehicle.	1.35	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 3

TASK ANALYSIS NO. 27

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION: Chine Area
PANEL SIZE: 40" Segment

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of Chine Segment (Cont.)			
11. Position the new chine segment on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the chine segment attaching fasteners.	1.40	1	
12. Install the (8) chine segment attaching fasteners.	1.60	1	1 Socket Wrench
13. Torque the chine segment attaching fasteners.	1.65	1	1 Torque Wrench
14. Visually inspect the chine segment at aching fasteners for proper installation.	1.70	1	1 Flashlight 1 Inspection Mirror
15. Apply a small quantity of RTV 106 adhesive to each of the (8) chine segment attaching fastener ablative plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Verify that plug does not extend below the mold line of the chine segment. Plugs in this configuration must be removed. Plugs extending above the mold line must be trimmed to match evenly with the mold line. Allow 24 hours mini um cure time before handling or stressing joint.	1.80	1	RTV 106 Adhesive

NUMBER FOLLOWING TIME BAR IS MANLOADING

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION Chine Area
PANEL SIZE: 40" Segment

TASK ANALYSIS NO. 27

REMOVAL AND REPLACEMENT

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of Chine Segment (Cont.)			
Full cure will develop in 2 to 3 days.			
16. Visually inspect chine segment attaching fastener plugs for proper installation.	1.85	1	1 Flashlight 1 Inspection Mirror
17. Visually inspect the complete chine installation	1.90	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Leading Edge Attach Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: Small 20"

TASK ANALYSIS NO. 28

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of Ablative Leading Edge			
1. Locate the (12) leading edge segment attaching fastener plugs	0.05	1	
2. Drill out the (12) ablative leading edge segment attaching fastener plugs	1.05	1	1 drill
3. Remove the (12) leading edge segment attaching fasteners	1.20	1	1 socket wrench
4. Maneuver the ablative sleeve leading edge segment free of the vehicle wing	1.35	1	1 edge freeing tool
5. Transport ablative sleeve to the storage area to await disposition	1.45	1	
6. Store ablative sleeve on a prescribed storage rack	1.50	1	1 leading edge storage rack
o Inspection			
7. Visually inspect wing leading edge attaching hardware for damage, deterioration and overheat conditions	1.55	1	1 flashlight 1 inspection mirror
8. Visually inspect rib sleeve support for damage, deterioration and overheat condition	1.60	1	
9. Visually inspect wing spar insulation for damage, deterioration and overheat condition	1.65	1	
o Replacement of Ablative Sleeve Leading Edge			
10. Transport a new ablative sleeve leading edge to the vehicle	1.70	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Leading Edge Attach Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: Small 20"

TASK ANALYSIS NO. 28

REMOVAL AND REPLACEMENT

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
11. Position leading edge ablative sleeve on vehicle wing and align for installation	1.75	1	
12. Install the leading edge sleeve (12) attaching fasteners	1.90	1	1 socket wrench
13. Torque the (12) leading edge sleeve attaching fasteners	1.95	1	1 torque wrench
14. Visually inspect the leading edge sleeve attaching fasteners for proper installation	2.00	1	1 flashlight 1 inspection mirror
15. Apply a small quantity of RTV 106 adhesive to each of the (12) leading edge sleeve attaching fastener ablative plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	2.15	1	RTV 106 adhesive
16. Visually inspect ablator plugs for proper installation		1	1 flashlight 1 inspection mirror
17. Visually inspect the complete leading edge installation		1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 29

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Insulation - Foil - Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" X 100"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of Insulation Segments			
1. Remove the appropriate TPS panels as per applicable removal and replacement task analysis.			
NOTE: (1) Each insulation blanket measures 20" x 100". (2) Each blanket has 10 support and drag strut insulation blankets, size 9" x 10"			
2. Remove the laces (4) on each of the 10 support and drag strut insulation blankets that are attached to the 20" x 100" insulation blanket. Place on transportation dolly.	1.00	4	
3. Remove 32 attaching fasteners from 2 wire grids	1.40	4	
4. Remove the wire grids from the bottom side of the 20" x 100" insulation blanket. Place wire grids on transportation dolly.	1.80	4	
5. Maneuver the 20" x 100" insulation blanket. Place wire grids on transportation dolly.	2.20	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 29

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Insulation-Foil-Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 100"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Removal of Insulation Segment cont			
6. Transport insulation blanket and accessories to a storage area.	2.60	4	
o Inspection			
7. Remove the insulation blanket (20" x 100") from transportation dolly and visually inspect the segment for obvious damage, contamination, overheating and deterioration.	3.00	4	
8. Store insulation segment in appropriate storage rack.	3.20	4	
9. Remove the wire grids (20" x 48") from the transportation dolly and visually inspect wire grid for obvious damage, corrosion, contamination, overheating and deterioration.	3.60	4	
10. Store wire grid on an appropriate storage rack.	3.80	4	
11. Remove the (32) insulation attaching fasteners from the transportation dolly and visually inspect fasteners for obvious damage, contamination, overheating and deterioration.	4.00	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 29

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Insulation-Foil-Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 100"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3–4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection (cont'd)			
12. Store the insulation attaching fasteners with insulation and wire grids.	4.10	2	
13. Remove the (10) support and drag strut insulation blankets (9" x 10") from the transportation dolly and visually inspect panels for obvious damage, contamination overheating and and deterioration.	4.50	4	
14. Visually inspect the associated panel supports, drag struts and support hardware, on the vehicle, for obvious damage, contamination, deterioration and overheating.	4.90	4	
o Replacement of Insulation Segments			
15. Transport the insulation blanket and associated equipment, on dolly, from storage area to the vehicle for installation.	5.30	4	
16. Install insulation blanket and align the 20" x 48" wire grids on the bottom side of the 20" x 100" insulation blanket and position both as an assembly in the right location on the vehicle.	6.50	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 4

TASK ANALYSIS NO. 29

REMOVAL AND REPLACEMENT

HEAT SHIELD TYPE: Insulation-Foil-Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 100"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (3–4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Replacement of Insulation Segments (cont'd)			
17. Install the (32) insulation attaching fasteners and torque to prescribed value.	6.90	4	
18. Install the (10) support and drag strut insulation blankets in their proper places and attach each to the wire grid with 4 laces.	7.90	4	
19. Visually inspect the insulation blanket for proper installation.	8.10	2	
20. Remove transportation dolly from the vehicle work area.	8.30	4	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 30

REPAIR

HEAT SHIELD TYPE: Ablative - ULD-100-4 Series
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE:

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel (Repair of ULD - 100 Series Material)			
1. Isolate damage to specific panel and small sections of ULD-100-4 materials which would not be practicable to replace but could be repaired.	0.10	1	1 Flashlight 1 Inspection Mirror
2. Remove all loose, friable materi al by brushing clean or using clean, filtered compressed air.	0.20	1	1 Compressor
3. Brush or spray catalyzed silicone resin (G.E.RTV 615) freshly pre- pared as a primer, on all sur- faces to be filled by repair material. A light coat of several mils is adequate.	0.30	1	1 Brush or 1 Spray Gun
4. Pack firmly but gently the correct formulation of uncured ULD-100-4 series material (stor- age or freshly mixed) into the primed repair section. Apply suf- ficient material to a height of approximately 50 to 100 mils above the level of the surround- ing material.	0.40	1	
5. Place platen over repair and sup- port platen with air bag with sufficient pressure to compress uncured ablator. Allow 8 hours to cure ablator	0.50	1	1 Platen 1 Air Bag 1 Air Bag Support 1 Compressor

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 30

REPAIR

HEAT SHIELD TYPE: Ablative - ULD-100-4 Series
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE:

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (9, 10)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
6. Remove air bag and platen.	0.60	1	
7. Post cure ablator repair for one hour at 200±10 degrees F.	0.70	1 1	1 Heat Lamp
8. After cure, use a sharp edged knife to trim surface of repair section flush with surrounding material.	0.80	1	
9. Apply dispersion coating. Allow to cure for 12 hours.	0.90	1	1 Brush or 1 Spray Gun
10. Visually inspect repair for proper application.	1.00		1 Flashlight 1 Inspection Mirror

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 31

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION Bottom
PANEL SIZE: 20" x 20"

REPAIR

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel			
1. Isolate damage to specific panel on the vehicle. NOTE: (1) Repairs to damage on panel on vehicle shall be limited to area of 1 to 1 1/2 inch in diameter, any damage with a larger area shall warrant panel removal and repair accomplished in a refurbishment area. (2) This task analysis depicts the damage repair on vehicle.	0.05	1	
2. Using a grinding tool, grind away damaged material down to the bondline on the fiberglass honeycomb substrate.	0.20	1	1 grinding tool
3. Remove bonding agent using methyl ethyl ketone, assure area is thoroughly clean free of any foreign matter.	0.30	1	
4. Cut a plug of prepared, cured ablative material to appropriate thickness to fit the damaged area.	0.40	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 31

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION Bottom
PANEL SIZE: 20" x 20"

REPAIR

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2, 9)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. Apply primer DC #1203 to the honeycomb substrate on the vehicle repair area and the bond side of the cured ablative honeycomb repair plug. A thin film and only one coat is required. Allow primer to dry for a minimum of 1 hour with relative humidity at 50 ±5%.	0.50	1	
6. Apply a small quantity of RC #3145 adhesive sealant to the fiber glass substrate bonding surface and sides of the repair area, with a spatula or a brush to a thickness of 10 to 30 mils over the entire contact area. NOTE: It is not necessary to apply adhesive to both surfaces to be bonded.	0.60	1	
7. Align and join the ablative honeycomb repair plug immediately (within 10 minutes) after spreading the adhesive. Press the plug firmly into the repair area. NOTE: 1. Plug should not be more than .030 below the mold line of surrounding material.	0.65	1 1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 31

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION Bottom
PANEL SIZE: 20" x 20"

REPAIR

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (9, 10)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
2. Allow a 24 hour (minimum air cure period before handling or stressing the bonded joint under normal conditions of temperature (75°F) relative humidity above 20%. After 8 hrs adhesives are set sufficiently to allow clean up and trimming.			
8. Remove the excess adhesive and any residue which may have accumulated. Trim as required.	0.75	1	
o Inspection			
9. Visually inspect TPS panel for proper repair.	0.80	1	
10. Using the x-ray method or microwave tester. Check the plug repair for voids in the adhesive bond.	1.80		1

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 31

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION Bottom
PANEL SIZE: 20" x 20"

REPAIR

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (10, 11)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel (Cont.)			
11. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM+P NAPTHA.	1.90	1	
12. Fill spray gun and test for proper function and mixture.	2.00	1	
13. Spray dispersion coating with line pressure at 55 psig. Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches, spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30 minutes if a thickness buildup is desired. Cure the dispersion coating at room temperatre for 12 to 18 hours.	2.05	1	
14. Visually inspect repair for proper accomplishment.	2.10	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 32

REPAIR

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching, Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel Requirements (1) The area shall be air-conditioned. Filters in the system may be of the commercial throw away or recleaning type (2) The area shall be maintained at a temperature of 72 ±3°F and a relative humidity of 50 ±5% (3) The area shall be vacuumed at least once during each 24 hour operational period. Portable vacuum cleaners may be used provided vacuuming is not performed during any processing or qualification operations. (4) If visible dust or contamination on storage cabinet tops, ledges, pipes and ducting is present, it shall be removed with cheesecloth, moistened with water, before starting any operation. (5) All hand tools used in any operations in this area shall be solvent cleaned with a cheesecloth dampened with either methyl ethyl ketone (MEK) or tolulene before being used. Safety disposable cans shall be provided for discarding used cloths			

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 32

REPAIR

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching, Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
(6) Only clean cheesecloths shall be used in cleaning and wiping operations (7) During trimming and cutting operations, pick up all pieces immediately after the pieces fall to the floor. Any debris producing operation shall be followed by vacuum cleaning after completion of what whole operation and before another processing operation is begun (8) Clean, white shop coats, surgical style caps and clean cotton gloves shall be worn at all times during any processing or qualifying operations in this area. Coats, caps and cotton gloves must be replaced when they become soiled (9) Wear safety glasses (or goggles) and rubber gloves while working with solvents and grinding of HCF materials (10) Wear respirator mask to prevent the inhalation of foreign matter during grinding operation			
o Repair of TPS Panel (Repair on HCF Material)			
1. Locate the damaged panel	0.10	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 5

TASK ANALYSIS NO. 32

REPAIR

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching, Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1 – 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
2. Remove the damaged panel per task analysis no. ________ mechanical fastener attaching Concept #2	0.85	1	
3. Transport panel to the refurbishment area	0.95	1	
4. Using a grinding wheel, grinding disc and a sharp knife like device remove the HCF material from the panel down to the bond line on the fiberglass honey comb substrate	1.05	1	1 grinding tool 1 sharp knife
5. Clean the bonding agent from the fiberglass honeycomb substrate, using a methyl, ethyl ketone after substrate is clean and free of any foreign material, cover substrate with clean cloth to prevent contamination	1.15	1	Cleaning cloth
6. Procure a serviceable HCF segment, sized to fit the fiberglass honeycomb substrate	1.20	1	
7. Remove cloth cover from the fiberglass honeycomb substrate. Apply primer DC#1203 to the substrate and the bond side of the HCF segment. A thin film and only one coat is required. Allow primer to dry for a minimum of 1 hour with relative humidity at 50 $\pm$5%	1.25	1	1 brush

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 5

TASK ANALYSIS NO. 32

REPAIR

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching, Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (2 – 3)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
8. Apply a small quantity of RC#3145 adhesive sealant to the fiberglass substrate bonding surface and spread with a spatula or brush to a thickness of 10 to 30 mils over the entire contact area NOTE: It is not necessary to apply adhesive to both surfaces to be bonded	1.30	1	1 spatula or 1 brush
9. Align and join the HCF segment to the fiberglass honeycomb substrate immediately (with in 10 minutes) after spread the adhesive. Press the parts firmly together with finger pressure using a progressive action starting at one end so air will be excluded from the joint. NOTE: Allow a 24 hour (minimum) air cure period before handling or stressing the bonded joint. Under normal conditions of temperature (75°F) relative humidity above 20% the bonded parts will cure to handle in 24 hours. Full cure will develop in 2 to 3 days.	1.35	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 32

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching, Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

REPAIR

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (27 – 28)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
10. Remove the excess adhesive and any residue which may have accumulated	1.45	1	
o Inspection			
11. Visually inspect TPS panel for proper repair	1.50	1	1 flashlight 1 inspection mirror
12. Using the x-ray method or microwave tester procedure check the HCF panel for voids in the adhesive bond	2.50	1	x-ray equipment or microwave tester
13. After inspection serviceability verification, return the serviceable HCF panel assembly to the vehicle for installation	2.60	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 33

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

REPAIR

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair Coating of TPS Panel			
1. Isolate discrepancy to be repaired. NOTE: Repair of defective coating area shall be limited to a three inch diameter circle and shall not extend to panel edge. Defective coating in excess of above limitations shall require removal of panel and shop repair.	0.05	1	1 flashlight 1 inspection mirror
2. Prepare the defective area for repair coating by sanding the defective area until all loose material is removed and the surface is smooth.	0.20	1	aluminum oxide sanding paper
3. Wash the area with water to remove all grit and loose material.	0.25	1	water cleaning cloth
4. Wash area with acetone to remove all other contamination.	0.30	1	acetone cleaning cloth
5. Inspect surface to assure area is clean and smooth prior to coating application.	0.35	1	1 flashlight 1 inspection mirror
6. Prepare the thermal-spraygun, the vibrator unit and the air-jet unit, which is set at 70 psi. For base coat application; and test instrument.	1.05	2	1 thermal-spraygun 1 vibrator unit 1 air-jet unit 1 thermo electric test instrument or 1 eddy current tester

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 4

TASK ANALYSIS NO. 33

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

REPAIR

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel – Cont'd.			
7. Apply the thermal-spray powder to the defective area holding spray gun perpendicular to and 6-8 inches from surface being coated. Control the base coat thickness between 2-1/2 and 3-1/2 mils by controlling the speed and number of passes of the thermal-spray unit. Insure that the thermal-spray powder covers all of the defect area and extends one-half inch past the perimeter of the defect onto the good coating in all directions.	1.10	1	thermal spray powder (AL_2O_3) 1 thermal spraygun 1 masking template 1 set safety clothing 1 fire extinguisher
8. Inspect the base coat application to assure that conditions of step 7 are met.	1.20	1	1 thermo electric test instrumentor 1 eddy current tester
9. Obtain repair glass from shop.	1.30	1	
10. Apply the repair glass with a camel's hair brush. Each application should be as thin as possible to obtain a coating as crack free as possible. Assure that thermal-spray powder is covered with glass, but that glass not extend onto the good coating.	1.40	1	repair glass 1 camel's hair brush
11. Visually inspect glass for proper application.	1.45	1	1 flashlight 1 inspection mirror
12. Dry repair glass at 120-150 degree F for one hour.	1.55	1	1 heat lamp
13. Obtain repair glass from shop	1.65	1	repair glass

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 4

TASK ANALYSIS NO. 33

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

REPAIR

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel - Cont'd.		1 2	
14. Apply the repair glass (see Task Number 10.)	1.75	1	1 camel's hair brush
15. Visually inspect glass for proper application.	1.80	1	1 flashlight 1 inspection mirror
		ELAPSED TIME IN HOURS 3 4	
16. Dry repair glass at 120-150 degree F for one hour	1.90	1	1 heat lamp
17. Obtain repair glass from shop	2.00	1	repair glass
18. Apply the repair glass. (see Task Number 10.)	2.10	1	1 camel's hair brush
19. Visually inspect glass for proper application.	2.15	1	1 flashlight 1 insp-ction mirror
20. Dry repair glass at 120-150 degree F for one hour.	2.20	1	1 heat lamp
		ELAPSED TIME IN HOURS 5 6	
20. (Cont'd.) Dry repair glass at 120-150 degrees F for one hour.	2.25	1	1 heat lamp
21. Obtain repair glass from shop	2.35	1	repair glass
22. Apply the repair glass. (see Task Number 10.)	2.45	1	1 camel's hair brush
23. Visually inspect glass for proper application.	2.50	1	1 flashlight 1 inspection mirror
24. Dry repair glass at 120-150 degree F for one hour	2.60	1 1	1 heat lamp
25. Inspect repair for proper coating thickness, of 10-15 mils.	2.70	1	1 thermo electric test instrument or 1 eddy current tester.

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 33

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

REPAIR

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Repair of TPS Panel - Cont'd.		7 8	
26. Obtain repair glass from shop.	2.80	1	repair glass
27. Apply the repair glass. (See Task Number 10.)	2.90	1	1 camel's hair brush
28. Visually inspect glass for proper application.	2.95	1	1 flashlight 1 inspection mirror
29. Dry repair glass at 120-150 degree F for one hour.	3.05	1 1	1 heat lamp
30. Inspect repair for proper coating thickness of 10-15 mils.	3.15	1	1 thermo electric test instrument or 1 eddy current tester.
31. Return tester to shop	3.25	1	
32. Return thermal spraygun and equipment to shop.	3.35	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

TASK ANALYSIS NO. 34

REPAIR

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Leading Edge Repair			
1. Locate leading edge segment that has the damage condition			
2. Remove the leading edge segment from the wing of the vehicle per task analysis no. _______ carbon-carbon leading edge concept #9			
3. Transport leading edge segment to the refurbishment area NOTE: (1) Repair of carbon-carbon leading edge segment is limited to scratches and score marks. (2) Any punctures, cracks thru the material would warrant removal of segment and replacement with a like serviceable segment (3) Segment with major damage would be submitted for disposition			
4. Using an abrasive (fine) sand paper smooth off any burrs that may exist.	0.10	1	Sand paper

NUMBER FOLLOWING TIME BAR IS MANLOADING

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TASK ANALYSIS NO. 34

REPAIR

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20"

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 4)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
5. Using Methyl Ethyl Ketone to remove any debris that may remain. NOTE: Air dry repair for three hours before proceeding with repair.	0.15	1	Solvent
6. Apply powdered silicon metal using the flame spray method. Assure that the application adequately covers the damaged area. NOTE: Powdered silicon metal is fed into an oxyacetyline flame and blown onto the repair area.	0.30	1	1 Frame Spray Gun
7. Using an oxyacetylene torch heat treat repair area to 2800°F NOTE: This type of repair is satisfactory for operating temperarures of 3000°F.	0.45	1 1	1 Oxyacetylene Torch

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 3

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20"

TASK ANALYSIS NO. 34

REPAIR

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (4 – 5)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection			
8. Visually inspect the repair and assure that the silicon metal coating covers the damaged area adequately.	0.50	1	1 Flashlight 1 Inspection Mirror
o Leading Edge Repair (Cont)			
9. Transport leading edge to the vehicle for installation.			
10. Install leading edge on wing of vehicle per task analysis no._______ Carbon-Carbon Leading Edge Concept #9			

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 3 OF 3

HEAT SHIELD TYPE: Ablative - ULD

PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2

PANEL LOCATION: Bottom

PANEL SIZE: 20" x 20"

TASK ANALYSIS NO. 35

INSPECTION

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel			
1. Using a spot light, visually inspect the entire area of the ablative panel for dents, abrasions, pit marks, erosion and deterioration	0.025	1	1 spot light
2. Visually inspect ablative panel attaching fastener plugs for proper position and alignment (plug is even with mold line - surface mismatch between plug and panel allowable - .030 inches)	0.05	1	
3. Visually inspect panel edge molded seal for damage, proper alignment and for proper sealing NOTE: (1) Any damage of a magnitude affecting the integrity of the fiberglass honeycomb substrate will warrant the removal of the ablative panel assembly for further inspection and repair. (2) Remove ablative panel assembly per applicable removal and replacement task analysis. (3) Visually inspect all attaching fasteners for serviceability. (4) Visually inspect support hardware for damage, corrosion, and overheating.	0.075	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 1

HEAT SHIELD TYPE: HCF (Hardened Compacted Fibers)
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION Bottom
PANEL SIZE: 20" x 20"

TASK ANALYSIS NO. 36

INSPECTION

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel			
1. Using a spot light, visually inspect the entire area of the HCF panel for dents, abrasions, pit marks, erosion and deterioration	0.025	1	1 spot light
2. Visually inspect the HCF panel surface coating for damage	0.050	1	
3. Visually inspect HCF panel attaching fastener plugs for proper bonding and alignment (plug is even with mold line. Surface mismatch between plug and panel .030 inches allowable)	0.075	1	
4. Visually inspect panel edge molded seal for damage, proper alignment and for proper sealing	0.10	1	
NOTE: (1) Any damage of a magnitude affecting the integrity of the fiberglass honeycomb substrate, will warrant the removal of the HCF panel for further inspection and repair. (2) Remove HCF panel per applicable removal and replacement task analysis. (3) Visually inspect all attaching fasteners for serviceability (4) Visually inspect support hardware for damage, corrosion, and overheating.			

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 1

TASK ANALYSIS NO. 37

HEAT SHIELD TYPE: Metallic - Coated Columbium
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #7B with Intermediate Panel Support, Concept
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

INSPECTION

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel			
1. Using a spot light and magnifying glass visually inspect the entire area of the coated metallic panel for deep dents, scratches, abrasions and pit marks that may cause oxidation and deterioration of the metallic coated material	0.05	1	1 spot light 1 magnifying glass
2. Visually inspect the edges of the panel for signs of chafing and chipping of the metallic panel coating	0.10	1	
3. Visually inspect the longitudinal panel joint for distortion, excessive gapping, chafing and chipping of the metallic coating at the joint	0.15	1	
4. Using nylon gloves, place hands on panel and check panel for looseness (excessive end play and side play)	0.20	1	
5. Check pi-straps for damage (deep dents, scratches, abrasion and pit marks that may cause oxidation and deterioration of the metallic coated material)	0.25	1	
6. Visually inspect all panel pi-strap attaching fasteners for tool damage to coating and burring of the tool slots	0.30	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 37

HEAT SHIELD TYPE: Metallic - Coated Columbium
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

INSPECTION

FUNCTION - TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS (1, 2)	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel			
NOTE: (1) Any deep dent or hole in panel will warrant removal of panel for repair due to the fact that the coating material on the back side of panel skin will be affected and will require a similar repair. (2) Remove panel per applicable removal and replacement task analysis.			
7. Inspect entire back side of panel for deep dents, scratches abrasions and pit marks affecting panel coating	0.35	1	
8. Visually inspect the backside edges of the panel for chafing and chipping of the coating	0.40	1	
9. Visually inspect backside of panel, panel joint for distortion, excessive gapping and chafing and chipping of panel coating	0.45	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 38

INSPECTION

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel			
1. Using a spot light and magnifying glass, visually inspect the entire area of the panel surface for dents, scratches, abrasions and pit marks, that cause oxidation and deterioration	0.05	1	1 spot light 1 magnifying glass
2. Visually inspect the edges of the panel for signs of chafing of the panel	0.10	1	
3. Visually inspect the longitudinal panel joints for distortion, excessive gapping and chafing	0.15	1	
4. Using nylon gloves, place hands on panel and check panel for looseness (excessive end play and side play)	0.20	1	
5. Check pi-straps for damage (deep dents, scratches, abrasions and pit marks that may cause oxidation and deterioration of material)	0.25	1	
6. Visually inspect all panel pi-strap attaching fasteners for tool damage such as burring of tool slots	0.30	1	
NOTE: (1) Any damage of a magnitude affecting panel structure, will warrant the panel removal for further inspection and repair.			

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 38

INSPECTION

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Panel (Cont.)			
(2) Remove panel per applicable removal and replacement task analysis.			
7. Inspect backside of panel for major structural damage, dents, abrasions and pit marks	0.35	1	
8. Visually inspect panel backside edges for chafing	0.40	1	
9. Visually inspect panel backside panel joints for distortion excessive gapping and chafing	0.45	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 2 OF 2

TASK ANALYSIS NO. 39

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-carbon leading edge concept
PANEL LOCATION: Leading edge
PANEL SIZE: 20"

INSPECTION

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Leading Edge			
1. Using a spot light and magnifying glass, visually inspect the entire outside surface of the leading edge segment for scratches, abrasions, pit marks erosion and deterioration	0.025	1	1 spot light 1 magnifying glass
2. Visually inspect the mating surfaces for indications of chafing, erosion and deterioration.	0.05	1	
3. Using nylon gloves, check leading edge segment for security of attachment (excessive end play and side play) NOTE: (1) Any damage of a magnitude affecting leading edge segment integrity, will warrant the leading edge segment removal for further inspection and repair. (2) Remove leading edge segment per applicable removal and replacement task analysis.	0.075	1	
4. Inspect the inside of the leading edge segment for obvious damage and evidence of overheating of the support hardware and the attaching fasteners.	0.10	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

PAGE 1 OF 2

TASK ANALYSIS NO. 39

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-carbon leading edge concept
PANEL LOCATION: Leading edge
PANEL SIZE: 20"

INSPECTION

FUNCTION – TASK DESCRIPTION	CUMULATIVE MANHOURS	ELAPSED TIME IN HOURS	TOOLS AND EQUIPMENT PARTS AND MATERIAL
o Inspection of TPS Leading Edge (Cont.)			
5. Visually inspect wing spar attaching area for damage and evidence of overheating.	0.125	1	
6. Visually inspect the inside areas of the two adjacent leading edge segments for obvious damage, and evidence of overheating of support hardware and attaching fasteners.	0.15	1	

NUMBER FOLLOWING TIME BAR IS MANLOADING

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APPENDIX B

COST AND DESIGN EVALUATION

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Ablative Material from Vehicle NOTE: Due to the extensive grinding and cutting operation required to remove the ablative material from the double face honeycomb on the vehicle, the use of goggles/eye shields, breathing mask and vacuum cleaner is mandatory safety equipment.			
1. Using grinding wheel, sanding disc and a suitable knife like cutting tool, remove the ablative material from the structural double face honeycomb on the vehicle, down to the bond line.	3	3	Can ablative material be removed with listed tools and in the time estimated? Reason: Surface of structural honeycomb will be subjected to damage.
2. Clean the structural double face honeycomb with methyl ethyl ketone (MEK) to remove debris from the surface.	1	1	
o Inspection			
3. Visually inspect surface of structural honeycomb for damage resulting from ablative material removal.	1	1	
4. Cover the cleaned surface with anti-tarnish tissue.	1	1	

PAGE 1 OF 6

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replace Ablative Material on Vehicle			
5. Transport ablative material segment to the vehicle.	1	1	
6. Thoroughly clean all surfaces to be bonded by wiping with a clean cloth dampened with cleaning solvent. Wipe dry with a clean, dry cloth before evaporation of the solvent. Always clean an area wider than the width of the finally applied adhesive. It is essential that clean cloths and clean solvent be used in the cleaning operation. Do not use contaminated materials. Repeat cleaning operations until a clean, oil free surface is assured. Cleaned surfaces shall be allowed to dry 3 to 5 minutes before the application of any bonding material. Adhesive should be applied as soon as possible after cleaning. Do not allow handling or storage between the cleaning and bonding operations.	1	1	

PAGE 2 OF 6

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replace Ablative Material on Vehicle			
7. Before applying adhesive apply a single uniform thin brush-coat of SS-4004 Silicone Primer to clean mating surfaces. Apply primer to cover an area wider than the width of the finally applied adhesive. Allow primer to air dry a minimum of 30 minutes at ambient temperature prior to applying adhesive. A longer dry time shall be allowed if there are wet spots evident in the primer coat. Remove the primer and repeat the priming procedure when ever the primer becomes contaminated or when the RTV silicone adhesive is not applied within 72 hours after priming. Use applicable cleaning procedure to remove primer.	2	1	Can primer be applied on spacecraft in refurbishment maintenance area? Reason: Contamination of primer while drying. Pollution of surrounding area and curtailment of parallel maintenance actions.
8. Mix RTV-90 in the weight ratio of 1 percent Silicure L-24 Catalyst to weight of base compound. It is imperative that the accelerators be thoroughly	1	1	

PAGE 3 OF 6

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replace Ablative Material on Vehicle			
dispersed throughout the base compounds. Stirring and folding in the accelerator must be done slowly to avoid excessive air entrapment. Approximately 5 to 7 minutes of hand mixing or blending with a spatula is normally required to obtain uniformity.			
9. Apply adhesive to one of the mating surfaces using a sealant gun. Cover entire surface to be bonded with a layer of material approx. 25 mils thick.	2	1	Can adhesive be applied on spacecraft in refurbishment maintenance area? Contamination of adhesive while drying. Pollution of surrounding area and curtailment of parallel maintenance actions.
Place the surfaces to be bonded together and effect the bond using even contact pressure and squeezing out any excess adhesive. Care should be taken to insure that no air is trapped between the mating surfaces. The adhesive has sufficient substance to support the bonded surface during cure but if a vertical bond or similar condition is to be made tooling should be used to hold the bond together until the adhesive is tack free.	3	2	Can air bags be used to apply contact pressure? Reason: TPS support structure has limited design loads.

PAGE 4 OF 6

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replace Ablative Material on Vehicle (Cont.)			
The adhesive shall be cured to tack-free, firm, rubbery condition prior to trimming (8 hours). Remove the excess adhesive by scraping with a plastic scraper.			
o Inspection			
10. Visually inspect ablative material for proper installation.	1	1	
11. Set up microwave tester.	2	1	Can panel bondline integrity be tested on the spacecraft in the time estimated? Reason: Limited experience of microwave testing.
12. Microwave test panel for bondline integrity.			
13. Using sealant gun, fill in void on the perimeter of panel.	1	1	
14. Place platen over the repair and support with sufficient pressure to compress adhesive smoothly. Allow supported platen to remain in place for 9 hours to allow adhesive to cure.	3	1	Can air bags be used to apply contact pressure? Reason: TPS support structure has limited design loads.
15. After curing, use sharp edge knife to trim surface of adhesive section flush with surrounding panel.	1	1	

PAGE 5 OF 6

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Ablative Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 1

COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replace Ablative Material on Vehicle (Cont.)			
16. Apply dispersion coating to adhesive. Allow to cure for 12 hours.	2	1	Can dispersion coating be applied on spacecraft in refurbishment maintenance area? Reason: Contamination of dispersion coating while curing. Pollution of surrounding area and curtailment of parallel maintenance actions.
17. Inspect panel sealing operation for proper installation.			

PAGE 6 OF 6

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 2

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS HCF Material from Vehicle			
NOTE: Due to the extensive grinding and cutting operation required to remove the HCF material from the structural double face honeycomb on the vehicle, the use of goggles/eyeshields, breathing masks and vacuum cleaner is mandatory safety equipment.			
1. Using a grinding wheel, sending disc and a suitable knife like cutting tool, remove the HCF material from the structural double face honeycomb on the vehicle, down to the bond-line.	3	4	Can HCF material be removed with listed tools and in the time estimated? Reason: Surface of structural honeycomb will be subjected to damage.
2. Clean the surface of the structural double face honyecomb with methyl ethyl ketone (MEK) to remove the debris.	1	1	
3. Cover the cleaned surface with anti-tarnish tissue after cleaning procedure.	1	1	
o Inspection			
4. Inspect the structural	1	1	

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 2

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
double face honeycomb surface for damage deterioration overheating and cleanliness.			
5. Cover the structural double face honeycomb surface with the anti-tarnish tissue	1	1	
o Replacement of HCF Segment on Vehicle			
6. Transport a new HCF segment from the storage area to the vehicle.	1	1	
NOTE: Exercise care in handling the HCF segment (20" x 20" tile) to prevent damage to the exterior coating applied to each tile.			
7. Remove the anti-tarnish tissue from the structural double face honeycomb surface of the vehicle.	1	1	
8. Make visual check to assure that the structural double face honeycomb surface is still clean and free of any foreign matter.	1	1	

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 2

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of HCF Segment on Vehicle (Cont.)			
9. Apply a single uniform coat of #1203 silicone primer to the structural double face honeycomb surface and the inside surface of the HCF tile.	2	1	Can primer be applied on spacecraft in refurbishment maintenance area? Reason: Contamination of primer. Pollution of surrounding area and curtailment of parallel maintenance actions.
10. Apply a uniform coat of DC#3145 approximately 0.010-0.030 inch thick to the bonding surface of the structural double face honey comb surface on the vehicle.	3	2	Can adhesive be applied on spacecraft in refurbishment maintenance area? Reason: Contamination of adhesive. Pollution of surrounding area and curtailment of parallel maintenance actions.
11. Position and align the HCF tile on the vehicle in a manner to prevent as much entrapment of air bubbles as possible.	1	1	
12. Roll the outside tile surface with a rubber roller to insure intimate contact at the bondline and to squeeze out excess adhesive. Work from the center of the tile to the four sides. Allow the assembly to cure at room temperature (65°F to 100°F) for 24 hours before handling. The #3145 will be full cured in 5 to 7 days.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: HCF Heat Shield Attachment Concept #1
PANEL LOCATION: Bottom
PANEL SIZE: Small 20" x 20"

TASK ANALYSIS NO. 2

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of HCF Segment on Vehicle (Cont.)			
13. Remove excess cure #3145 with a plastic scraper (45° cutting edge). Exercise care to prevent damage to the HCF tile coating.	1	1	
14. Visually inspect HCF tile for proper installation.	1	1	
15. Set up microwave tester. 16. Microwave test panel for bondline integrity.	2	1	Can panel bondline integrity be tested on the spacecraft? Reason: Limited experience of microwave testing.
17. Using sealant gun, fill in void on the perimeter of panel.	1	1	
18. Place platen over the repair and support with sufficient pressure to compress adhesive smoothly. Allow support platen to remain in place for 8 hours to allow adhesive to cure.	3	1	Can air bags be used to apply contact pressure? Reason: TPS support structure has limited design loads.
19. After curing, use sharp edge knife to trim surface of adhesive flush with surrounding panel.			

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 3

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (6) panel attaching fastener plugs.	1	1	
2. Drill out (6) panel attaching fastener plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free panel edges from adjacent panels.	2	3	Can charred gaskets be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator has not been experienced.
4. Remove (6) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
5. Maneuver the panel free of the vehicle.	1	1	
6. Transport panel to storage area for disposition	1	1	
7. Store panel on the prescribed storage rack.	1	1	
o Inspection			
8. Visually inspect fibrous insulation for damage. Deterioration and signs of overheating.	1	1	
9. Remove, replace or repair insulation as required (see task analysis no. 29).	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 3

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Insulation (Cont.)			
10. Visually inspect the support hardware for damage deterioration and overheating.	1	1	
11. Visually inspect attaching fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
12. Transport a new panel from storage area to the vehicle.	1	1	
13. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	1	1	
14. Install the (6) panel attaching fasteners.	1	1	Can attaching fasteners be installed in estimating time? Reason: Misalignment of fastener holes in ablator panel and fastener holes and platenuts in panel support structure.
15. Torque the (6) panel attaching fasteners.			
16. Visually inspect the panel attaching fastener for proper installation.			

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 3

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
17. Apply a small quantity of RVT 106 adhesive to each of the (6) panel attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs in plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 or 3 days.	1	1	
18. Visually inspect attaching fastener plugs for proper installation.	1	1	
19. Visually inspect the complete panel installation.			

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 4

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (26) panel attaching fastener plugs.	1	1	
2. Drill out (26) panel attaching fastener plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free panel edges from adjacent panels.	2	3	Can charred gaskets be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator has not been experienced.
4. Position panel dolly for the panel removal.	1	1	
5. Elevate dolly platform for panel retrieval.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on the dolly.	1	1	
7. Remove the (26) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	1	1	
9. Lower panel dolly platform with panel from the elevated position to the transport position.	2	2	Same as item 5.
10. Unlock panel dolly brakes.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 4

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
11. Transport panel to the storage area to await disposition.	1	1	
12. Store panel on a prescribed storage rack.	1	1	
o Inspection			
13. Visually inspect the fibrous insulation for damage, deterioration and signs of overheating.	1	1	
14. Remove, replace, or repair insulation as required (see task analysis no. 29)			
15. Visually inspect the support hardware for damage, deterioration and overheating.	1	1	
16. Visually inspect the attaching fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
17. Load a new panel onto the panel dolly and transport panel to the vehicle.	1	1	
18. Position panel dolly for panel installation.	2	2	Same as Item 5.
19. Elevate panel dolly platform with panel to the install position.	2	2	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 4

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
20. Lock panel dolly brakes.	1	1	
21. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torquing of the panel attaching fasteners.			
22. Install the (26) panel attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator panel and fastener holes and platenuts in panel support structure.
23. Lower the panel dolly platform to transport position.	2	2	Same as item 5.
24. Release panel dolly brakes.	1	1	
25. Remove panel dolly from the work area.	1	1	
26. Torque the (26) panel attaching fasteners.	1	1	
27. Visually inspect the panel attaching fasteners for proper installation.	1	1	
28. Apply a small quantity of RTV 106 adhesive to each of the (26) panel attaching fastener plugs with a brush or spatula to a thickness of 10-30 mils over the entire contact area.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 4

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allo 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
29. Visually inspect plugs for proper operation.	1	1	
30. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 5

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (62) panel attaching fastener plugs.	1	1	
2. Drill out (62) panel attaching fastener plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free the panel edges from adjacent panel.	2	3	Can charred gaskets be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator has not been experienced.
4. Position a panel dolly for the panel removal.	1	1	
5. Elevate dolly platform for panel removal.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on the dolly.	1	1	
7. Remove the (62) panel attaching fasteners. NOTE: The panel is bonded directly to the fiberglass honeycomb substrate and are removed or replaced as one unit.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	1	1	
9. Lower panel dolly platform from the elevated position to the transport position.	2	2	Same as Item 5.

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 5

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
10. Unlock panel dolly brakes	1	1	
11. Transport panel to the storage area to await disposition.	1	1	
12. Store panel on a prescribed storage rack.	1	1	
o Inspection			
13. Visually inspect the fibrous insulation for damage, deterioration and signs of overheating.	1	1	
14. Remove, replace or repair insulation as required (see task analysis no. 29).			
15. Visually inspect the support hardware for damage, deterioration and overheating.	1	1	
16. Visually inspect the attached fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
17. Load a new panel onto the panel dolly and transport panel to the vehicle.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 5

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
18. Position panel dolly for panel installation.	2	2	Same as Item 5.
19. Elevate panel dolly platform with panel to the install position.	2	2	Same as Item 5.
20. Lock panel dolly brakes	1	1	
21. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	1	1	
22. Install the (62) panel attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator panel and fastener holes and platenuts in panel support structure.
23. Lower the plane dolly platform to transport position.	2	2	Same as Item 5.
24. Release panel dolly brakes.	1	1	
25. Remove panel dolly from the work area.	1	1	
26. Torque the (62) panel attaching fasteners.	1	1	
27. Visually inspect the panel attaching fasteners for proper installation.	1	1	
28. Apply a small quantity of RTV 106 adhesive to each of the (62) panel	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attach Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 5

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
attaching fastener plugs, with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
29. Visually inspect plugs for proper operation.	1	1	
30. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 6

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate the (10) pi-strap attaching fastener plugs.	1	1	
2. Drill out the (10) pi-strap attaching fastener plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free panel edges and pi-straps edges from adjacent panels.	2	3	Can charred ablator pi-strap be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap from charred ablator panel has not been experienced.
4. Remove the (10) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
5. Remove the associated pi-straps.	1	1	
6. Maneuver panel free of vehicle. NOTE: Panel is bonded directly to a fiberglass honeycomb substrate, therefore are removed as a single unit.	1	1	
7. Transport panel and associated pi-straps to the storage area to await disposition.	1	1	
8. Store panel on prescribed storage rack.	1	1	
o Inspection			
9. Visually inspect fiberglass	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 6

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
insulation for damage, overheating and deterioration.			
10. Remove, replace, and repair insulation (as required (see task analysis no. 29)			
11. Visually inspect all support hardware for damage, deterioration and over-heating.	1	1	
12. Visually inspect attaching fasteners for damage, deterioration and signs of overheating.	1	1	
o Replacement of TPS Panel			
13. Transport a new panel with associated pi straps to the vehicle.	1	1	
14. Position panel on the vehicle and align for installation.	1	1	
15. Align pi-straps on panel for fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.	1	1	
16. Install the (10) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimating time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenuts in panel support structure.

PAGE 2 OF

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 6

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
17. Torque the (10) pi-strap attaching fasteners.			
18. Visually inspect pi-strap attaching fasteners for proper installation.	1	1	
19. Apply a small quantity of RTV 106 adhesive to each of the (10) pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	
20. Visually inspect pi-strap attaching fastener plugs for proper installation.	1	1	
21. Visually inspect the complete panel installation.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 7

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate the (28) pi-strap attaching fastener plugs.	1	1	
2. Drill out the (28) pi-strap attaching fastener plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free panel edges and pi-strap edges from adjacent panels.	2	3	Can charred ablator pi-strap be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap from charred ablator panel has not been experienced.
4. Position a panel dolly for the panel removal.	1	1	
5. Elevate panel dolly platform for panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on panel dolly.			
7. Remove the (28) panel attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Remove the associated pi straps.	1	1	
9. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	1	1	
10. Lower panel dolly platform with panel from the installed position to the transport position.	2	2	Same as Item 5.
11. Unlock panel dolly brakes.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 7

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
12. Transport panel with associated pi straps to a storage area to await disposition.	1	1	
13. Store panel on a storage rack.	1	1	
o Inspection			
14. Visually inspect fibrous insulation for damage, deterioration and overheating.	1	1	
15. Remove, replace or repair insulation (see task analysis no.).			
16. Visually inspect all support hardware for damage, deterioration and overheating.	1	1	
17. Visually inspect attaching fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
18. Load a new panel and associated pi-straps, on the panel dolly.	1	1	
19. Transport panel on dolly to the vehicle.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 7

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
20. Position panel dolly for panel installation.	1	1	
21. Elevate panel dolly platform with panel to installed position.	2	2	Same as Item 5.
22. Lock panel dolly brakes.	1	1	
23. Position the new panel on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.	1	1	
24. Align the pi-strap for the attaching fastener installation.	1	1	
25. Install the (28) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in the estimated time? Reason: Misalignment of fastener holes in ablative pi-strap and fastener holes and platenutes in panel support structure.
26. Lower platform of the panel dolly from the installed position to the transport position.	2	2	Same as Item 5.
27. Release panel dolly brakes.	1	1	
28. Remove panel dolly from the work area.	1	1	
29. Torque the (28) pi-strap attaching fasteners.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 7

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
30. Visually inspect the pi-strap attaching fasteners for damage and proper installation.	1	1	
31. Apply a small quantity of RTV 106 adhesive to the pi-strap attaching fastener plugs (28) with a brush or a spatula to a thickness of 10 to 30 miles over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from the joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 or 3 days.	1	1	
32. Visually inspect plugs for proper operation.	1	1	
33. Visually inspect the complete panel installation.			

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate the (62) pi-strap attaching fastener plugs	1	1	
2. Drill out the (62) pi-strap	4	3	Can charred ablator plugs be drilled out with standard equipment in the estimated time? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using aprescribed tool, free panel edges and pi-strap edges from adjacent panels.	2	3	Can charred ablator pi-strap be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap from charred ablator panel has not been experienced.
4. Position a panel dolly for the panel removal.	1	1	
5. Elevate panel dolly platform for panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed, similar type dolly used for aircraft maintenance.
6. Lock brakes on panel dolly.	1	1	
7. Remove the (62) panel attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Remove the associated pi-straps.	1	1	
9. Maneuver the panel free of the vehicle and lower panel onto panel dolly.	1	1	
10. Lower panel dolly platform with panel.	2	2	Same as Item 5
11. Unlock panel dolly brakes.	1	1	
12. Transport panel with associated pi-straps to a storage area to await disposition.	1	1	
13. Store panel on a storage rack.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection			
14. Visually inspect fibrous insulation for damage, deterioration and overheating.	1	1	
15. Remove, replace or repair insulation as required (see task analysis no. 29).			
16. Visually inspect all support hardware for damage, deterioration and overheating.	1	1	
17. Visually inspect attaching fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
18. Load a new panel and associated pi-straps, on the panel dolly.	1	1	
19. Transport panel on dolly to the vehicle.	1	1	
20. Position panel dolly for panel installation.	1	1	
21. Elevate panel dolly platform with panel to install position.	2	2	Same as Item 5.
22. Lock panel dolly brakes.	1	1	
23. Position the new panel on the vehicle and align for installation.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #3
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
NOTE: Exercise care to prevent damage during installation and torqueing of the panel attaching fasteners.			
24. Align the pi-straps for the attaching fastener installation.	1	1	
25. Install the (62) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in the estimated time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenuts in panel support structure.
26. Lower platform of the panel dolly from the install position to the transport position.	2	2	Same as Item 5.
27. Release panel dolly brakes.	1	1	
28. Remove panel dolly from the work area.	1	1	
29. Torque the (62) pi-strap attaching fasteners.	1	1	
30. Visually inspect the pi-straps attaching fasteners for damage, and proper installation.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative/HCF
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attachment Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 8

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
31. Apply a small quantity of RTV 106 adhesive to the pi-strap attaching fastener plugs (62) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure time before handling or stressing joint. Full cure will develop in 2 or 3 days.	1	1	
32. Visually inspect plugs for proper operation.	1	1	
33. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 9

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (6) pi-strap attaching fastener ablator plugs.	1	1	
2. Drill out (6) pi-strap attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	2	3	Can charred ablator pi-strap or gasket be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap or gasket from charred ablator panel has not been experienced.
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	2	3	
5. Remove (6) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred plug adhesive.
6. Remove associated pi-straps.	1	1	
7. Maneuver ablator panel assy. (includes ablator panel attached to honyecomb substrate panel) free of vehicle.	1	1	
NOTE:			
(1) Ablator panel and honey-comb substrate panel are removed as an assembly.	1	1	
(2) Disassembly of panels (16 studs) to be accomplished in the refurbishment area and disposition of sub-assemblies determined.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 9

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
8. Transport ablator panel assembly and associated pi-straps to refurbishment area.	1	1	
9. Store panel on storage rack.	1	1	
o Inspection			
10. Visually inspect the fibrous insulation for damage, overheating and deterioration.	1	1	
11. Remove, replace or repair insulation as required (see task analysis no. 29).			
12. Visually inspect all support hardware for damage, deterioration and over heating.	1	1	
13. Visually inspect attaching fasteners for damage, deterioration, and signs of overheating.	1	1	
o Replacement of TPS Panel			
14. Transport a new ablator panel assembly and associated pi-straps to the vehicle.	1	1	
15. Position the new ablator panel assembly on the vehicle for installation.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fasteners Concept #4A Pi-Strap
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 9

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o <u>Replacement of TPS Panel (Cont.)</u>			
16. Position the pi-strap on the ablator panel for installation.	1	1	
17. Install the (6) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenutes in panel support structure.
18. Torque the (6) attaching fasteners.	1	1	
19. Visually inspect the pi-strap attaching installation.	1	1	
20. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure period before handling. Full cure will develop in 2 to 3 days.			
21. Visually inspect pi strap attaching fastener plug installation.	1	1	
22. Visually inspect the complete panel installation.	1	1	

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 10

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (26) pi-strap attach-fastener ablator plugs.	1	1	
2. Drill out (26) pi-strap attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	2	3	Can charred ablator pi-strap or gasket be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap or gasket from charred ablator panel has not been experienced.
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	2	3	
5. Position panel dolly for ablator panel assembly removal.	1	1	
6. Elevate dolly platform for panel assembly removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
7. Lock brakes on dolly.	1	1	
8. Remove (26) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
9. Remove associated pi-straps.	1	1	
10. Maneuver ablator panel assy (comprised of ablator panel attached to the honeycomb substrate panel) free of vehicle. NOTE:			
(1) Ablator panel and honey-comb substrate panel are removed as an assembly.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 10

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
(2) Disassembly of panel (72 stubs) to be accomplished in the refurbishment area and disposition of sub assemblies determined.	1	1	
11. Lower panel dolly with panel from installed position to transport position.	2	2	Same as Item 6.
12. Unlock panel dolly brakes.	1	1	
13. Transport ablator panel assy and associated pi-straps to the refurbishment area.	1	1	
14. Unload ablator panel assy from panel dolly and store on prescribed storage rack.	1	1	
o Inspection			
15. Visually inspect the fibrous insulation for damage, overheating and deterioration.	1	1	
16. Visually inspect all support hardware for damage, deterioration and over-heating.	1	1	
17. Visually inspect attaching fasteners for damage, deterioration and over heating.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 10

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel			
18. Load a new ablator panel assembly and associated pi-straps on the panel dolly and transport to the vehicle.	1	1	
19. Position panel dolly for ablator panel assembly installation.	2	2	Same as Item 6.
20. Elevate ablator panel assy to installation position.	2	2	Same as Item 6.
21. Lock the panel dolly brakes.	1	1	
22. Position the new ablator panel assembly on the vehicle and align for installation.	1	1	
23. Position pi-straps on panel and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.	1	1	
24. Install the (26) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimating time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenuts in panel support structure.
25. Lower the panel dolly platform.	1	1	
26. Release panel dolly brakes.	1	1	
27. Remove panel dolly from work area.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 10

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
28. Torque the (26) pi-strap attaching fasteners.	1	1	
29. Visually inspect the pi-strap fasteners for proper installation.	1	1	
30. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs (26) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	
31. Visually inspect pi strap attaching fastener ablator plugs for proper installation.	1	1	
32. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (62) pi-strap attaching fastener ablator plugs.	1	1	
2. Drill out (62) pi-strap attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in time estimated? Reason: Drilling of charred ablator plugs has not been experienced.
3. Using a prescribed tool, free both sides of the pi-straps from the ablator panel.	2	3	Can charred ablator pi-strap or gasket be freed from charred ablator panel? Reason: Freeing of charred ablator pi strap or gasket from charred ablator panel has not been experienced.
4. Using a prescribed tool, free flexible gaskets at inter panel sealing space.	2	3	Same as Item 3.
5. Position panel dolly for ablator panel assembly removal.	1	1	
6. Elevate dolly platform for panel assembly removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
7. Lock brakes on dolly.	1	1	
8. Remove (62) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
9. Remove associated pi-straps.	1	1	
10. Maneuver ablator panel assy (Comprised of ablator panel attached to the honeycomb substrate panel) free of vehicle.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
NOTE:			
(1) Ablator panel and honeycomb substrate are removed as an assembly.	1	1	
(2) Disassembly of panel (184 stubs) to be accomplished in the refurbishment area and disposition of sub-assemblies determined.	1	1	
11. Lower panel dolly with panel from installed position to transport position.	2	2	Same as Item 6.
12. Unlock panel dolly brakes.	1	1	
13. Transport ablator panel assy and associated pi-straps to the refurbishment area.	1	1	
14. Unload ablator panel assy from panel dolly and store on prescribed storage rack.	1	1	
o Inspection			
15. Visually inspect the fibrous insulation for damage, overheating and deterioration.	1	1	
16. Remove, replace or repair insulation as required (see task analysis no.).			

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
17. Visually inspect all support hardware for damage, deterioration and overheating.	1	1	
18. Visually inspect attaching fasteners for damage, deterioration and overheating.	1	1	
o Replacement of TPS Panel			
19. Load a new ablator panel assembly and associated pi-straps on the panel dolly and transport to the vehicle.	1	1	
20. Position panel dolly for ablator panel assembly installation.	2	2	Same as Item 6.
21. Elevate ablator panel assy to installation position.	2	2	
22. Lock the panel dolly brakes.	1	1	
23. Position the new ablator panel assembly on the vehicle and align for installation.	1	1	
24. Position pi-straps on panel and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of pi-strap attaching fasteners.			

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 11

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
25. Install the (62) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenut in panel support structure.
26. Lower the panel dolly platform.	1	1	
27. Release panel dolly brakes.	1	1	
28. Remove panel dolly from work area.	1	1	
29. Torque the (62) pi-strap attaching fasteners.	1	1	
30. Visually inspect the pi-strap fasteners for proper installation.	1	1	
31. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs (62) with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	
32. Visually inspect pi-strap attaching fastener ablator plugs for proper installation.	1	1	
33. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 12

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (16) ablator panel attaching fastener ablator plugs.	1	1	
2. Drill out the (16) attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the inter panel sealing space.	2	3	Can charred gaskets be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator has not been experienced.
4. Remove the (16) ablator panel attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred plug adhesive.
5. Maneuver the panel free of the fiberglass honeycomb substrate panel on the vehicle.	1	1	
6. Transport ablator panel to the storage area to await disposition.	1	1	
o Inspection			
7. Visually inspect the fiber glass honeycomb substrate panel for damage, deterioration and overheating.	1	1	
8. Visually inspect the associated hardware for damage and overheating.	1	1	
9. Visually inspect attaching fasteners for damage, deterioration and signs of overheating.			

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 12

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel			
10. Transport a new ablator panel to the vehicle.	1	1	
11. Position the new ablator panel on the vehicle for installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.	1	1	
12. Install the (16) attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator panel and threaded fastener holes in fiber-glass honeycomb substrate.
13. Torque the (16) attaching fasteners.	1	1	
14. Visually inspect attaching fasteners for proper installation.	1	1	
15. Apply a small quantity of RTV 106 adhesive to each of the attaching fastener ablator plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs in plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time, before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 12

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
16. Visually inspect the attaching fastener plugs for proper installation.	1	1	
17. Visually inspect the complete panel installation	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 13

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (72) ablator panel attaching fastener ablator plugs.	1	1	
2. Drill out the (72) attach-fastener ablator plubs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablative plugs has not been experienced.
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the interpanel sealing space.	2	3	Can charred gasket be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator panel has not been experienced.
4. Position a panel dolly for the ablator panel removal.	1	1	
5. Elevate dolly platform for ablator panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on dolly.	1	1	
7. Remove the (72) ablator panel attaching fasteners.	1	1	Can fastener be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Maneuver ablator panel free of the fiberglass honeycomb substrate panel on the vehicle and lower plane onto panel dolly.	1	1	
9. Lower panel dolly with panel from installed position to transport position.	2	2	Same as Item 5.
10. Unlock panel dolly brakes.	1	1	
11. Transport ablator panel to the storage area to await disposition.			

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 120 inches

TASK ANALYSIS NO. 13

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
12. Store ablator panel on a prescribed storage rack.	1	1	
o Inspection			
13. Visually inspect the fiberglass honeycomb substrate panel for damage, deterioration and overheating.	1	1	
14. Visually inspect the associated hardware for damage and overheating.	1	1	
15. Visually inspect attaching fasteners for damage, deterioration and signs of overheating.	1	1	
o Replacement of TPS Panel			
16. Transport a new ablator panel to the vehicle.	1	1	
17. Position panel dolly for ablator panel installation.	2	2	Same as Item 5.
18. Elevate ablator panel to installation position.	2	2	
19. Lock panel dolly brakes.	1	1	
20. Position the new ablator panel on the vehicle and align for installation.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept 4B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 13

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
NOTE: Exercise care to prevent damage during installation and torqueing of the ablator panel attaching fasteners.			
21. Install the (72) ablator panel attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator panel and threaded fastened holes in fiberglass honeycomb substrate.
22. Lower panel dolly platform.	1	1	
23. Release panel dolly brakes.	1	1	
24. Remove panel dolly from work area.	1	1	
25. Torque the (72) ablator panel attaching fasteners.	1	1	
26. Visually inspect the ablator panel attaching fasteners for proper installation.	1	1	
27. Apply a small quantity of RTV 106 adhesive to each of the (72) attaching fastener ablator plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling	1	1	

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 13

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
or stressing joint. Full cure will develop in 2 to 3 days.			
28. Visually inspect ablator plugs for proper installation.	1	1	
29. Visually inspect the complete panel installation.	1	1	

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate (176) ablator panel attaching fastener ablator plugs.	1	1	
2. Drill out the (176) attach-	4	'3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablator plugs has not been experienced.
3. Using a prescribed tool, free flexible gaskets on all sides of the ablator panel at the inter panel sealing space.	2	3	Can charred gasket be freed from charred ablator panel? Reason: Freeing of charred gasket from charred ablator panel has not been experienced.
4. Position a panel dolly for the ablator panel removal.	1	1	
5. Elevate dolly platform for ablator panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
6. Lock brakes on dolly.	1	1	
7. Remove the (176) ablator panel attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
8. Maneuver ablator panel free of the fiberglass honeycomb substrate panel on the vehicle and lower panel onto panel dolly.	1	1	
9. Lower panel dolly with panel from installed position to transport position.	2	2	Same as Item 5
10. Unlock panel dolly brakes.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
11. Transport ablator panel to the storage area to await disposition.	1	1	
12. Store ablator panel in a prescribed storage rack.	1	1	
o Inspection			
13. Visually inspect the fiberglass honeycomb substrate panel for damage, deterioration and overheating.	1	1	
14. Visually inspect the associated hardware for damage and overheating.	1	1	
15. Visually inspect attaching fasteners for damage, deterioration, and overheating.	1	1	
o Replacement of TPS Panel (Cont)			
16. Transport a new ablator panel to the vehicle.	1	1	
17. Position panel dolly for ablator panel installation.	2	2	Same as Item 5.
18. Elevate ablator panel to installation position.	2	2	
19. Lock panel dolly brakes.			
20. Position the new ablator panel on the vehicle and align for installation.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
NOTE: Exercise care to prevent damage during installation and torqueing of the ablator panel attaching fasteners.			
21. Install the (176) ablator panel attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator panel and threaded fastener holes in fiberglass honeycomb substrate.
22. Lower panel dolly platform.	1	1	
23. Release panel dolly brakes.	1	1	
24. Remove panel dolly from work area.	1	1	
25. Torque the (176) ablator panel attaching fasteners.	1	1	
26. Visually inspect the ablator panel attaching fasteners for proper installation.	1	1	
27. Apply a small quantity of RTV 106 adhesive to each of the (176) attaching fastener ablator plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into the plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Multiple Mechanical Fastener Concept #4B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 14

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
28. Visually inspect ablator plugs for proper installation.	1	1	
29. Visually inspect the complete panel installation.			

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 15

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate each (3) pi-strap attaching fastener ablator plugs. NOTE: One pi-strap is used to secure every 3 panels. This study deals with panel nearest the pi-strap.	1	1	
2. Drill out (3) pi-strap attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimate? Reason: Drilling of charred ablato plugs has not been experienced.
3. Remove pi-strap attaching fasteners (3).	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred ablative.
4. Using a prescribed tool free pi-strap of panels.	2	3	Can charred pi-strap and charred gasket be freed from charred ablator panel? Reason: Freeing of charred pi-strap or charred gasket from charred ablator panel has not been experienced.
5. Using a prescribed tool free flexible gasket at inter panel sealing space.	2	3	
6. Maneuver ablator panel approximately .75 inches to unlock panel attaching keyway and pull panel free of vehicle.	4	4	Can panel be unlocked and freed from vehicle in the time estimated? Reason: Binding due to distortion of TPS supporting structure.
7. Transport ablator panel and associated pi-strap to the storage area to await disposition.	1	1	
8. Store panel on storage rack.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 15

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection			
9. Visually inspect ablator panel attaching fasteners for damage, deterioration and overheating.	1	1	
10. Visually inspect insulation and associated hardware for damage, deterioration and overheating.	1	1	
11. Remove, replace or repair insulation as required (see task analysis no. 29).			
o Replacement of TPS Panel			
11. Transport the new ablator panel and pi-strap to the vehicle.	1	1	
12. Position the new ablator panel on vehicle, matchup keyway and align for installation.	4	4	Can new ablator panel be positioned and aligned for installation in the time estimated? Reason: Misalignment of keyways due to distortion of TPS support structure.
13. Check the flexible gaskets on two sides of the panel for position and alignment.	1	1	
14. Install the new pi-strap and align for fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.	1	1	

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 15

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
15. Install the (3) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenut in panel support structure.
16. Torque the (3) pi-strap attaching fasteners.	1	1	
17. Visually inspect pi-strap attaching fastener installation.	1	1	
18. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area – insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure period before handling or stressing joint. Full cure will develop in 2 to 3 days.	1	1	
19. Visually inspect the pi-strap attaching fastener plug installation.	1	1	
20. Visually inspect the complete panel installation.			

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 16

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate each (3) pi-strap attaching fastener ablator plugs.	1	1	
2. Drill out (3) pi-strap	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablator plugs has not been experienced.
3. Remove (3) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred ablator.
4. Using a prescribed tool, free pi-strap of panels.	2	3	Can charred ablator pi-strap and charred gasket be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap and charred gasket from charred ablator panel has not been experienced.
5. Using a prescribed tool, free flexible gasket at inter panel sealing space.	2	3	
6. Position panel dolly for ablator panel removal.	1	1	
7. Elevate panel dolly platform for ablator panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this type of operation. Similar type dolly used for aircraft maintenance.
8. Lock brakes on panel dolly.	1	1	
9. Manuever ablator panel approximately .75 inches to unlock panel attaching keyway, pull panel free of vehicle and place on panel dolly.	4	4	Can panel be unlocked and freed from vehicle in the time estimated? Reason: Binding due to distortion of TPS supporting structure.
10. Lower panel dolly with panel from install to transport position.	2	2	Same as Item 7.

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 16

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
11. Transport ablator panel and associated pi-straps to the refurbishment area to await disposition.	1	1	
12. Unload panel and pi-straps and store the panel on a prescribed storage rack.	1	1	
o Inspection			
13. Visually inspect ablator panel attaching fasteners for damage, deterioration and overheating.	1	1	
14. Visually inspect insulation and associated hardware for damage, deterioration and overheating.	1	1	
15. Remove, replace or repair insulation as required (see task analysis no. 29).			
o Replacement of TPS Panel (Cont.)			
16. Load the new ablator panel and associated pi-straps on the panel dolly and transport to the vehicle.	1	1	
17. Position panel dolly for ablator panel installation.	2	2	Same as Item 7.

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 16

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
18. Elevate ablator panel to install position.	2	2	
19. Lock the panel dolly brakes.	1	1	
20. Position the new ablator panel on the vehicle matchup keyway and align for installation.	4	4	Can new ablator panel be positioned and aligned for installation in the time estimated? Reason: Misalignment of keyways due to distortion of TPS support structure.
21. Check the flexible gaskets on two sides of the panel for position and alignment.	1	1	
22. Install the new pi strap and align for attaching fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.	1	1	
23. Install the (3) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator pi-strap and fastener holes and platenuts in panel support structure.
24. Lower panel dolly platform.	1	1	
25. Release panel dolly brakes.	1	1	
26. Remove panel dolly from work area.	1	1	
27. Torque the (3) pi-strap attaching fasteners.	1	1	
28. Visually inspect pi-strap fasteners for proper installation.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 20 x 120 inches

TASK ANALYSIS NO. 16

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
29. Apply a small quantity of 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure period before handling or stressing joint. Full cure will develop in 2 or 3 days.	1	1	
30. Visually inspect the pi-strap attaching fastener plug installation.	1	1	
31. Visually inspect the complete panel installation	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5 PANEL LOCATION: Bottom PANEL SIZE: Large: 20 x 300 inches	**TASK ANALYSIS NO. 17** **COST AND DESIGN EVALUATION**

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Locate each (6) pi-strap attaching fastener ablator plugs.	1	1	
2. Drill out (6) pi-strap attaching fastener ablator plugs.	4	3	Can charred ablator plugs be drilled out with standard equipment in the time estimated? Reason: Drilling of charred ablator plugs has not been experienced.
3. Remove (6) pi-strap attaching fasteners.	1	1	Can fasteners be removed with socket wrench in the time estimated? Reason: Space around bolthead filled with charred adhesive.
4. Using a prescribed tool, free pi-straps of panels.	2	3	
5. Using a prescribed tool, free flexible gasket at inter panel sealing space.	2	3	Can charred ablator pi-strap and charred gasket be freed from charred ablator panel? Reason: Freeing of charred ablator pi-strap and charred gasket from ablator panel has not been experienced.
6. Position panel dolly for ablator panel removal.	1	1	
7. Elevate panel dolly platform for ablator panel removal.	2	2	Will panel dolly work satisfactory for this operation? Reason: Dolly has not been designed for this operation. Similar type dolly used for aircraft maintenance.
8. Lock brakes on panel dolly.	1	1	
9. Maneuver ablator panel approximately .75 inches to unlock panel attaching keyway, pull panel free of vehicle and place on panel dolly.	4	4	Can panel be unlocked and freed from vehicle in the time estimated? Reason: Binding due to distortion of TPS supporting structure.
10. Lower panel dolly with panel from installation to transport position.	2	2	

PAGE 1 OF 4

HEAT SHIELD TYPE: Ablative PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5 PANEL LOCATION: Bottom PANEL SIZE: Large: 20 x 300 inches	**TASK ANALYSIS NO. 17** **COST AND DESIGN EVALUATION**

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
11. Transport ablator panel and associated pi-straps to the refurbishment area to await disposition.			
12. Unload panel and pi-straps and store the panel on a prescribed storage rack.			
o Inspection			
13. Visually inspect ablator panel attaching fasteners for damage, deterioration and overheating.	1	1	
14. Visually inspect insulation and associated hardware for damage, deterioration and overheating.	1	1	
15. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Replacement of TPS Panel			
16. Load the new ablator panel and associated pi-straps on the panel dolly and transport to the vehicle.	1	1	
17. Position panel dolly for ablator panel installation.	2	2	Same as Item 7.
18. Elevate ablator panel to install position.	2	2	

PAGE 2 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 17

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
19. Lock the panel dolly brakes.	1	1	
20. Position the new ablator panel on the vehicle, match up keyway and align for installation.	4	4	Can new ablator panel be positioned and aligned for installation in the time estimated? Reason: Misalignment of keyways due to distortion of TPS support structure.
21. Check the flexible gaskets on two sides of the panel for position and alignment.	1	1	
22. Install the new pi strap and align for attaching fastener installation. NOTE: Exercise care to prevent damage during installation and torqueing of attaching fasteners.			
23. Install the (6) pi-strap attaching fasteners.	1	1	Can attaching fasteners be installed in estimated time? Reason: Misalignment of fastener holes in ablator pi strap and fastener holes and platenuts in panel support structure.
24. Lower panel dolly platform.	1	1	
25. Release panel dolly brakes.			
26. Remove panel dolly from work area.	1	1	
27. Torque the (6) pi-strap attaching fasteners.	1	1	
28. Visually inspect pi-strap fasteners for proper installation.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Keyway Attach Concept #5
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 17

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
29. Apply a small quantity of RTV 106 adhesive to each of the pi-strap attaching fastener plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hour minimum cure period before handling or stressing joint-full cure will develop in 2 or 3 days.	1	1	
30. Visually inspect the pi-strap attaching fastener plug installation.	1	1	
31. Visually inspect the complete panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners - No Intermediate Support #6A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 18

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Install panel removal handling tools on panel.	3	2	Will panel removal handling tools work satisfactorily on metallic panels? Reason: To date none designed for this operations, similar type tool used for handling of plate glass.
2. Remove (6) panel attaching fasteners.	1	1	Can fasteners be removed in the allocated time? Reason: To date no fasteners designed or fabricated to withstand thermal conditions.
3. Using panel removal tools maneuver panel free of panel joints.	3	2	Same as Item 1.
o Inspection			
4. Visually inspect panel for damage and deterioration. NOTE: Pay particular attention to mating surfaces.	1	1	
5. Visually inspect fasteners (6) for serviceability.	1	1	
6. Visually inspect panel support hardware.	1	1	
7. Visually inspect insulation and associated hardware.	1	1	
8. Remove, replace or repair insulation as required (see task analysis no. 29).			
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area.	1	1	
10. Store panel on storage rack.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners - No Intermediate Support #6A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 18

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
NOTE: Panels to be individually packed to prevent damage to panel surface.			
11. Remove panel removal handling tools.	3	2	Will panel removal handling tools work satisfactorily on metallic panels? Reason: None designed for this operation to date. Similar type tool used for handling plate glass.
12. Place protective cover over panel on storage rack.	1	1	
o Replacement of TPS Panel			
13. Remove cover from panel on storage rack.	1	1	
14. Install panel removal handling tools.	3	2	Same as Item 11.
15. Transport panel to vehicle for installation.	1	1	
16. Position panel on vehicle and align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	1	1	
17. Install (6) panel attaching fasteners.	3	2	Can coated fasteners be reused? Reason: Coated metallic fasteners have never been used on TPS panels.
18. Remove panel removal handling tools.	3	2	Same as Item 11.
19. Torque fasteners (6).	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTAC. CONCEPT: Flush Fasteners - No Intermediate Support #6A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 18

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL		COST AND DESIGN FEASIBILITY QUESTIONS
	OPERATING EXPERIENCE	STATE-OF-ART	
o Replacement of TPS Panel (Cont.)			
20. Visually inspect fastener installation.	1	1	
21. Visually inspect panel installation.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners Attachment, Concept #6B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 19

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Install panel removal handling tools on panel.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date none designed for this type of operation, similar type tool used to handle plate glass.
2. Remove the (18) panel attaching fasteners.	1	1	
3. Using the handling tools maneuver panel free of longitudinal panel joints and vehicle.	3	2	Same as Item 1 above.
o Inspection			
4. Visually inspect panel for damage and deterioration. NOTE: Pay particular attention to mating surfaces.	1	1	
5. Visually inspect fasteners (18) for serviceability.			
6. Visually inspect panel support hardware.	1	1	
7. Visually inspect insulation and associated hardware.	1	1	
8. Remove, replace or repair insulation as required (see task analysis no. 29).	1	1	
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners Attachment, Concept #6B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 19

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
10. Store panel on storage rack.	1	1	
11. Remove panel removal handling tools (5). NOTE: Panels to be individually racked to prevent damage	3	2	Same as Item 1 above.
12. Place protective cover over panel on storage rack.	1	1	
o Replacement of TPS Panel			
13. Remove cover from panel on storage rack.	1	1	
14. Install panel removal handling tools.	3	2	Will panel removal handling tool work satisfactorily? on metallic panels? Reason: To date, none designed for this operation, similar type tool is used for handling plate glass.
15. Transport panel to vehicle for installation.	1	1	
16. Position panel on vehicle and shift in two directions to achieve proper overlap and alignment of the longitudinal panel joint. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	1	1	
17. Install the (18) panel attaching fasteners.	3	2	Can fasteners be installed in time allocated? Reason: To date, fasteners not designed, fabricated or used in this configuration.

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Flush Fasteners Attachment, Concept #6B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 19

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL		COST AND DESIGN FEASIBILITY QUESTIONS
	OPERATING EXPERIENCE	STATE-OF-ART	
o Replacement of TPS Panel (Cont.) NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin.			
18. Remove the panel removal handling tools.	3	2	Same as Item 14 above.
19. Torque the (18) panel attaching fasteners.	3	2	Same as Item 17 above.
20. Visually inspect the (18) panel attaching fastener installation for damage.	3	2	Same as Item 17 above.
21. Visually inspect the completed panel installation.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 20

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Install panel removal handling tools on panel.	3	2	Will panel removal handling tool work satisfactorily on metallic panels? Reason: To date, no tool designed for this operation, similar type tool used to handle plate glass.
2. Remove pi-strap fasteners (6) and pi-strap from panel. NOTE: Exercise extreme care to prevent damage to the panel coated surface.	3	2	Can metallic fasteners be removed in time allocated? Reason: To date, no fasteners designed, fabricated to withstand thermal conditions.
3. Using panel removal handling tools, maneuver panel free of panel joints.	3	2	Same as Function-Task Description No. 1 above.
o Inspection			
4. Visually inspect panel and pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces.	1	1	
5. Visually inspect pi-straps fasteners (6) for serviceability.	1	1	
6. Visually inspect panel support hardware.	1	1	
7. Visually inspect insulation and associated hardware.	1	1	
8. Remove, replace or repair insulation as required (see task analysis no. 29).	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 20

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel (Cont.)			
9. Transport panel to storage area.	1	1	
10. Store panel on panel storage rack. NOTE: Panels to be individually racked to prevent damage to panel surface.	1	1	
11. Remove panel removal handling tools.	3	2	Will panel removal handling tool work satisfactorily on metallic panels? Reason: To date, no tool designed for this operation, similar type tool used for handling plate glass.
12. Place protective cover over panel on storage rack.	1	1	
o Replacement of TPS Panel			
13. Remove cover from panel on storage rack.	1	1	
14. Install panel removal handling tools.	3	2	Same as Function-Task Description No. 11 above.
15. Transport panel to vehicle for installation.	1	1	
16. Position panel on vehicle and align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	1	1	
17. Install the pi-straps and pi-straps fasteners (6).	3	2	Can pi-straps and fasteners be installed in the estimated time? Reason: Misalignment of fastener holes in metallic panel and fastener holes and plate nuts in panel support structure.

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 20

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
18. Remove panel removal handling tools (2).	3	2	Same as Function-Task Description No. 11 above.
19. Torque pi-strap fasteners (6).	1	1	
20. Visually inspect pi-strap fasteners (6) installation.	1	1	
21. Visually inspect TPS panel installation.			

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
• Removal of TPS Panels			
1. Install panel removal handling tools on panel.	3	2	Will panel removal handling tool work satisfactorily on metallic panels? Reason: To date, no tool designed for this operation; similar type tool used to handle plate glass.
2. Position and elevate panel dolly for panel removal.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation.
3. Lock brakes on panel dolly.	2	2	Same as function-task description No. 2 above.
4. Remove Pi-strap attaching fasteners (26) and Pi-straps from panel. NOTE: Exercise care to prevent damage to panel surface and panel fastener head slots.			Can Pi-straps and fasteners be removed in the estimated time? Reason: Thermal action on threaded surface.
5. Using the panel removal handling tools maneuver panel free of panel joints and vehicle. Lower panel onto panel dolly and lower dolly platform.	3	2	Same as function-Task description No. 1 above.
• Inspection			
6. Visually inspect panel and Pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces and fastener holes.	1	1	
7. Visually inspect Pi-strap fasteners (26) for serviceability	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
8. Visually inspect panel support hardware.	1	1	
9. Visually inspect insulation and associated hardware. Remove, replace or repair insulation, as required (See Task Analysis No. 29).	1	1	
10. Transport panel with dolly to storage area.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation.
11. Store panel on prescribed panel storage rack. NOTE: Panels to be individually racked to prevent damage.	1	1	
12. Remove panel removal handling tools.	3	2	Will panel handling tool work satisfactorily on metallic panels? Reason: To date, no such tool designed for this operation; however, similar tool used to handle plate glass.
13. Install protective cover over panel on storage rack.	1	1	
• Replacement of TPS Panels			
14. Remove protective cover from panel on storage rack.	1	1	
15. Install panel removal handling tools.	3	2	Same as function-Task description No. 12 above.
16. Remove panel from panel storage rack and place on panel dolly.	1	1	
17. Transport panel and dolly from storage area to vehicle.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Medium 20" x 120"

TASK ANALYSIS NO. 21

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
18. Position and elevate dolly for panel installation on vehicle.	1	1	
19. Lock brakes on panel dolly.			
20. Raise panel from dolly and position on vehicle. Align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	1	1	
21. Install (26) Pi-strap attaching fasteners. NOTE: Exercise care during installation to prevent damage to the fastener heads and surrounding panel skin.	3	2	Can Pi-strap attaching fasteners be installed in the estimated time? Reason: Misalignment of fastener holes in panel and fastener holes and platenuts in panel support structure.
22. Remove the panel removal handling tools	3	2	Will panel removal handling tool work satisfactorily on metallic panels? Reason: To date, no tool has been designed or fabricated for this operation; however, similar type tool is used to handle plate glass.
23. Unlock brake on panel dolly.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation.
24. Remove panel dolly from work area.	2	2	Same as Item 23 above.
25. Torque the (26) Pi-strap attaching fasteners.	1	1	
26. Visually inspect the (26) Pi-strap attaching fastener installation for damage.	1	1	
27. Visually inspect the completed panel installation	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 22

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panels			
1. Install panel removal handling tools on panel.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? To date no tool designed for this operation; however, similar tool used to handle plate glass.
2. Position and elevate panel dolly for panel removal.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation.
3. Lock brakes on panel dolly.	2	2	Same as Item 2.
4. Remove pi-strap attaching fasteners (58) and pi-straps from panel. NOTE: Exercise care to prevent damage to panel coated surface and panel fastener head slots.	3	2	Can pi-straps and fasteners be removed in estimated time? Reason: Thermal reaction on threaded surfaces.
5. Using the panel removal handling tools (16), maneuver panel free of panel joints and vehicle. Lower panel onto panel dolly and lower dolly platform.	3	2	Same as Item 1.
o Inspection			
6. Visually inspect panel and pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces and fastener holes.	3	2	Same as Item 4.

PAGE 1 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 22

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
7. Visually inspect pi-strap fasteners (58) for serviceability.	3	2	Same as Item 4.
8. Visually inspect panel support hardware.	1	1	
9. Visually inspect insulation and associated hardware. Remove, replace or repair insulation, as required (see task analysis no. 29)	1	1	
10. Transport panel with dolly to storage area. NOTE: Panels to be individually racked to prevent damage.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
12. Remove panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
13. Install protective cover over panel on storage rack.	1	1	
o Replacement of TPS Panels			
14. Remove protective cover from panel on storage rack.	1	1	
15. Install panel removal handling tools (16).	3	2	Same as Item 12.
16. Remove panel from panel storage rack and place on panel dolly.	2	2	Same as Item 10.

PAGE 2 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 22

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panels			
17. Transport panel and dolly from storage area to vehicle.	2	2	Same as Item 10.
18. Position and elevate dolly for panel installation on vehicle.	2	2	Same as Item 10.
19. Lock brakes on panel dolly.	2	2	Same as Item 10.
20. Raise panel from dolly and position on vehicle. Align panel joints. NOTE: Exercise extreme care to prevent damage to the mating surfaces.	1	1	
21. Install (58) pi strap attaching fasteners.	3	2	Can pi-straps and fasteners be used satisfactorily on this operation? Reason: Misalignment of fastener holes in panel and fastener holes and platenuts in panel support structure.
22. Remove the panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date, no tool designed for this operation, however a similar tool is used to handle plate glass.
23. Unlock brake on panel dolly. Remove panel dolly from work area.	2	2	
24. Torque the (58) pi-strap attaching fasteners.	1	1	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
25. Visually inspect the (5) pi-strap attaching fastener installation for damage.			

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attaching Concept #7A
PANEL LOCATION: Bottom
PANEL SIZE: Large: 20 x 300 inches

TASK ANALYSIS NO. 22

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
26. Visually inspect the completed panel installation.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 23

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Remove body chine on one side of the panel (see task analysis no. 27).	1	1	
2. Install panel removal handling tools on panel.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reasons: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
3. Remove (2) indexing screws from panel.	1	1	
4. Remove (14) pi-strap fasteners and pi strap from panel.	3	2	Can pi-straps and fasteners be removed satisfactorily on this operation? Reason: Thermal reaction on the threaded surfaces.
5. Using panel removal handling tools, maneuver panel toward side with removed chines, to release the panel from mid panel support, and panel joints.	3	2	Can mid panel support unlock easily from the panel stiffener during this operation? Reason: This operation has not been experienced.
o Inspection			
6. Visually inspect panel and pi-straps for damage and deterioration. NOTE: Pay particular attention to mating surfaces.	1	1	
7. Visually inspect pi-strap fasteners (14) for service ability.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 23

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection			
8. Visually inspect panel support hardware.	1	1	
9. Visually inspect insulation and associated hardware.	1	1	
10. Remove, replace or repair insulation as required (see task analysis no. 29)			
o Removal of TPS Panel (Cont.)			
11. Transport panel to storage area.	1	1	
12. Store panel on storage rack. NOTE: Panels to be individually racked to prevent damage	1	1	
13. Remove panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
14. Install protective cover over panel on storage rack. NOTE: Repeat preceding steps to remove each panel in sequence to reach the specific panel desired.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 23

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel			
15. Remove protective cover from panel on storage rack.	1	1	
16. Install panel removal handling tools.	3	2	Same as Item 13.
17. Transport panel from storage rack to vehicle.	1	1	
18. Using handling tools, position panel on vehicle and slide panel in panel channel to its prescribed location and align indexing screw holes. NOTE: Exercise care to prevent damage to mating surfaces.	3	2	Can mid panel support lock easily with the panel stiffener during this operation? Reason: This operation has not been experienced.
19. Install indexing screw (2).	1	1	
20. Install pi straps and pi-strap fasteners (14). NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin.	3	2	Can pi-straps and fasteners be installed in the estimated time? Reason: Misalignment of fasteners in panel and fastener holes and platenuts in panel support structure.
21. Remove the panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
22. Torque pi-strap fasteners (14) and indexing screws (2).	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Concept with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Small: 40 x 40 inches

TASK ANALYSIS NO. 23

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
NOTE: Repeat preceding steps to replace each panel in sequence to install the specific panel desired.			
23. Visually inspect pi-strap fastener installation on panels installed.	1	1	
24. Visually inspect panel installations of panels affected.	1	1	
25. Install body chine (see task analysis no. 27).	1	1	

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

TASK ANALYSIS NO. 24

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Remove body chine on one side of the panel. (see task analysis no. 27)	1	1	
2. Install panel removal handling tools on panel.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar is used to handle plate glass.
3. Position and elevate panel dolly for panel removal.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
4. Remove (2) indexing screws from panel.			
5. Remove (28) pi-strap fasteners and pi-straps from panel. NOTE: Exercise care to prevent damage to panel coated surface and panel fastener head slots.	3	2	Can pi-straps and fasteners be removed satisfactorily on this operation? Reason: Thermal reaction to the threaded surfaces.
6. Using the panel removal handling tools, maneuver panel toward side with removed chines, to release the panel from mid panel support, and panel joints. Lower panel on to panel dolly and dolly platform.	3	2	Can mid panel support unlock easily from the panel stiffener during this operation? Reason: This operation has not been experienced.
o Inspection			
7. Visually inspect panel and pi-straps for damage and deterioration.	1	1	

PAGE 1 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

TASK ANALYSIS NO. 24

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
NOTE: Pay particular attention to mating surfaces and indexing screw holes.			
8. Visually inspect pi-strap fasteners (28) for serviceability.	1	1	
9. Visually inspect panel support hardware.			
10. Visually inspect insulation and associated hardware.	1	1	
11. Remove, replace or repair insulation as required (see task analysis no. 29)			
12. Transport panel with panel dolly to storage.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
13. Store panel on prescribed panel storage rack. NOTE: Panel to be individually racked to prevent damage.	1	1	
14. Remove panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
15. Install protective cover over panel on storage rack. NOTE: Repeat preceding steps to remove each panel in sequence to reach the specified panel desired.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

TASK ANALYSIS NO. 24

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel			
16. Remove protective cover from panel on storage rack.	1	1	
17. Install panel removal handling tools.	3	2	Same as Item 14.
18. Remove panel from rack and place on panel dolly.	1	1	
19. Transport panel on dolly from storage to vehicle.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
20. Position and elevate dolly for panel installation on vehicle.	2	2	Same as Item 19.
21. Using panel handling tools position panel on vehicle and slide panel in panel support channel to its prescribed location and align indexing screw holes. NOTE: Exercise care to prevent dmage to mating surfaces.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
22. Install indexing screws (2)	1	1	
23. Install pi-straps and (28) pi-strap fasteners. NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin.	3	2	Can pi-straps and fasteners be installed in estimated time? Reason: Misalignment of fastener holes in panel and fastener holes and platenuts in panel support structure.

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Medium: 40 x 120 inches

TASK ANALYSIS NO. 24

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
24. Remove the panel handling tools.	3	2	Same as Item 21.
25. Remove panel dolly from work area.	2	2	Same as Item 20.
26. Torque (28) pi-strap fasteners and (2) indexing screws. NOTE: Repeat preceding steps to replace each panel in sequence to install the specific panel desired.	3	2	Same as Item 23.
27. Visually inspect pi-strap fastener installation on panels installed.	3	2	Same as Item 23.
28. Visually inspect panel installation of panels affected.	1	1	
29. Install body chine (see task analysis no. 27)	1	1	

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

TASK ANALYSIS NO. 25

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of TPS Panel			
1. Remove body chine on one side of panel. (see task analysis no. 27)	1	1	
2. Install panel removal handling tools on panel.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
3. Position and elevate panel dolly for panel removal.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
4. Remove (2) indexing screws from panel.	1	1	
5. Remove (62) pi-strap fasteners and pi-straps from panel. NOTE: Exercise care to prevent damage to panel coated area.	3	2	Can pi-straps and fasteners be removed satisfactorily on this operation? Reason: Thermal reaction on the threaded surfaces.
6. Using the panel removal handling tools maneuver panel toward side with removed chines, to release the panel from mid panel support and panel joints. Lower panel on panel dolly and lower dolly platform.	3	2	Can mid panel support unlock easily from the panel stiffner during this operation? Reason: This operation has not been experienced.
o Inspection			
7. Visually inspect panel and pi-straps for damage and deterioration.	1	1	

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

TASK ANALYSIS NO. 25

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
NOTE: Pay particular attention to mating surfaces and indexing screw holes.			
8. Visually inspect pi-strap fasteners (62) for serviceability.			
9. Visually inspect panel support hardware.	1	1	
10. Visually inspect insulation and associated hardware.	1	1	
11. Remove, replace or repair insulation as required (see task analysis no. 29).			
o Removal of TPS Panel (Cont.)			
12. Transport panel on panel dolly to storage.	2	2	Will panel dolly work satisfactorily for this operation? Reason: To date, no such dolly is designed for this operation.
13. Store panel on prescribed panel storage rack. NOTE: Panel to be individually racked to prevent damage.	1	1	
14. Remove panel removal handling tools.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however a similar tool is used to handle plate glass.
15. Install protective cover over panel on storage rack.			

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

TASK ANALYSIS NO. 25

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel			
16. Remove protective cover from panel on storage rack.	1	1	
17. Install panel removal handling tools.	3	2	Same as Item 14.
18. Remove panel from rack and place on panel dolly.	1	1	
19. Transport panel on dolly from storage to vehicle.	2	2	Same as Item 12.
20. Position and elevate dolly for panel installation on vehicle.	2	2	Same as Item 12.
21. Using panel handling tools, position panel on vehicle and slide panel in panel support channel to its prescribed location and align indexing screw holes. NOTE: Exercise care to prevent damage to mating surfaces.	3	2	Will the panel removal handling tool work satisfactorily on metallic panels? Reason: To date no tool designed for this operation, however, a similar tool is used to handle plate glass.
22. Install indexing screws (2).	1	1	
23. Install pi straps and (62) pi-strap fasteners. NOTE: Exercise care during installation to prevent damage to fastener heads and surrounding panel skin.	3	2	Can pi-straps and fasteners be installed in estimated time? Reason: Misalignment of fastener holes in panel and fastener holes and platenuts in panel support structure.

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap with with Intermediate Panel Support Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: Large: 40 x 300 inches

TASK ANALYSIS NO. 25

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of TPS Panel (Cont.)			
24. Remove the panel handling tools.	3	2	Same as Item 21.
25. Remove panel dolly from work area.	2	2	Will panel dolly work satisfactorily for this operation? Reason: Dolly has not been designed for this operation.
26. Torque (62) pi-strap fasteners and (2) indexing screws.	3	2	Same as Item 23.
27. Visually inspect pi-strap fastener installation.	3	2	Same as Item 23.
28. Visually inspect panel installation.	1	1	
29. Install body chine (see task analysis no. 27)	1	1	Same as Item 23.

PAGE 4 OF 4

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 26

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Leading Edge Segment			
1. Remove the (14) screws from the access door adjacent to the leading edge panel segment to be removed.	1	1	
2. Using a socket wrench turn the hex shaft, protruding from the backside of the main wing spar, in the counter clockwise direction to retract the (4) spring loaded locking pins. (Support the leading edge segment during this operation).	2	2	Can the locking device guarantee positive locking action each time? Reason: no such device to date has been designed for this concept.
3. With the (4) leading edge spring loaded locking pins retracted, pull the leading edge segment straight forward and free of the vehicle wing. NOTE: (1) Each leading edge segment which is accessible thru the access door on the top of the wing, overlaps the leading edge segment to the right and left of this specific segment. (2) Therefore, any right hand or left hand segment requires removal of two overlap segments.	2	2	Can leading edge segment be removed in the allotted time? Reason: To date, no such leading edge segment has been designed or fabricated.

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HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 26

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Leading Edge Segment (Cont.)			
4. Transport leading edge segment to the storage area to await disposition.	1	1	
5. Store leading edge segment on a prescribed storage rack.	1	1	
o Inspection			
6. Visually inspect wing spar forward area and attaching points, for damage, deterioration and overheat conditions.	1	1	
7. Visually inspect backside of main wing spar thru the wing access door for damage, deterioration and an overheat condition.	1	1	
8. Visually inspect main wing spar forward insulation for damage, deterioration and overheat condition.	1	1	
o Replacement of Leading Edge Segment			
9. Transport a new leading edge segment to the vehicle.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Attach Concept
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 26

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Leading Edge Segment (Cont.)			
10. Position and align the leading edge segment in the appropriate place on the forward side of the main wing spar. NOTE: As previously noted, any right hand or left hand leading edge segment replacement involves two other segments due to the overlap principle.	2	2	Will a new leading edge segment align properly with the leading edge slot? Reason: To date, no leading edge segment has been designed or fabricated.
11. Using the socket wrench, turn the hex shaft protruding from the backside of the main wing spar, in the clockwise direction to extend the spring loaded locking pins. (Pull forward on leading edge segment to assure locking pins are in full lock position).	2	2	Can the locking device guarantee positive locking action each time? Reason: To date, no such device has been designed for this concept.
12. Replace the access door with (14) screws, adjacent to the leading edge segment that was replaced.	1	1	
13. Torque the access door (14) attaching screws.			
14. Visually inspect access door for proper installation.	1	1	

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HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION: Chine
PANEL SIZE: 40" Segment

TASK ANALYSIS NO. 27

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Chine Segment			
1. Locate the (8) chine attaching fastener plugs.	1	1	
2. Drill out the (8) chine attaching fastener ablative plugs.	2	2	Can plugs be drilled out with standard equipment in the estimated time? Drilling of charred plugs has not been experineced.
3. Using a prescribed tool, free the chine segment from the adjacent chine segments, from the metallic spring seal and at metallic lip seal.	1	1	Can a prescribed hand tool free charred joints? Reason: Freeing of charred joints has not been experienced.
4. Remove the (3) chine segment attaching fasteners.	2	2	Can the fasteners be removed in the estimated time? Reason: Space around bolt filled with charred adhesive.
5. Maneuver the chine segment free of the vehicle.	1	1	
6. Transport chine segment to the storage area to await disposition.	1	1	
7. Store chine segment on a prescribed storage rack.	1	1	
o Inspection			
8. Visually inspect the chine supports for damage, deterioration and signs of overheating.	1	1	
9. Visually inspect the attaching hardware for damage, deterioration and signs of overheating.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION: Chine Area
PANEL SIZE: 40" Segment

TASK ANALYSIS NO. 27

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Chine Segment			
10. Transport a new chine segment to the vehicle.	1	1	
11. Position the new chine segment on the vehicle and align for installation. NOTE: Exercise care to prevent damage during installation and torqueing of the chine segment attaching fasteners.	2	2	Can the new chine align properly for installation? Reason: To date, no chine has been designed or fitted for alignment.
12. Install the (8) chine segment attaching fasteners.	2	2	Can the attaching fasteners be installed in the estimated time? Reason: Misalignment of fastener holes in ablator panel and fastener holes and platenuts in panel support structure.
13. Torque the chine segment attaching fasteners.	1	1	
14. Visually inspect the chine segment attaching fasteners for proper installation.	1	1	
15. Apply a small quantity of RTV 106 adhesive to each of the (8) chine segment attaching fastener ablative plugs with a brush or spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Chine Attach-Metallic Interface Concept
PANEL LOCATION: Chine
PANEL SIZE: 40" Segment

TASK ANALYSIS NO. 27

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Chine Segment (Cont.) Verify that plug does not extend below the mold line of the chine segment. Plugs in this configuration must be removed. Plugs extending above the mold-line must be trimmed to match evenly with the mold line. Allow 24 hours minimum cure time before handling or stressing joint. Full cure will develop in 2 to 3 days.			
16. Visually inspect the chine segment attaching fastener plugs for proper installation.	1	1	
17. Visually inspect the complete chine installation.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Leading Edge Attach Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20" Segment

TASK ANALYSIS NO. 28

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Ablative Leading Edge			
1. Locate the (12) leading edge segment attaching fastener plugs.	1	1	
2. Drill out the (12) ablative leading edge segment attaching fastener plugs.	2	2	Can plugs be removed using standard equipment and in the estimated time? Reason: Drilling of charred ablative plugs has not been experienced.
3. Remove the (12) leading edge segment attaching fasteners.	1	1	
4. Maneuver the ablative sleeve leading edge segment free of the vehicle wing.	1	1	Can the prescribed tool free the charred leading edge segment from the adjacent segments? Reason: Prescribed tool not experienced on this operation.
5. Transport ablative sleeve to the storage area to await disposition.	1	1	
6. Store ablative sleeve on a prescribed storage rack.	1	1	
o Inspection			
7. Visually inspect wing leading edge attaching hardware for damage, deterioration and overheating conditions.	1	1	
8. Visually inspect rib sleeve support for damage, deterioration and overheating condition.	1	1	
9. Visually inspect wing spar insulation for damage, deterioration and overheating condition.	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: Ablative Leading Edge Attach Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20" Segment

TASK ANALYSIS NO. 28

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Ablative Sleeve Leading Edge			
10. Transport a new ablative sleeve leading edge to the vehicle.	1	1	
11. Position leading edge ablative sleeve on vehicle wing and align for installation.	2	2	Will the new ablative leading edge sleeve align properly for installation? Reason: Misalignment of fastener holes in the ablative sleeve and fastener holes and platenuts in the sleeve support structure.
12. Install the leading edge sleeve (12) attaching fasteners.	2	2	Same as Item 11.
13. Torque the (12) leading edge sleeve attaching fasteners.	1	1	
14. Visually inspect the leading edge sleeve attaching fasteners for proper installation.	1	1	
15. Apply a small quantity of RTV 106 adhesive to each of the (12) leading edge sleeve attaching fastener ablative plugs with a brush or a spatula to a thickness of 10 to 30 mils over the entire contact area. Insert plugs into plug holes firmly with finger pressure to exclude air from joint. Allow 24 hours minimum cure time before handling or			

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative
PRINCIPAL ATTACH CONCEPT: ~~Ablative Leading~~ Edge Attach Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20" Segment

TASK ANALYSIS NO. 28

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Ablative Sleeve Leading Edge			
or stressing joint. Full cure will develop in 2 to 3 days.			
16. Visually inspect ablator plugs for proper installation.	1	1	
17. Visually inspect the complete leading edge installation.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: Insulation - Foil - Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported

PANEL LOCATION: Bottom

PANEL SIZE: 20" x 100"

TASK ANALYSIS NO. 29

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Insulation Segments			
1. Remove the appropriate TPS panels as per removal and replacement task analysis no. multiple mechanical fastener concept #4B panel size 20" x 300". NOTE: (1) Each insulation blanket measures 20" x 100". (2) Each blanket has 10 support and drag strut insulation blankets, size 9" x 10".			
2. Remove the laces(4) on each of the 10 support and drag strut insulation blankets that are attached to the 20" x 100" insulation blanket. Place on transportation dolly.	1	1	
3. Remove 32 attaching fasteners from 2 wire grids.	1	1	
4. Remove the wire grids from the bottom side of the 20" x 100" insulation blanket. Place wire grids on transportation dolly.	1	1	
5. Maneuver the 20" x 100" insulation blanket free of vehicle and place on the transportation dolly.			

PAGE 1 OF 4

HEAT SHIELD TYPE: Insulation - Foil - Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported

PANEL LOCATION: Bottom

PANEL SIZE: 20" x 100"

TASK ANALYSIS NO. 29

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Removal of Insulation Segment (Cont.)			
6. Transport insulation blanket and accessories to a storage area.	1	1	
o Inspection			
7. Remove the insulation blanket (20" x 100") from transportation dolly and visually inspect the segment for obvious damage, contamination, overheating and deterioration.	1	1	
8. Store insulation segment in appropriate storage rack.	1	1	
9. Remove the wire grids (20" x 48") from the transportation dolly and visually inspect wire grid for obvious damage, corrosion, contamination, overheating and deterioration.	1	1	
10. Store wire grid on an appropriate storage rack.	1	1	
11. Remove the (32) insulation attaching fasteners from the transportation dolly and visually inspect fasteners for obvious damage, contamination, overheating and deterioration.	1	1	

PAGE 2 OF 4

HEAT SHIELD TYPE: Insulation - Foil - Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 100"

TASK ANALYSIS NO. 29

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection (Cont.)			
12. Store the insulation attaching fasteners with insulation and wire grids.	1	1	
13. Remove the (10) support and drag strut insulation blankets (9" x 10") from the transportation dolly and visually inspect panels for obvious damage, contamination, overheating and deterioration.	1	1	
14. Visually inspect the associated panel supports, drag struts and support hardware, on the vehicle for obvious damage, contamination, deterioration and overheating.	1	1	
o Replacement of Insulation Segments			
15. Transport the insulation blanket and associated equipment, on dolly, from storage area to the vehicle for insulation.	1	1	
16. Install insulation blanket and align the 20" x 48" wire grids on the bottom side of the 20" x 100" insulation blanket and position both as an assembly in the right location on the vehicle.	1	1	Can insulation blanket and wire grids be installed in the time estimated? Reason: Insulation blanket and wire grids installation has not been experienced.

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HEAT SHIELD TYPE: Insulation - Foil - Wrapped
PRINCIPAL ATTACH CONCEPT: Grid Mesh-Supported
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 100"

TASK ANALYSIS NO. 29

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Replacement of Insulation Segments (Cont.)			
17. Install the (32) insulation attaching fasteners and torque to prescribed value.	1	1	
18. Install the (10) support and drag strut insulation blankets in their proper places and attach each to the wire grid with 4 laces.	1	1	
19. Visually inspect the insulation blanket for proper installation.	1	1	
20. Remove transportation dolly from the vehicle work area.	1	1	

PAGE 4 OF 4

HEAT SHIELD TYPE: Ablative - ULD-100-4 Series

PRINCIPAL ATTACH CONCEPT:

PANEL LOCATION: Bottom

PANEL SIZE:

TASK ANALYSIS NO. 30

COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o <u>Repair of TPS Panel (Repair of ULD - 100 Series Material)</u>			
1. Isolate damage to specific panel and small sections of ULD-100-4 materials which would not be practicable to replace but could be repaired.	1	1	
2. Remove all loose, friable material by brushing clean or using clean, filtered compressed air.	1	1	
3. Brush or spray catalyzed silicone resin (G.E.RTV 615) freshly prepared as a primer, on all surfaces to be filled by repair material. A light coat of several mils is adequate.	1	1	
4. Pack firmly but gently the correct formulation of uncured ULD-100-4 series material (storage or freshly mixed) into the primed repair section. Apply sufficient material to a height of approximately 50 to 100 mils above the level of the surrounding material.	1	1	
5. Place platen over repair and support platen with air bag with sufficient	2	2	Can air bag be efficiently adapted to apply contact pressure for ablative material repair? Reason: TPS support structure has limited design loads.

PAGE 1 OF 2

HEAT SHIELD TYPE: Ablative - ULD-100-4 Series

PRINCIPAL ATTACH CONCEPT:

PANEL LOCATION: Bottom

PANEL SIZE:

TASK ANALYSIS NO. 30

COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o <u>Repair of TPS Panel (Repair of ULD - 100 Series Material) (Cont.)</u>			
pressure to compress uncured ablator. Allow 8 hours to cure ablator.			
6. Remove air bag and platen.	1	1	
7. Post cure ablator repair for one hour at 200±10 degrees F.	2	2	Can cure at 200°F be accomplished on vehicle? Reason: This operation has not been previously performed.
8. After cure, use sharp edged knife to trim surface of repair section flush with surrounding material.	1	1	
9. Apply dispersion coating. Allow to cure for 12 hours.	1	1	
10. Visually inspect repair for proper application.	1	1	

PAGE 2 OF 2

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

TASK ANALYSIS NO. 31

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel			
1. Isolate damage to specific panel on the vehicle. NOTE: (1) Repairs to damage on panel on vehicle shall be limited to area of 1 to 1½ inch in diameter, any damage with a larger area shall warrant panel removal and repair accomplished in a refurbishment area. (2) This task analysis depicts the damage repair on vehicle.	1	1	
2. Using a grinding tool, grind away damaged material down to the bondline on the fiberglass honeycomb substrate.	2	3	This operation accomplished only under laboratory conditions. No experience on a production operation.
3. Remove bonding agent using methyl ethyl ketone, assure area is thoroughly clean free of any foreign matter.	2	3	Can Methyl Ethyl Ketone (MEK) solvent poison material in adjacent area? Reasons MEK reacts on these types of material.
4. Cut a plug of prepared, cured ablative material to appropriate thickness to fit the damaged area.	1	1	
5. Apply primer DC #1203 to the honeycomb substrate on the vehicle repair area and the bond side of the cured ablative honeycomb repair plug. A thin film and only one coat is required. Allow primer to	1	1	

PAGE 1 OF 3

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener
Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

TASK ANALYSIS NO. 31

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Cont.) dry for a minimum of 1 hour with relative humidity at 50 ±5%.			
6. Apply a small quantity of RC #3145 adhesive sealant to the fiber glass substrate bonding surface and sides of the repair area, with a spatula or a brush to a thickness of 10 to 30 mils over the entire contact area. NOTE: It is not necessary to apply adhesive to both surfaces to be bonded.	1	1	
7. Align and join the ablative honeycomb repair plug immediately (within 10 minutes) after spreading the adhesive. Press the plug firmly into the repair area. NOTE: 1. Plug should not be more than .030 below the mold line of surrounding material. 2. Allow a 24 hour (minimum air cure period before handling or stressing the bonded joint under normal conditions of temperature (75°F) relative humidity above 20%. After 8 hrs adhesives are set sufficiently to allow clean up and trimming.	1	1	

PAGE 2 OF 3

HEAT SHIELD TYPE: Ablative ULD-Ultra Low Density Material
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20" x 20"

TASK ANALYSIS NO. 31

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
8. Remove the excess adhesive and any residue which may have accumulated. Trim as required.	1	1	
o Inspection			
9. Visually inspect TPS panel for proper repair.	1	1	
10. Using the x-ray method or microwave tester. Check the plug repair for voids in the adhesive bond.	2	2	Are the testing units x-ray or the microwave tester portable? Reason: Inspection of repairs of TPS panels must at times be accomplished on the vehicle.
11. Mix ingredients of the dispersion coating. Combine 70 parts of weight of DC92-009 with 30 parts by weight of VM+P NAPTHA.	1	1	
12. Fill spray gun and test for proper function and mixture.	1	1	
13. Spray dispersion coating with line pressure at 55 psig. Use standard cross coat paint spray technique, with gun nozzle at distance of 8 inches spray ULD material, at least 4 passes are allowed per coat. Successive coats must be applied within 30 minutes if a thickness buildup is desired. Cure the dispersion coating at room temperature for 12 to 18 hours.	2	2	Will vehicle be in a controlled environment during this operation? Reason: Dispersion coating must cure at room temperature.
14. Visually inspect repair for proper accomplishment.	1	1	

PAGE 3 OF 3

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 32

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel Requirements (1) The area shall be air-conditioned. Filters in system may be of the commerical throw away or recleaning type. (2) The area shall be maintained at a relative humidity of 50±5% and a temperature of 72±3°F. (3) The area shall be vacuumed at least once during each 24 hour operational period. Portable vacuum cleaners may be used provided vacuuming is not performed during any processing or qualification operations. (4) If visible dust or contamination on storage cabinet tops, ledges, pipes and ducting is present, it shall be removed with cheesecloth, moistened with water, before starting any operation. (5) All hand tools used in any operations in this area shall be solvent cleaned with a cheesecloth dampened with either methyl ethyl ketone (MEK) or tolulene before being used. Safety			

PAGE 1 OF 5

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 32

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Cont.) disposable cans shall be provided for discarding used cloths. (6) Only clean cheesecloths shall be used in cleaning and wiping operations. (7) During trimming and cutting operations, pick up all pieces immediately after the pieces fall to the floor. Any debris producing operation shall be followed by vacuum cleaning after completion of what whole operation and before another processing operation is begun. (8) Clean, white shop coats, surgical style caps and clean cotton gloves shall be worn at all times during any processing or qualifying operations in this area. Coats, caps and cotton gloves must be replaced when they become soiled. (9) Wear safety glasses (or goggles) and rubber gloves while working with solvents and grinding of HCF materials. (10) Wear respirator mask to prevent the inhalation of foreign matter during grinding operation.			

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HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 32

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Repair on HCF Material)			
1. Locate the damaged panel.	1	1	
2. Remove the damaged panel per task analysis no. mechanical fastener attaching Concept #2.	1	1	
3. Transport panel to the refurbishment area.	1	1	
4. Using a grinding wheel, grinding disc and a sharp knife like device remove the HCF material from the panel down to the bond line on the fiberglass honeycomb substrate.	1	1	
5. Clean the bonding agent from the fiberglass honeycomb substrate, using a methyl, ethyl ketone after substrate is clean and free of any foreign material, cover substrate with clean cloth to prevent contamination.	1	1	
6. Procure a serviceable HCF segment, sized to fiththe fiberglass honeycomb substrate.	1	1	
7. Remove cloth cover from the fiberglass honeycomb substrate. Apply primer DC#1203 to the substrate and the bond side of the	1	1	

PAGE 3 OF 5

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 32

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Repair on HCF Material) (Cont.)			
HCF segment. A thin film and only one coat is required. Allow primer to dry for a minimum of 1 hour with relative humidity at 50 +5%.			
8. Apply a small quantity of RC#3145 adhesive sealant to the fiberglass substrate bonding surface and spread with a spatula or brush to a thickness of 10 to 30 mils over the entire contact area. NOTE: It is not necessary to apply adhesive to both surfaces to be bonded.	1	1	
9. Align and join the HCF segment to the fiberglass honeycomb substrate immediately (with in 10 minutes) after spreading the adhesive. Press the parts firmly together with finger pressure using a progressive action starting at one end so air will be excluded from the joint.	1	1	

PAGE 4 OF 5

HEAT SHIELD TYPE: HCF
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 32

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Repair on HCF Material) (Cont.)			
NOTE: Allow a 24 hour (minimum) air cure period before handling or stressing the bonded joint. Under normal conditions of temperature (75° relative humidity above 20% the bonded parts will cure to handle in 24 hours. Full cure will develop in 2 to 3 days.			
10. Remove the excess adhesive and any residue which may have accumulated.	1	1	
o Inspection			
11. Visually inspect TPS panel for proper repair.	1	1	
12. Using the x-ray method or microwave tester procedure check the HCF panel for voids in the adhesive bond.	1	1	
13. After inspection serviceability verification, return the serviceable HCF panel assembly to the vehicle for installation.	1	1	

PAGE 5 OF 5

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

TASK ANALYSIS NO. 33

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair Coating of TPS Panel			
1. Isolate discrepancy to be repaired. NOTE: Repair of defective coating area shall be limited to a three inch diameter circle and shall not extend to panel edge. Defective coating in excess of above limitations shall require removal of panel and shop repair.	1	1	
2. Prepare the defective area for repair coating by sanding the defective area until all loose material is removed and the surface is smooth.	1	1	
3. Wash the area with water to remove all grit and loose material.	1	1	
4. Wash area with acetone to remove all other contamination.	1	1	
5. Inspect surface to assure area is clean and smooth prior to coating application.	1	1	
6. Prepare the thermal-spraygun, the vibrator unit and the airjet unit, which is set at 70 psi. For base coat application; and test instrument.			

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)
PRINCIPAL ATTACH CONCEPT:
PANEL LOCATION: Bottom
PANEL SIZE: Not Applicable

TASK ANALYSIS NO. 33

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Cont.)			
7. Apply the thermal-spray powder to the defective area holding spray gun perpendicular to and 6 8 inches from surface being coated. Control the base coat thickness between 2 1/2 and 3-1/2 mils by controlling the speed and number of passes of the thermal spray unit. Insure that the thermal-spray powder covers all of the defect area and extends one half inch past the perimeter of the defect onto the good coating in all directions.	2	2	Can the thermal spraygun be safely used on vehicle to make repair, or should panel be removed and repaired in refurbishment area? Reason: To date, this operation has not been checked for feasibility.
8. Inspect the base coat application to assure that conditions of step 7 are met.	1	1	
9. Obtain repair glass from shop.	1	1	
10. Apply the repair glass with a camel's hair brush. Each application should be as thin as possible to obtain a coating as crack free as possible. Assure that thermal-spray powder is covered with glass, but that glass not extend onto the good coating.	1	1	

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)

PRINCIPAL ATTACH CONCEPT:

PANEL LOCATION: Bottom

PANEL SIZE: Not Applicable

TASK ANALYSIS NO. 33

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Cont.)			
11. Visually inspect glass for proper application.	1	1	
12. Dry repair glass at 120-150 degree F for one hour.	1	1	
13. Obtain repair glass from shop.	1	1	
14. Apply the repair glass (see task number 10).	1	1	
15. Visually inspect glass for proper application.	1	1	
16. Dry repair glass at 120-150 degree F for one hour.	1	1	
17. Obtain repair glass from shop.	1	1	
18. Apply the repair glass. (see task number 10).	1	1	
19. Visually inspect glass for proper application).	1	1	
20. Dry repair glass at 120-150 degree F for one hour.	1	1	
21. Obtain repair glass from shop.	1	1	
22. Apply the repair glass. (see task number 10).	1	1	
23. Visually inspect glass for proper application.	1	1	
24. Dry repair glass at 120-150 degree F for one hour.	1	1	
25. Inspect repair for proper coating thickness, of 10-15 mils.	1	1	

PAGE 3 OF 4

HEAT SHIELD TYPE: Coated Columbium (Type I Field Repair Coating)

PRINCIPAL ATTACH CONCEPT:

PANEL LOCATION: Bottom

PANEL SIZE: Not Applicable

TASK ANALYSIS NO. 33

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Repair of TPS Panel (Cont.)			
26. Obtain repair glass from shop.	1	1	
27. Apply the repair glass. (see task number 10).	1	1	
28. Visually inspect glass for proper application.	1	1	
29. Dry repair glass at 120-150 degree F for one hour.	1	1	
30. Inspect repair for proper coating thickness of 10-15 mils.	1	1	
31. Return tester to shop.	1	1	
32. Return thermal spray gun and equipment to shop.	1	1	Manhours required to perform repair task questionable. Reason: To date, task has not been accomplished except under laboratory conditions.

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HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 34

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Leading Edge Repair			
1. Locate leading edge segment.	1	1	Is it absolutely necessary to remove leading edge segment for repair? Reason: This task was never performed before
NOTE: (1) Due to the lack of information pertaining to repair or carbon-carbon leading edge segments a repair is construed to be limited to scratches and score marks. (2) Any punctures, cracks thru the material would warrant removal of segment and replacement with a like serviceable segment. (3) Segment with major damage would be submitted for disposition. (4) As more knowledge becomes available the above mentioned steps 1 thru 3 will be subject to change.			
2. Using an abrasive (fine) sand paper and smooth off any burrs that may exist.	1	1	
3. Use a suitable solvent to remove any debris that may remain.	1	1	

PAGE 1 OF 2

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 34

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Leading Edge Repair (Cont.)			
4. Using a heat gun apply heat to the repair area for a sufficient length of time to thoroughly dry repair area.	1	1	
5. Apply powered silicon metal using the flame spray method. Assure that the application adequately covers the damaged area.	2	2	Can flame spray method be accomplished on vehicle? Reason: This operation not experienced before.
6. Using an oxyacetylene torch heat treat repaired area to 2800°F. NOTE: This type of repair is satisfactory for operating temperatures of 3000°F.	2	2	Can torch be used on repair area on vehicle? Reason: This operation never experienced before.
o Inspection			
7. Visually inspect the repair and assure that the silicon metal coating covers the damage area adequately.	1	1	

PAGE 2 OF 2

HEAT SHIELD TYPE: Ablative - ULD
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: Small: 20 x 20 inches

TASK ANALYSIS NO. 35

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Panel			
1. Using a spot light, visually inspect the entire area of the ablative panel for dents, abrasions, pit marks, erosion and deterioration.	1	1	
2. Visually inspect ablator panel attaching fastener plugs for proper position and alignment (plug is even with mold line - surface mismatch between plug and panel allowable ~ .030 inches).	1	1	
3. Visually inspect panel edge molded seal for damage, proper alignment and for proper sealing. NOTE: (1) Any damage of a magnitude affecting the integrity of the fiberglass honeycomb substrate will warrant the removal of the ablative panel assembly for further inspection and repair. (2) Remove ablative panel assembly per removal and replacement, task analysis no. , mechanical fastener attaching Concept #2.	1	1	

PAGE 1 OF 1

HEAT SHIELD TYPE: HCF (Hardened Compacted Fibers)
PRINCIPAL ATTACH CONCEPT: Mechanical Fastener Attaching Concept #2
PANEL LOCATION: Bottom
PANEL SIZE: 20 x 20 inches

TASK ANALYSIS NO. 36

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o <u>Inspection of TPS Panel</u>			
1. Using a spot light, visually inspect the entire area of the HCF panel for dents, abrasions, pit marks, erosion and deterioration.	1	1	
2. Visually inspect the HCF panel surface coating for damage.	1	1	
3. Visually inspect HCF panel attaching fastener plugs for proper bonding and alignment (plug is even with mold line. Surface mismatch between plug and panel .030 inches allowable).	1	1	
4. Visually inspect panel edge molded seal for damage, proper alignment and for proper sealing. <u>NOTE</u>: (1) Any damage of a magnitude affecting the integrity of the fiber-glass honeycomb substrate will warrant the removal of the HCF panel for further inspection and repair. (2) Remove HCF panel per removal and replacement, task analysis no. mechanical fastener attaching Concept #2.			

PAGE 1 OF 1

HEAT SHIELD TYPE: Metallic - Coated Columbium
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40 x 40 inches

TASK ANALYSIS NO. 37
COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Panel			
1. Using a spot light and magnifying glass visually inspect the entire area of the coated metallic panel for deep dents, scratches, abrasions and pit marks that may cause oxidation and deterioration of the metallic coated material.	1	1	
2. Visually inspect the edges of the panel for signs of chafing and chipping of the metallic panel coating.	1	1	
3. Visually inspect the longitudinal panel joint for distortion, excessive gapping, chafing and chipping of the metallic coating at the joint.	1	1	
4. Using nylon gloves, place hands on panel and check panel for looseness (excessive end play and side play).	1	1	
5. Check pi-straps for damage (deep dents, scratches, abrasion and pit marks that may cause oxidation and deterioration of the metallic coated material).	1	1	

PAGE 1 OF 2

HEAT SHIELD TYPE: Metallic - Coated Columbium
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40 x 40 inches

TASK ANALYSIS NO. 37
COST AND DESIGN EVALUATION

FUNCTION - TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Panel (Cont.)			
6. Visually inspect all panel pi strap attaching fasteners for tool damage to coating and burring of the tool slots. NOTE: (1) Any deep dent or hole in panel will warrant removal of panel for repair due to the fact that the coating material on the back side of panel skin will be affected and will require a similar repair. (2) Remove panel per removal and replacement, task analysis no. pi-strap attach concept with intermediate panel support Concept #8. (3) Inspect entire back side of panel for deep dents, scratches, abrasions and pit marks affecting panel coating. (4) Visually inspect the backside edges of the panel for chafing and chipping of the coating. (5) Visually inspect backside of panel, panel joint for distortion, excessive gapping and chafing and chipping of panel coating.	1	1	

PAGE 2 OF 2

HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

TASK ANALYSIS NO. 38

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Panel			
1. Using a spot light and magnifying glass, visually inspect the entire area of the panel surface for dents, scratches, abrasions and pit marks, that cause oxidation and deterioration	1	1	
2. Visually inspect the edges of the panel for signs of chafing of the panel	1	1	
3. Visually inspect the longitudinal panel joints for distortion, excessive gapping and chafing.	1	1	
4. Using nylon gloves, place hands on panel and check panel for looseness (excessive end play and side play)	1	1	
5. Check pi-straps for damage (deep dents, scratches, abrasions and pit marks that may cause oxidation and deterioration of material)	1	1	
6. Visually inspect all panel pi-strap attaching fasteners for tool damage such as burring of tool slots NOTE: (1) Any damage of a magnitude affecting panel structure, will warrant the panel removal for further inspection and repair.	1	1	

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HEAT SHIELD TYPE: Metallic
PRINCIPAL ATTACH CONCEPT: Pi-Strap Attach Concept with Intermediate Panel Support, Concept #7B
PANEL LOCATION: Bottom
PANEL SIZE: 40" x 40"

TASK ANALYSIS NO. 38

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL: OPERATING EXPERIENCE	CODE LEVEL: STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Panel (Cont.)			
(2) Remove panel per applicable removal and replacement task analysis.			
7. Inspect backside of panel for major structural damage, dents, abrasions and pit marks	1	1	
8. Visually inspect panel backside edges for chafing	1	1	
9. Visually inspect panel backside panel joints for distortion excessive gapping and chafing	1	1	

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HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20 x 20 inches

TASK ANALYSIS NO. 39

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Leading Edge			
1. Using a spot light and magnifying glass, visually inspect the entire outside surface of the leading edge segment for scratches, abrasions, pit marks, erosion and deterioration.	1	1	
2. Visually inspect the mating surfaces for indications of chafing, erosion and deterioration.	1	1	
3. Using nylon gloves, check leading edge segment for security of attachment (excessive end play and side play).	1	1	
NOTE:			
(1) Any damage of a magnitude affecting leading edge segment integrity, will warrant the leading edge segment removal for further inspection and repair.			
(2) Remove leading edge segment per removal and replacement task analysis no. .			
(3) Inspect the inside of the leading edge segment for obvious damage and evidence of overheating of the support hardware and the attaching fasteners.			

HEAT SHIELD TYPE: Carbon-Carbon
PRINCIPAL ATTACH CONCEPT: Carbon-Carbon Leading Edge Concept
PANEL LOCATION: Leading Edge
PANEL SIZE: 20 x 20 inches

TASK ANALYSIS NO. 39

COST AND DESIGN EVALUATION

FUNCTION – TASK DESCRIPTION	CODE LEVEL OPERATING EXPERIENCE	CODE LEVEL STATE-OF-ART	COST AND DESIGN FEASIBILITY QUESTIONS
o Inspection of TPS Leading Edge (Cont.)			
(4) Visually inspect wing spar attaching area for damage and evidence of overheating.			
(5) Visually inspect the inside areas of the two adjacent leading edge segments for obvious damage, and evidence of overheating of support hardware and attaching fasteners.			