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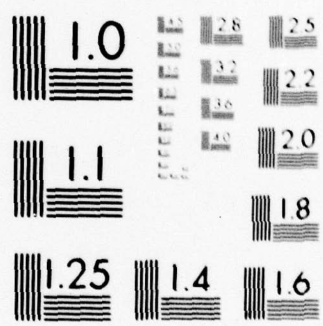

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PALLETIZATION/MODULARIZATION CONCEPT

July 1979

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The basic feasibility, probable scope, implications, and costs of implementing the Defense Communications System palletization/modularization concept are examined in the context of requirements for the worldwide present and future (1980's) DCS and the applicable capabilities, techniques, and technologies. Source materials for the study included relevent military documents, program reports and plans, and industry literature surveys, supplemented by visits to selected organizations and representative facilities.

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1. PALLETIZATION/MODULARIZATION CONCEPT

The palletization/modularization (P/M) concept is based on a combination of mechanical and electrical equipment that provides an improved capability for installing and/or relocating modular increments of communication systems. Typical applications are in communication centers such as those of the Defense Communications Systems (DCS). The improved capabilities provided by the P/M concept are important for the following reasons:

a. The communication capabilities at any center can be augmented or otherwise changed quickly to meet new requirements.

b. Reduced numbers of installation personnel and supporting equipments are required for site upgrades or changes in communication capabilities.

c. Fixed communication equipment assets can be converted into readily available resources for redeployment as necessary to meet military emergencies.

d. The delays (and much of the costs) associated with equipment ordering, manufacturing, assembly, test/acceptance, transhipment to DCS centers, installation by hardwire techniques, test, and cutover of new equipment can be eliminated by taking working (available) modules of equipment from selected sites.

e. Rapid and effective recovery of equipment from centers impacted by forced closure actions by host countries is possible.

For these and other reasons, the P/M concept represents a distinct technological advancement in the provision of communication services. Anticipated benefits to be derived from implementation of the P/M concept are summarized in Table 1-1.

1.1 PALLET DESCRIPTION AND APPLICATIONS

A pallet is a platform for the secure mounting of electrical equipment cabinets and/or racks. The equipment installed in the cabinets/racks of the pallet would be selected to provide various modules of communications function capability. Thus an ensemble of pallets and their various communications subsystems could implement an entire communications terminal. Examples of such modules include the AN/FRC-162 and -165 digital radios and the AN/FCC-98 and -99 multiplexers, each of which can be readily installed in one or two cabinets and mounted on a pallet. Utilizing solid state equipment and digital techniques, the modules of communication subsystems are reduced in size and require less cooling requirements, permitting a given communication capability to be implemented with fewer cabinets of equipment. Consequently, it is now feasible to use small and easily handled pallets with one or two cabinets of equipment to provide significant modules of communication capability. A tabulation of the benefits obtainable through successful application of the palletization/modularization concept in the DCS is shown in Table 1-1.

TABLE 1-1. EXPECTED BENEFITS OF THE P/M CONCEPT

Phase	Benefits
I. Acquisition	1. Convert fixed resources for transport/recovery 2. Reduce overall DCS equipment acquisition requirements 3. Reduce delays in emergency site upgrades 4. Reduce costs in emergency site upgrades 5. Redistribute equipment for changing requirements 6. Reduce on-site documentation, spares, test gear
II. Employment	1. Quick installation or removal of major modules 2. Minimize installation teams and support equipment requirements 3. Minimize hard wiring and testing on site 4. Reduce maintentenance actions required on site 5. Simplify controls and operational adjustments 6. Standardize DCS site characteristics worldwide

A concept for such a pallet has been developed, and is illustrated in Figure 1-1. The structure is formed of aluminum extrusions (channels) combining strength with light weight. The top surface permits secure mounting of standard cabinets and racks, e.g., commercial and MIL-STD-189 types, as well as providing the access needed to secure the pallets in place in communication centers. Provisions for joining the pallets physically and electrically permit their assembly into large, stable communication complexes. Open sections in the pallet structure and front and rear recessed areas enable cable routing between cabinets, between pallets, and as required to the local facilities/services. The pallet is designed to accommodate forklift handling to facilitate its movement for assembly of modules, transhipment, and installation. Detail discussion of these and related considerations are presented later under the respective design and engineering topic headings.

1.2 MODULE DESCRIPTIONS AND APPLICATIONS

Communication modules for use in P/M assemblies should comprise significant functional entitles, i.e., each should be an integrated, interconnected assembly of discrete items of equipment that in sum provides a distinct function. Examples of such modules are digital RF radios such as the AN/FRC-162 and -165. Included in their integrated assembly of components are power control units, transceiver assemblies, jackfield assembly, ancillary card cage assembly, and connector panel; and for the AN/FRC-165, the traveling wave tube power supplies and amplifier. As integrated modules, they have specific and minimal interconnections among their component boxes and panels and their total functional capability is available through

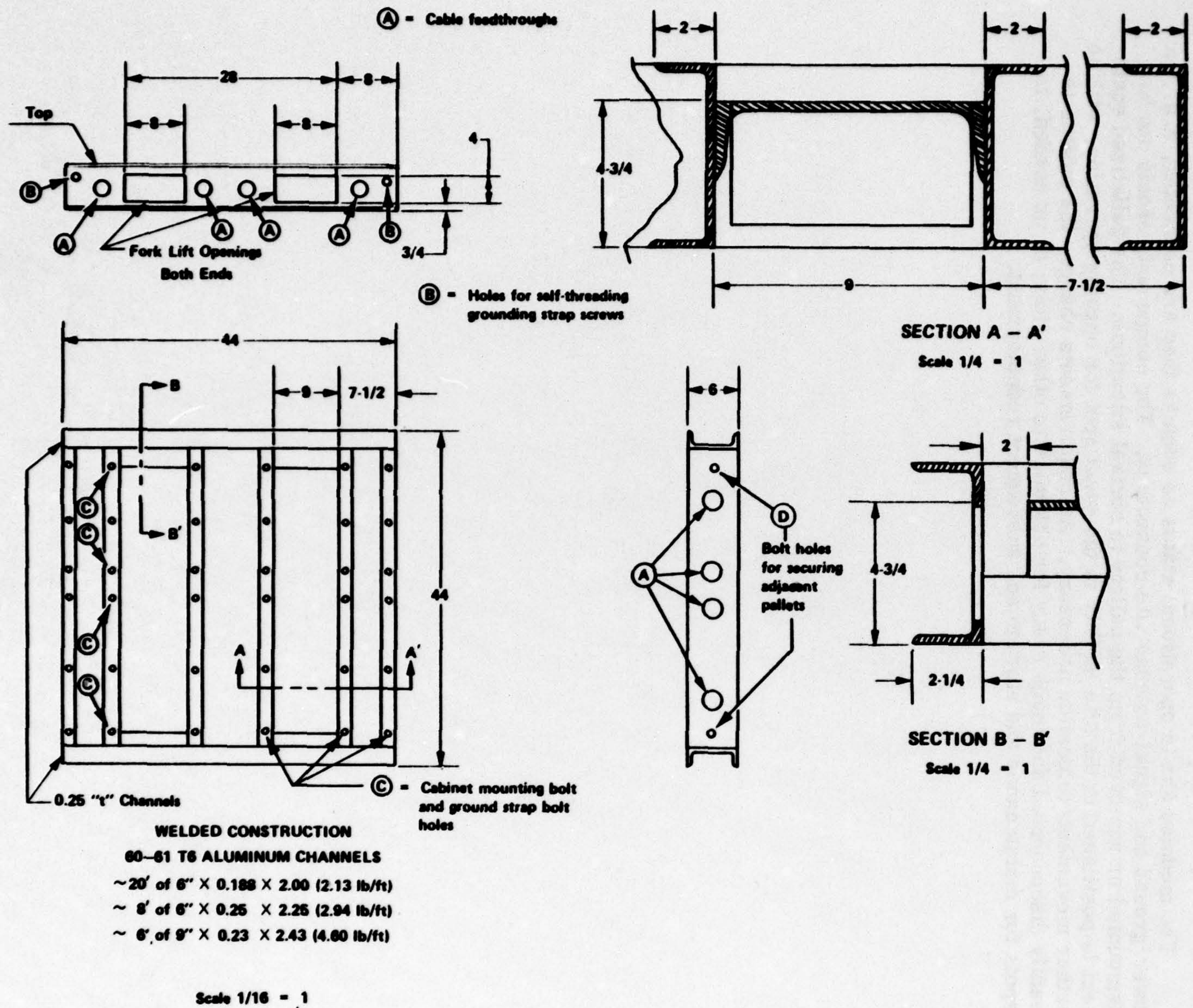

Figure 1-1. Proposed Pallet for DCS Palletization/Modularization Concept

signal and power connectors without need for on-site hardwire attachments to pin or terminal boards. Accordingly, such modules can be readily interchanged at a given site or between sites configured for their use.

The modules are in operational status as soon as they are connected, e.g., to power/ground and signal/antenna site connectors. The components should not be dismounted or removed from the pallets in normal situations. The palletized equipment is positioned in the site facility in the exact spot for ongoing operation, with no further movement/relocation necessary. As requirements change, the module is readily disconnected and made ready for shipment to other sites; or as needed, to depots for maintenance and storage and subsequent redeployment.

2. DESIGN AND ENGINEERING CONSIDERATIONS

A diversity of potential designs of pallets suitable for mounting, transport, and operational installation of modules of DCS equipments is possible. Development of detailed design parameters is beyond the scope or intent of the current study effort. The approach taken in this section is to provide broad design guidelines and constraints (e.g., light weight yet sturdy enough for forklift handling), and supplement these with specific requirements where they can be established from the analyses performed. Thus the candidate pallet suppliers will have the maximum opportunity to exercise design creativity and expertise for proper performance, cost-effective use of materials, and efficient manufacturing techniques and processes.

The format used herein will address specific topics of concern to identify limiting as well as unique requirements. Relevant technology employed in other military and commercial applications will be noted for possible adaptation as appropriate; the intent is to provide the broadest possible information on applications and limitations. Following each discussion of the separate topics will be a summary statement of pallet design recommendations addressing any specific requirements that a successful pallet design must meet.

2.1 CONNECTIVITY TECHNIQUES

2.1.1 Discussion of Considerations

Connectivity, in the context of this study, is the capability to electrically interconnect the palletized modules of equipment in the DCS sites. To ensure that the quality of electrical connections meets the requirements of the analog circuitry in the DCS, the techniques of hard wiring or soldering have been widely used. Hard wiring provides long-term minimum electrical resistance to the passage of signals through the connection. An alternative connection technique involving coacting male and female connectors can be quick and easy to use, but the electrical resistance to signal flow through the contacting elements is usually greater than through soldered connections, and would tend to increase with time. Since the increased resistance causes signal degradation through many interconnections, hard wiring has been the preferred method.

This philosophy may now be subject to change. The transition of the DCS from analog to digital transmission and circuitry will reduce the stringent requirements on the equipment-to-equipment connections, i.e., digital signaling does not require the highest quality (minimal resistance) connections provided by hard wiring. The technique of using coacting male and female connectors, with the recent advances such as increased contact unit pressures and inert protective embedments, provides adequate quality for use in P/M connections. Such connectors enable rapid on-site assembly and checkout, and standard connector types facilitate interchange of modules between sites. Accordingly, the design of the pallet should be consistent with the increased use of such connection techniques for DCS site installations.

Ideally the pallet design should contribute in a supportive manner to internal and external connectivity of the module equipments. For example, for module internal connections such as between cabinets or racks of components, the pallet should not obstruct the routing of short cables out of the bottom of one cabinet and into the bottom of another. For module external connections, the pallet should allow access openings and protected pathways for cable routing to the base of the equipment cabinets or racks. The variety and mix of such provisions must be weighed against their production costs, particularly if they are not fully utilized in most module assemblies and site installations. It would appear desirable for the pallet design to allow space and mounting surfaces for internal mounting of connectors or junction boxes in selected modules. Consideration of MIL-STD-1353A to promote standardization of connectors, and of MIL-STD-454E, e.g., its Requirements #10 (Electrical Connectors) and #69 (Internal Wiring Practices) is essential for design guidance regarding specific constraints in fixed mounting of connector devices. Figure 2-1 shows suggested cable routings which leave each module free for removal after the few local module drop cables are disconnected.

The size of the pallet in the current P/M concept is 44" x 44" x 6" high. At most, it would accommodate two cabinets or two racks of equipment. Thus, the use of short conventional leads and cables with connectors between component units is favored over terminal boards because of the close proximity of the units on the pallet. Further, any modules with large numbers of leads, as for technical control equipment, are not expected to pose any major space and connector access/placement problems. No features have been identified that would render fiber-optic cabling and connectorization incompatible with any expected near-term development and application of pallet-modules of DCS equipment.

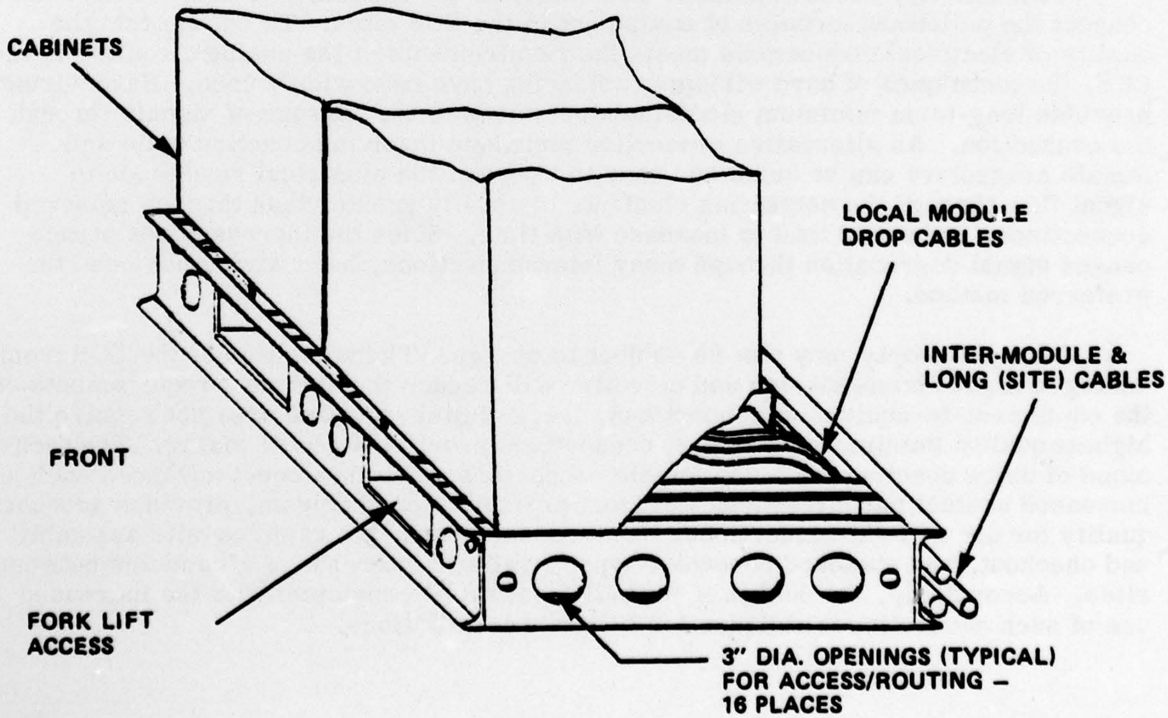

Figure 2-1. Proposed Pallet Cabling Access

2.1.2 Pallet Design Recommendations

The pallet design should provide maximum internal space for cable routing and cable access, especially for cables running between two cabinets/racks on the same pallet. Analyses to date have not indicated any requirement for including signal connectors as an integral part of the pallet. However, design consideration should be given to allowing space and flat mounting surfaces inside the pallet for mounting connectors or junction boxes in the event that such installations would be of benefit to selected module assemblies. As a minimum, unobstructed pathways should be provided to allow separation of different types of cabling/signal conductors routed between two cabinets/racks on the same pallet. Access holes should allow cables to be brought from the bottom of each cabinet and through the front or back face of the pallet. The front and back face channels should provide recessed pathways for cables running from module to module.

2.2 ELECTRICAL POWER REQUIREMENTS AND TECHNIQUES

2.2.1 Discussion of Considerations

MIL-STD-454E, Standard General Requirements for Electronic Equipment, specifically Requirement 25 (Electrical Power), directs consideration of MIL-STD-205, Frequencies for Electric Power, and MIL-STD-255, Electric Voltages, Alternating and Direct Current, to establish the characteristics and power-utilization requirements for the individual equipment involved. Since DCS sites will utilize many equipment types, requiring or supplying various electric power characteristics, it would be difficult to establish a common built-in power junction box/board/connector design for the pallet itself. The variety of modules, radios, multiplexers, patch and test equipment, and support equipment would pose universal installation problems in terms of connector types, locations on the pallet, and circuitry protection. Further, the separation of power leads from Class 1 circuits and communication signal conductors is essential. The National Electrical Code Handbook, Article 800, "Communication Circuits", establishes separation requirements for permanent installations of conductors. The installed module represents a permanent installation in the context defined therein, and should be consistent with such guidelines.

The possible advantage of providing a power bus built into the pallet appears small as compared to the expense of building power circuitry and receptacles into the pallet as an integral design feature. No significant advantages have been identified for built-in power distribution in all pallets.

An equally effective approach would employ factory-assembled power harnesses to/from the actual equipment on the pallet, with these harnesses enabling power hookup to/from the DCS site facilities/services with no connections to or through the pallet structure. Quantitative requirements for any built-in power connectors based on current equipment specifications may not be appropriate for the 1990s time frame. Built-in power connectors (and power cutoffs) could place restrictions on C-E equipment locations or arrangements in modules. Finally, provision of power connectors on the pallet would not decrease the overall number of on-site power connections required to any smaller number than could be attained with a factory-prepared power harness for the module. Each module's power harness would terminate in a single quick-disconnect connector, serving the same function as a pallet-mounted connector without adding the cost to every pallet.

2.2.2 Pallet Design Recommendations

No provisions are required for electrical power connectors or transmission lines to be built into the pallet. All electrical power distribution will be by means of cables or cable harnesses external to the pallet.

2.3 GROUNDING, BONDING, SHIELDING

2.3.1 Discussion of Considerations

2.3.1.1 Grounding

The basic objectives of grounding are:

a. Personnel safety – Prevent the buildup of electrical voltages between or within metal frames and structures that could create a shock hazard.

b. Equipment protection – Provide adequate fault current paths so that protective (overcurrent) devices can function as intended.

c. Equipment operation – Provide a common ground potential reference for all site communications equipment.

d. Noise reduction – Minimize electrical static and interference by maintaining low impedence paths throughout the communication system ground points.

In the interests of personnel safety (Requirement 1, paragraph 5.13, of MIL-STD-454), the pallet should provide a common protective grounding capability separate from both sides of the supply voltages for its equipment modules. This ground must then be strapped to the site's station ground, also known as comcenter ground, buried ground, central office ground, or main ground. The station ground is the point where equipment ground, cable-shield ground, and signal ground are tied together. In addition to but separate from this protective ground, consideration must be given to signal ground requirements for modular equipment. Generally, the equipment in the modules will have unit wiring and connector arrangements that provide for signals and signal grounds. In some modules, however, it may be desirable to provide means for common signal grounds, separate from the common protective ground, e.g., as noted in paragraph 3-20, "Cross Connections", of CCTM 105-50-21, Installation, General. Such requirements should be met by ground busses within the cabinets to avoid two separate grounds built into a pallet. Extensive details of grounding techniques for special requirements are described in Article 250, "Grounding", of the National Electrical Code Handbook (1978). Ground strap connection by means of self-threading screws, installed on-site, will ensure good metal-to-metal contact by cutting through any surface oxides on the aluminum pallets.

2.3.1.2 Bonding

Bonding requirements are defined in paragraph G, Article 250, of the NEC Handbook as: ". . . where necessary to assure electrical continuity and the capacity to conduct safely any fault current likely to be imposed". An electronics dictionary defines bonding as, "The means employed to obtain an electromagnetically homogenous mass having an equi-potential surface". As concerns the pallet, bonding requirements affect the manner of assembly of the structural and covering materials of metallic nature. Electrical (interface) resistance between adjoining metal surfaces must be minimized, e.g., by removing any oxide films, nonconductive paint, dirt, and grease, to ensure good electrical contact. Any combination of riveted or bolted joints on a single pallet must exhibit an electrical resistance of under 0.1 ohm overall. This value is suggested by Requirement 1, MIL-STD-454G, as opposed to CCTM 105-50-21, which cites 5 ohms as the maximum value for an acceptable ground resistance. The lower value is selected for an individual pallet to prevent the cumulative ground resistance in a row of interconnected pallets from exceeding the CCTM 105-50-21 value.

2.3.1.3 Shielding

High-energy electromagnetic pulses (HEMP) as from high-altitude nuclear weapon bursts, and electromagnetic pulses (EMP) as from large radars, are phenomena that can induce very large voltages in conductive materials unless they are suitably grounded. In the absence of site facility shielding, the equipment units on the pallets may be vulnerable to such pulses. For HEMP/EMP protection and grounding, no problems or requirements introduced by the pallet concept have been identified. Protection in and between racks will not be any more difficult than with current-configuration racks placed on facility floors. It is assumed that presently used protection measures will continue to be applied with the P/M concept.

2.3.2 Pallet Design Recommendations

A ground strap attachment point should be provided to 1) allow each equipment cabinet or rack to be grounded to the electrically conducting pallet structure, 2) allow the interconnection of the electrically conducting pallet structures of two adjacent pallets, and 3) connect the electrically conducting pallet structure to station ground. Punched or drilled holes, into which self-threading screws will be inserted on-site, are recommended for grounding-strap attachment points. The position of these holes are indicated in Figure 1-1. Holes in the pallet top surface would serve as ground attachment and/or cabinet tie-down points.

The measured electrical dc resistance between any two of the ground strap attachment points on a single pallet should not exceed 0.1 ohm. Construction and finishing of the pallet should ensure that this resistance is not exceeded after pallet storage for a period of 2 years and pallet use at a DCS site for 13 years*. The pallet need not provide shielding protection from HEMP-EMP; such shielding will be external to the pallet.

*Longest P/M C-E equipment expected lifetime, per DCAC 600-60-1.

2.4 PALLET SIZES

2.4.1 Discussion of Considerations

The determination of optimum pallet/module sizes in this study has considered anticipated near-term advances in equipment packaging and technology in context with transportation and facility constraints. Digital and solid state techniques, in combination with packaging integration developments, have in recent years contributed to major reductions in communication equipment sizes, weights, and power requirements. Transport constraints have also decreased in that larger equipment assemblies are routinely handled and transhipped with greater protection against damage and environmental exposure. Facilities housing the equipment installations have not changed appreciably in recent years, and are not expected to change greatly in the 1980s. Details of these considerations are discussed in Chapter 2, Section 2.3.8. Several additional implications have been considered during development of design criteria for pallet size; as discussed in the following paragraphs.

2.4.1.1 Weight and Handling

Large modules (weighing more than 3,000 to 6,000 pounds) would result in a requirement for heavy handling equipment at each site. This would require special deployment of such equipment to many of the DCS sites (an increase in installation cost), and may present operational problems in closing down a site quickly. Lack of heavy equipment on base in the last few days of operation could negate the intended ability to remove C-E resources quickly.

2.4.1.2 Configuration Flexibility

Since few new DCS facilities are planned, the P/M configuration must be flexible enough to allow its installation at various sites of varied facility configuration. A single pallet designed to carry as large an equipment load as possible would measure approximately 8 by 20 feet, limited to that size by shipping/packing constraints). Such a pallet would be incompatible with some small facilities. Further, for partial upgrades of some sites – where only selected racks of existing equipment are to be replaced – small pallets/modules would fit directly in place of the old equipment, while large pallets would require reconfiguration/rearrangement of existing equipments.

2.4.1.3 Size/Extent of Upgrades

The MEP shows that site upgrades will involve installation of 1 to 100 individual units at any given site in the DEB network. Clearly, no single pallet size is optimum for this entire range of upgrades. For an upgrade involving two to four racks of C-E equipment, for example, one large pallet would be of excessive mounting size and would be packing-inefficient.

Table 2-1 summarizes the number of equipment items to be installed at individual sites in the DEB I-IV upgrades.

As the table shows, few of the 153 total sites have more than 20 new items planned, and more than one-half of the sites being upgraded will receive 10 or fewer new items in the 1980s time period. Most of the equipment items are new radios and multiplexers. The interconnects between radios and second-level multiplexers that might be in separate small modules shipped to a site are simple, requiring only a few cables at most. Connections between second- and first-level multiplexers in separate modules typically require eight cables, which does not represent any extensive on-site effort. Connections from the first-level multiplexers to sites' distribution frames cannot be made until the upgrade equipment is delivered to the site, regardless of how large or fully integrated a module is assembled at the factory. Thus, for the great majority of the sites (81% receiving 20 or fewer items in the 1980s), increasing the pallet size above the current two-cabinet configuration would allow factory module assembly to a level that would typically reduce on-site connections by only several dozen. This small decrease in on-site assembly requirements would be attained at the expense of reduced flexibility of the module installation configuration, greatly increased on-site handling difficulties, reduce module compatibility with existing facilities, decreased shipping and packing efficiency, and increased pallet cost for small site upgrades.

Current patch-and-test equipment concepts would allow factory assembly of those units using the pallet concept in this document. Future applications of fiber optics may also permit modularization of distribution frames and associated multiplexer/demultiplexer equipment. However, neither of these items is a dominant factor in the utilization of the P/M concept of the 1980s.

TABLE 2-1. NUMBER OF UPGRADE EQUIPMENT ITEMS PER SITE, DEB I-IV

	Quantity of Equipment Items in Site Upgrades			
	1-10	11-20	21-50	50-up
No. of Sites	82	43	27	3
Percentage of Total Sites	53	28	17	2

2.4.1.4 Access to and from Facilities

If the objective of rapid deployment and retrieval of C-E resources is to be achieved, the modules must be compatible with facility access constraints. If facility construction/destruction/modification is required, install and remove times are increased. The larger the pallet is made, the more likely it will be that it will not fit through doorways, around corners, between columns, etc., in existing facilities. This in turn will result in more frequent site modifications.

If most of the site upgrades anticipated involved large numbers of C-E equipment items, the increased factory integration levels allowed by large pallets might result in sufficient decreases in on-site integration cost to compensate for the site modification cost. However, since such large upgrades have been shown to be the exception rather than the rule in the 1980s time frame, the large pallets would appear not to be cost effective. (Note: Since no specific data or statistics are presently available regarding DCS facility configurations, no detailed analysis of this cost question has been possible.)

2.4.1.5 Nature of Facilities

Present DCS permanent or fixed site-facilities are projected to continue in use for the next decade or longer. Their typical constructions have reflected the requirements for entry/removal of large equipments by provision for double-door access. Such double doors were observed to be 6 feet wide by 8 feet high at three California DCS sites. CCTM 105-50-6, Technical Control Facilities, recommends for new construction that the equipment loading door should be 96 inches (8 feet) wide by 120 inches (10 feet) high. The New Equipment-Building System (NEBS) technical reference document, published by AT&T as a guide for designers and manufacturers of equipment and systems that may be installed in Bell System equipment buildings, cites standard equipment entrances as being at least 4 feet wide and 8 feet high. In the interests of standardization of installation criteria for military-owned and leased (AT&T) systems, it appears desirable that the pallet width for this study should fit through building doorways 4 feet wide.

For transportable or mobile shelters, e.g., the 8 x 8 x 20-foot ANSI/ISO type, special purpose vans, semi-trailers and expandable trucks, the constraints on pallet size can be quite stringent. Fortunately, in the case of the 8 x 8 x 20-foot shelters, the new designs (such as Craig's H-753 and H-760) have at least one side 8 feet high and 20 feet long removable so that pallet size is not constrained. However, in other military shelters, vans, semi-trailers and expandable trucks, the double doors for equipment installation are definitely limiting on pallet/module size. These double doors typically are 4 feet wide by 6 feet high. Accordingly, the limiting door-width dimension, once again, was 4 feet wide, the same as recommended by AT&T's NEBS document.

Considerations affecting the optimum length of the pallets are more complex. Given the fact that pallet widths can be determined by the size of doorway openings, the length of the pallet may be constrained by the aisle widths on either side of doorways where these aisle widths would limit the swing clearance if a turn were necessary. This could be critical, particularly if a forklift truck was involved in moving the pallet to, through, and beyond the doorway. To eliminate the potential constraints contributed by the forklift truck in such entry and turn situations, the pallet could have casters to enable it to be rolled on level surfaces without a lift truck. Alternatively, a manual "walkie" pallet truck or a dolly could be used under the pallet to enable such movement.

The digital equipment, as represented by the DCS Digital European Backbone, Stage I to IV upgrades, were seen to be sufficiently small that the indicated equipment cabinet heights could be under 57 inches. Further, each of these equipments could be assembled as significant modules (radios, first-, and second-level multiplexers, alarm monitor group, patch and test bays) in one or two such cabinets as required. Thus, significant system "building block" modules could be provided by pallets carrying one or two cabinets. These modules of integrated equipment units/components represent a major step in simplifying installation on-site. Increasing the size of such pallets to accommodate more cabinets would, as noted already, conflict with limitations on doorway width and forklift turning and positioning length. For facilities where higher cabinets are known to be acceptable, cabinets taller than 57 inches can be mounted on the pallets.

In addition to increased handling limitations on heavier pallet blanks, as well as the integrated assemblies with more equipment, there are other operational limitations to consider. For example, when one of the units on an integrated multi-unit pallet is down for parts or maintenance, the entire assembly is not operationally ready for service. For the individual (smaller) pallet module units, only the one module is down and may be readily bypassed for a backup module. It is expected that, in time, multi-units could be engineered to provide the flexibility of individual pallet/modules. However, as a first step in this direction, the simplicity of design and flexibility in use of single pallet/modules is recommended.

2.4.2 Pallet Design Recommendations

The finished pallet size, excluding removable top flooring, should measure 44" x 44" x 6", with tolerances, squareness, and flatness of finished structure in keeping with good commercial practices for a permanent hardware component. The pallet top surface should accommodate two cabinets or racks, each measuring 22 inches wide, mounted side by side in a fashion such that a forklift carrying the module approaches either the front or back face of the cabinets or racks.

2.5 PALLET/MODULE WEIGHT

2.5.1 Discussion of Considerations

Pallet sizing provides for up to two cabinets or two MIL-STD-189 racks for equipment. The maximum single cabinet weight identified in the FKV/DEB upgrades is 950 pounds (for the power supply group); other rack-mounted equipment identified for DCS upgrades weigh substantially less.

The recent advances in handling capability in transport support vehicles, e.g., hydraulic-augmented manual and motorized lift trucks, enable heavier equipment to be moved easily. The 4K forklift (4,000 pounds capacity) is widely used at air cargo terminals for handling items that are too heavy or bulky to be transported manually. Other forklift trucks have load ratings such as 6,000 pounds (A/S32H-7 and A/32H-13 for rough terrain use) or 10,000 pounds (A/S32H-10, and A/S32H-15 for adverse terrain and forward combat zone use). At the same time, communications equipment have been getting smaller and lighter for equivalent capabilities. As a result, the maximum cabinet weight (power supply group) modules will not exceed any identified transport constraints.

Facility and shelter constraints on module weights are not a problem. Technical control facilities as noted in CCTM 105-50-6, should have floor load capabilities of 150 lb/sq ft, which is typical for concrete slab on graded construction. AT&T in its NEBS guidelines calls for 115 lb/sq ft capability in equipment frame rooms (averaged across 20 x 20-foot areas including aisles), increasing to 140 lb/sq ft (on average for associated areas) in the power supply rooms. The manufacturers of transportable shelters and vans use a criterion of 600 lb/4 sq ft (nominally 150 lb/sq ft) as the load bearing value. The nature of such shelter and van floors, typically aluminum skins over honeycomb or 1-inch plywood, is vulnerable to concentrated local load points/areas. Since the pallet base is 44 x 44 inches, or approximately 14 square feet, pallet gross weights should be nominally limited to 2,100 pounds for installation in technical control facilities or in transportable shelters and vans. The heaviest single cabinet equipment identified in the Digital European Backbone upgrade was the power supply group at 950 pounds, with the balance of the one-cabinet units well under half that weight. Since typically only one power supply group cabinet is mounted on a pallet, the total weight of most modules will be much less than the allowable loading. The mounting of two PSGs and heavy cabinets on one pallet, to be permitted only where facility flooring would tolerate, could exceed the nominal limit of 2,100 pounds.

2.5.2 Pallet Design Recommendations

The weight of an empty pallet should be kept to a minimum, consistent with strength and size requirements. As a design goal, an empty pallet should be light enough for two men to lift and carry within a building or storage area. Aluminum is recommended as the structural material for the pallet.

The weight of equipment to be mounted in each of two cabinets on a pallet will not exceed 950 pounds, including the weight of the cabinets. The maximum expected weight of the equipment pallet is 100 pounds. Thus the entire maximum load weight of a P/M module will not exceed 2,000 pounds, and may generally be expected to be appreciably less than this amount.

2.6 PALLET CONSTRUCTION

2.6.1 Discussion of Considerations

The C-E equipment to be integrated in the modules can be readily mounted in standard commercial cabinets or on standard racks (MIL-STD-189). Thus the pallet construction must accommodate the mounting of such cabinets and/or racks with adequate strength and security for handling and transport of the complete module, without compromising forklift pallet handling.

The C-E equipment noted in Section 1.2, Module Descriptions, do not pose extreme requirements upon the design of the pallet structure to provide adequate strength for security in transport, installation, operation, or maintenance access. Limiting the height of the recommended equipment cabinets to some 57 inches (consistent with FKV/DEB requirements), in combination with the large footprint or bearing area of the cabinets, bounds the restraining or hold-down force requirements during transhipments. Handling stress estimates made during this study indicated that these forces can be accommodated readily, e.g., by suitable sizes and numbers of steel through-bolts and flanged structural aluminum (60-61T6) members such as standard 6-inch channels (Army-Navy series) of nominal 3/16-inch thicknesses. Carbon steel and stainless steel members would be heavier and more expensive, and their greater strength is not required. Epoxy-fiberglass "pull-trusion" channels do not provide adequate strength at joints.

The construction of the pallet, using structural aluminum channels with appropriately welded or riveted joints and corners, should be designed to be lifted and handled by forklift trucks. The pallet concept illustrated in Figure 1-1 has two forklift openings extending clear through, with access openings on two sides. For weight minimization, the bottom face of the pallet is left open. The upper face (where not covered by the cabinets/racks) will require suitable approved linoleum or other non-slip floor covering material sections or panels for operator standing or walking. Openings in the webs of the channel members, as shown in Figure 1-1, would permit inter-module cable routing if desired, would provide hand-holds on empty pallets, and would reduce weight. Detailed design must consider strength requirements. Provisions for attaching/bolting pallets, one to another or to the floor, will require access from the top. Holes for bolting together pallets and bolting down cabinets, as shown in Figure 1-1, should be incorporated into the standard pallet production design to avoid drilling individually at module assembly sites. Inter-module and site cables are routed through the rear recessed area of the pallets and local module cable drops and connectors can access the equipment cabinets up through the pallet structure as indicated in Figure 2-1.

2.6.2 Pallet Design Recommendations

Cabinet mounting points should withstand the stress exerted by a 950-pound (loaded) cabinet during module handling and shipping. The structural strength of the pallet should be sufficient to support the maximum pallet load of 2,000 pounds during forklift or other handling and during shipment/transport. The structure should allow unobstructed forklift access from either the front or back side of the pallet (front/back being defined by the direction of mounting of the C-E equipment racks).

The bottom surface of the pallet need not be sealed nor enclosed, i.e., not be so designed for structural or other purposes; the design should be consistent with strength and weight requirements. The top of the pallet should be compatible with removable floor surface sections that allow access downward into the pallet for cabling actions, and for pallet-to-pallet or pallet-to-site floor attachment. The top of the pallet should also be compatible with flexible configuration of removable flooring to provide flush fit of flooring against cabinets, continuous false flooring for personnel, or floor covering for site appearance.

The pallet structure should provide mounting points by which the pallet can be bolted or otherwise anchored to the site floor with sufficient strength to prevent accidental or unintentional movement of the module once it is installed. Bolt holes should be provided for grounding strap attachments, interconnecting pallets, and mounting cabinets to racks as indicated in Figure 1-1. Cable feed-through holes in the front and back edge members should be as large as structural strength requirements allow, so that cables and connectors can pass through easily and not be crowded. Feed-through hole edges should be burr-free to prevent cable damage or personnel injury when handling blank pallets.

2.7 PALLET HEIGHT

2.7.1 Discussion of Considerations

Pallet height has a direct influence on the allowable height to which C-E equipment cabinets and racks can be mounted on the pallet. Since military vans, semi-trailers, and expandable trucks have doorways of 6-foot height, the combined pallet and cabinet height must allow for some clearance for equipment installation through such doorways.

A principal consideration in establishing pallet height was the lack of an identified requirement for under-floor ducts for C-E equipment cooling air. The experience of industrial firms (e.g., Hughes Test Systems Department, Satellite Ground Systems) with commercially available, largely solid-state communications and control equipment is that room air provides sufficient cooling. In the module, the few units that need special cooling can be supplied with refrigerated air through flexible ducts appropriately attached to their cabinets. All other equipment cabinets can use the room air provided for operator comfort by means of screened openings at the bottom front of the cabinets. Thus there is no evident requirement to provide under-floor (in-pallet) air ducts.

Accordingly the height of the pallets is driven only by the structural and transport requirements, as noted above, and any cable routing and access requirements. The aluminum channels of 6-inch height in combination with the 9-inch channels (in width) form a box around the forklift openings (and form the strong backbone of the pallet). Thus the minimum height of the pallet would be established by the 6-inch channels. The thickness of the floor panels (and linoleum) will be an added minor increment (less than 1 inch) to the height. The cable routing, as by through-holes in the channel webs, will not contribute to increases in the pallet height; nor would access requirements for securing pallet to pallets or to the floors. The 6-inch pallet height, in combination with the 57-inch cabinets, adds to 63 inches, leaving clearance for moving such pallet modules through 6-foot high doorways when necessary.

2.7.2 Pallet Design Recommendations

The pallet, excluding any removable flooring panels, should be of minimum height, e.g., not exceeding 6 inches; and should be consistent with the forklift handling requirements discussed in Section 2.17.

2.8 PALLET SURFACE

2.8.1 Discussion of Considerations

The upper pallet surface is expected to be either part of or contiguous with the normal floor surface used by operational and maintenance personnel at the DCS site. Accordingly, the pallet surface should be uniform, of a standard height, and free of ridges or discontinuities when joined to other such pallets. The only references to the nature of flooring surface material are in TM 11-486-4, Electrical Communications, Inside Plant; and CCTM 105-50-6, Technical Control Facilities, which suggest floor coverings of either asphalt tile or linoleum. MIL-STD-1472B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, and Part 1910.268, Operational Safety and Health Administration Guidelines (Title 29, Labor), designate flooring requirements in outside or hazardous locations (stairways) in terms of design, materials, and application, but do not go beyond "nonslip or nonskid" flooring comments for inside work areas. Therefore it would seem reasonable to use asphalt tile or linoleum as pallet upper surface materials, if any small sections of open pallets are to be covered for safety or appearance. As discussed in Section 2.9 below, the use of covered pallets for large flooring areas is not considered cost-effective.

The bottom surface of the pallet would usually sit on the ground floor of a site, which is typically concrete that has been painted or chemically sealed and which has a subsurface moisture barrier. In a van, semi-trailer, expandable truck, or ANSI/ISO shelter, the pallet would sit on a floor of 1-inch plywood or aluminum surfaced honeycomb. In the interests of corrosion protection, the aluminum pallet structure is coated or treated in accordance with MIL-C-5541 (other treatments are used if the pallet structure is of steel or stainless steel construction). No other covering or bottom surface membrane is required between the floor and the pallet.

The two side surfaces of the pallet, assuming channel member construction as shown in Figure 1-1, are smooth and flat and appropriate for abutting pallets to provide even floor walkways. A suitable covering of snap-in panels could be used on the front and back of the recessed pallet to provide a finished appearance if needed.

2.8.2 Pallet Design Recommendations

Assuming aluminum construction of the pallets, MIL-C-5541 treatments are required for pallet corrosion protection. In addition, the top surface of the pallet should be compatible with removable tile or linoleum flooring sections necessary to cover open-top areas of pallets and provide personnel access around adjacent areas. All sides of the pallet should be capable of accommodating snap-on panels for improving site appearance and enhancing operator safety when the site installation is such that surrounding false flooring is not used.

2.9 PALLET WALKWAYS AND EQUIPMENT ACCESS

2.9.1 Discussion of Considerations

A basic requirement for successful use of the P/M concept is the capability to freely access the module equipment in the site installation. This requires that operators and/or maintenance personnel be able to directly approach the fronts of module cabinets/racks without constraint. Comparable access to the rear of the module cabinets/racks is expected in fixed sites, but is not essential in vans, semi-trailers, trucks, and other transportable shelters.

The placement of the equipment racks/cabinets on the pallet surface as shown in Chapter 2, Figure 2-5, was made to provide:

a. A 3-inch setback for the fronts of the racks/cabinets to protect knobs, etc. (that typically extend up to 2 inches from panel fronts) during transshipment; and

b. A 15-inch clear space behind cabinets so that two modules, back-to-back, provide a minimum of 30 inches for a rear access aisle. TM 11-486-4 on page 3-1 calls for 30-inch aisles for rear access to cabinets. Front access requirements vary from 40 inches per TM 11-486-4, to 42 inches per MIL-STD-1472B, to 48 inches per CCTM 105-60-6.

The use of blank pallets (without equipment cabinets) as spacers between equipment rows to provide aisles of ample width for front access does not appear to be cost-effective. For example, the cost of blank pallets is estimated at over $30 per square foot, whereas new access floor systems run between $4 to $5 per square foot, including fittings and finished floor surfaces. The Donn Corporation has installed its Wood-Cor Model 15 access floor systems in radio and television stations, in telephone and communications centers, and in offices, including many U.S. Navy facilities.

The access floor system uses 2 x 2- or 2-1/2 x 2-1/2-foot finished floor sections set onto four pedestals and capable of supporting live loads of 250 lb/ft^2. The pedestals have a square steel plate base that can be mounted (with mastic) anywhere on concrete floors, e.g., between the channel members of the pallet to support covering access floor sections. Thus such floor sections could be butted to the C-E equipment cabinets and so cover exposed areas of the pallets as required. The access floor system complements and finishes the modules without requiring any special hardware or fittings, yet is readily removed for full access to the pallets if required.

The removable floor panels (asphalt tile or linoleum sections) over the pallets enable access to cables under the cabinets, as well as to pallet-to-pallet attachments or to pallet-to-floor hold-downs, as may be required for servicing. The access floor surface is independent of any unevenness between pallets because each 2 x 2 panel rests on its four pedestals, which are individually threaded for height adjustments. The flooring can be leveled to within 0.062 inches in 10 feet.

2.9.2 Pallet Design Recommendations

An access floor system such as the Donn Wood-Cor Model 15 or equivalent is recommended for most flooring areas around pallets. The pallet need not be designed to serve as a false flooring base.

2.10 PALLET ANCHORING AND ATTACHMENT

2.10.1 Discussion of Considerations

The use of modules as parts of fixed DCS installations requires that the pallets exhibit characteristics of stability, rigidity, and immobility. These characteristics should be readily achieved during installation, without compromising the capability to quickly disconnect and prepare for shipment any pallet module.

The recommended open-top design of the pallet permits top access to the internal structure, to enable locating and placing hold-down bolts through holes in bottom flanges, or through clamping plates that fit over flanges, for anchoring pallets in place on concrete floors. This same access enables bolting pallets side-to-side or end-to-end to provide secure attachment and enlarged platform and equipment areas, walkways, or aisles. These practices have been used extensively in various NASA space program launch control and test equipment installations for palletized telemetry, communications, display and control modules. Some such pallet/modules have been installed, used, removed, and installed elsewhere many times without difficulty or the necessity of pallet repairs.

The use of shims between the pallet structure and the ground floor, in combination with bolt-down anchoring, provides maximum stability and eliminates any rocking or springing of the pallet structure on uneven surfaced floors. The use of aluminum structural members simplifies on-site drilling of anchoring holes where needed to provide added options for achieving desired installation stability.

2.10.2 Pallet Design Recommendations

It is suggested that simple hold-down blocks be used with (overlapping on) the central underside flanges of the pallet structure for anchoring the pallet to floors. By using blocks having holes with generous clearances for bolts, more latitude for pallet spotting in context with other pallets can be obtained. For attaching pallets to other pallets, suitable clearance holes at each corner in the side faces of the pallet will permit through-bolt and nut attachment for abutting pallets to one another with minimum separation.

2.11 ENVIRONMENTAL CONTROL

2.11.1 Discussion of Considerations

An objective of the C-E equipment P/M concept is to assemble the component units into a compact one- or two-cabinet module. It is important that the temperature of such closely located equipment is not permitted to rise excessively during normal operations. Exposure to or accumulation of moisture and excessive humidity and/or dust in storage or in shipment can also be detrimental to equipment performance. Environmental control of such factors is necessary to proper operation.

Reviews of the new and representative equipment specifications, e.g., the DRAMA radio and the associated first- and second-level digital multiplexers, show that refrigerated forced air cooling will not be required. In fact only the power supply group equipment of the TSEC-CY104, and transmitter units such as the traveling wave tube amplifier of the AN/FRC-165, may require special cooling air provisions. Since these equipments operate in floor-mounted cabinets without sub-floor cooling air inlets, it will also be possible to mount them onto the pallets and provide any special cooling air through flexible duct attachment to their cabinets. (This practice has been used for years by Hughes in its palletized Satellite Communications and Test Module installations. Thus it would not be necessary to build in air ducting capabilities into the pallets to provide underfloor air flows to equipment modules mounted on the pallets. The ambient room air provided for operator comfort is also adequate for convection cooling of equipment in pallet-mounted cabinets through lower-front entry panels of the equipment. Such air is normally filtered and dehumidified for the working areas in the typical DCS sites.

Requirements for environmental control during shipment of modules in CONUS and overseas are discussed in MIL-P-9024G, Packaging, Handling, and Transportability in System/Equipment Acquisition. Criteria for the selection of appropriate levels (A, B, or C) of packaging and protection for shipment and/or storage are described for selection by the procuring activity. Review of these requirements did not identify any design requirements for the pallet.

2.11.2 Pallet Design Recommendations

Cabinets and racks for mounting on DCS pallets should have provisions for a lower-front air entry panel (with dust filter) and for an optional blower unit. No requirement for through- or under-pallet air flow has been established, and it is recommended that no added pallet cost or weight be incurred to provide such capability. Use of blank pallets as air-tight flooring need not be provided in the pallet design, since other false flooring mechanisms would be considerably cheaper.

It is recommended that pallet designers review the packaging and preservation criteria cited in MIL-P-9024G, although no specific pallet design requirements have been identified during the study.

2.12 COMSEC/TEMPEST IMPLICATIONS

2.12.1 Discussion of Considerations

Communications security and TEMPEST are concerned with compromising emanations, i.e., unintentional data-related or intelligence-bearing signals or radiations which, if intercepted and analyzed, disclose the classified information transmitted, received, handled, or otherwise processed by any (DCS) site equipment.

The principal reference document on this subject is MIL-HDBK-232, Red/Black Engineering-Installation Guidelines (U), classified Confidential. Explicit and quantitative data are provided to guide equipment planning, engineering, and installation in terminal systems. A major concern is the potential coupling of classified information into paths, e.g., ground loops, that would be susceptible to tapping or interception by unauthorized individuals. Recognizing that some new C-E equipment modules may process classified information in the clear, appropriate signal and ground conductor protection will be essential. It was noted earlier (Section 2.3) that a simple common ground strap/bus for pallet-mounted equipment is inappropriate in certain situations. Relative to digital data communication processors, secure voice systems, and video systems processing classified information in the clear, MIL-HDBK-232 states: "Due to the number of variables in terminal systems characteristics, the cognizant engineering-installation agency should select the appropriate standards for area application from Sections 4 and 5 and key to the guidelines listed as a minimum. Under no circumstances should the area requirements be broadly applied but rather the engineering-installation agency should request TEMPEST data on such systems and plan guidance for facility hardware installation thereon."

Current DCS practices and techniques for COMSEC/TEMPEST protection are handled above the floor level, often with specially engineered cable conduits at each site. Further, only a portion of DCS site equipment require such provisions. Therefore, the inclusion of such protected interconnect paths in a highly versatile configuration on all pallets would impose unnecessary costs and constraints. It is concluded that COMSEC/TEMPEST requirements will be met with current techniques through the 1980s, with no pallet design impact. Use of new techniques (e.g., fiber optics) in future timeframes is not expected to require any special pallet design features, although above-pallet equipment or interconnect designs may have to be changed.

In some applications, the use of a common ground for all site C-E requirements can introduce an unwanted path for secure information. This problem suggests the use of relatively small pallets so that selected modules can be physically and electrically isolated from one another to provide the necessary security.

2.12.2 Pallet Design Recommendations

No unique features of pallet design are imposed by COMSEC/TEMPEST requirements. In the utilization of the pallets, careful attention should be given to the requirements of MIL-HDBK-232.

2.13 HUMAN FACTORS ENGINEERING

2.13.1 Discussion of Considerations

Personnel safety and hazard assessments as well as operator and maintenance requirements are key factors in the human engineering implications on the pallet/module design and its potential employment in the DCS.

Human factors in terms of operator and maintenance technician requirements have been principal drivers of the candidate pallet concept illustrated in Figure 1-1. That configuration provides unobstructed access to the fronts of all equipment cabinets and racks. Their heights (60 inches maximum) keep all equipment within easy sight and reach from the facility floor level. Rear access to all racks is available, and back-to-back modules provide the required 30-inch aisles. The pallet height of 6 inches is well within the single vertical step rise limitations cited in MIL-STD-1472B. No conflicts with human engineering considerations in the study-referenced MIL standards have been identified. Technology advances in the 1980s timeframe and their accommodation in the equipment modules should not be handicapped or compromised by the pallet design as proposed. The freedom for top, bottom, front, and back access to the pallet-mounted racks/cabinets should meet any requirements for monitoring, controlling, adjusting, and servicing equipment.

For personnel safety, OSHA and MIL-STD-1472B guidelines direct the use of guard rails 42 inches high, and within 2-1/2 inches of the edges of raised platforms or mezzanine areas. Because of the variations in site facilities, any planning to provide standard guard-rail post mounting holes in the pallets without site layouts of installations is not recommended. The low cost of access floor systems and their compatibility with pallets (as noted in Section 2.9 above) may allow their use wall-to-wall in many facilities, eliminating the need for railings. Where exposed edges do require railings, the commercial flooring systems also offer railing attachments, step units, and ramps in highly flexible configurations.

A preliminary hazard assessment was made. The principal risks of a physical nature concerned the installation of assembled modules into spaces between cabinets (palletized or conventional). Such handling of the modules is intended to be by hand-operated pallet trucks. These trucks would lift the pallets approximately 4 to 6 inches and enable 90 degree turns in narrow aisles, (e.g., under 6 feet wide) to facilitate the emplacement or removal movement of the modules. The use of powered lift trucks in such close quarters would be hazardous to site equipment. Hazards of an electrical nature were seen to be the same as already experienced, or possibly less since the metal pallets will be grounded.

2.13.2 Pallet Design Recommendations

The width of the forklift slot openings in the pallet should be limited to 8 inches so that powered-lift "walkie" pallet-trucks with their 9- to 10-inch wide lift members cannot be used to move these pallets in equipment bay aisles. The pallet height should not exceed 6 inches. No provision for attachment of safety railings directly to the pallets is required. Holes provided for bolting together adjacent pallets should also be suitable for bolting on ramp or step units, although such units will normally be attached to access floor systems rather than the pallets.

2.14 PALLET BLANKS

2.14.1 Discussion of Considerations

A study objective has been to make the pallets simple and clean in design to minimize costs and handling constraints. Earlier discussions in this report concerning the functional requirements imposed on the pallets have established shape, size, strength, and other necessary characteristics. Cost considerations direct the use of standard materials and available forms, together with the application of conventional techniques to facilitate fabrication and assembly of pallets. The optimum design approach requires careful assessment of the possible tradeoffs in alternative designs and manufacturing practices to meet the pallet's functional requirements. The indicated solution in Figure 1-1 represents a concept selected on the basis of preliminary assessments; further design studies may lead to a better compromise of costs and capabilities.

Use of pallet blanks as extensions of the raised flooring and walkways was found to be uneconomical as compared to existing access floor systems (see Section 2.9). The blank pallets could, however, be stored and transported in stacks. Such stacks could be held together by steel straps, as used with stacks of empty 463L pallets, to prevent shifting or falling. Forklift access to the bottom pallet would allow easy handling of the stack. It is important that individual pallet blanks be easily handled, and that they be free of any protrusions or vulnerable extensions subject to damage or breakage. Manual lifting or moving of individual blank pallets is not considered an absolute design requirement, due to the ease of forklift access. However, the current concept results in a weight of approximately 100 pounds, and minimum weight is a design objective.

2.14.2 Pallet Design Recommendations

Pallet weight should be as low as possible, with handling by two men an objective. Pallet design should be simple to reduce cost and weight to the extent consistent with strength requirements. Design of the pallets to serve as raised flooring sections is not required. Open channel construction and edge flanges on channel members shall facilitate manual handling of pallet blanks.

2.15 ADVANCED TECHNOLOGY

2.15.1 Discussion of Considerations

Experience has shown that aluminum palletized structures are life cycle cost (LCC)-effective with respect to production, durability, strength, etc. Deployment of the pallets in the 1980s timeframe rules out the application of future metallurgical breakthroughs.

Current low-lift "walkie" forklift capacities are adequate for the modules envisioned. No need has been identified for application of air cushion (ground effect machine) devices to move modules. Further, there are no known applications of built-in air cushion movement components in palletized electronic assemblies – the air cushion devices used are separate equipment onto which pallets are placed. Therefore no special pallet design features are considered necessary to accommodate the possible application of air cushion movement.

Fiber optic interconnects are not envisioned as a widespread technique in DCS C-E equipment of the early 1980s timeframe, since none of the equipment surveyed in the study have included any provision for such interconnects in their specifications. Further, the data rates and bandwidths indicated at interfaces are easily handled by conventional electrical cabling. Fiber optics do offer advantages with respect to HEMP/EMP and COMSEC/TEMPEST considerations, and are currently under study in other development programs. However, their application in the DCS does not seem to impact the design of pallets already constrained in size and weight by other considerations. Since fiber optic cable bundles should be smaller than electrical bundles, pallets able to accommodate the latter will also support the former. The true impact of fiber optics applications should possibly be in the node and network structure of the DCS as a system rather than at the intra-station module level, and should be addressed at the system level. The potential of fiber optics could impact the hardware design and modularity of equipment within the 1980s timeframe. However, attempts to drive the initial pallet design to accommodate such hypothesized fiber optics advances would be highly speculative, and a more reasonable approach would allow for pallet design modification or pallet family expansion some years from now.

Such equipment developments as bulk and trunk encryption devices, digital access exchanges to concentrate digital secure-voice traffic, narrative/record terminals, etc., are expected to exploit solid state and microchip technology. These new equipments will thus be compact, have low power requirements, and generally be adaptable to one- to two-cabinet modules for pallet mounting.

2.15.2 Pallet Design Recommendations

Anticipated advances in the near-term technology for C-E equipment will not impact the pallet design recommendations offered in this report.

2.16 COMMUNICATIONS-ELECTRONICS SUPPORT EQUIPMENT

2.16.1 Discussion of Considerations

The use of pallet-cabinet modules as a convenience for shipping various C-E support equipment units and miscellaneous items may be of limited utility. The principal C-E support equipment of sufficient value to warrant use of pallet-cabinet modules may be spare parts and items of test equipment. The manufacturers of prime C-E equipment spares and of test equipment are accustomed to providing appropriate packing/packaging for storage and overseas shipment of their products. The addition of a new requirement, i.e., capability for installation or mounting into a pallet-cabinet module, may increase equipment costs and reduce manufacturer responsibility for safe delivery (with full warranty) provisions.

No data regarding specific types of C-E support equipment sparing were available for this study, and therefore no quantitative requirements could be derived. No factors have been identified that would prevent the use of pallets for such items, especially if they could be mounted onto MIL-STD-189 racks or in standard C-E equipment cabinets.

2.16.2 Pallet Design Recommendations

It is recommended that no unique design features be included for the possible use of the pallet for C-E support equipment at this stage of the program.

2.17 FORKLIFT HANDLING OF PALLETS

2.17.1 Discussion of Considerations

The considerable weight of a complete pallet module warrants the use of power-assisted handling equipment such as forklift trucks. Pallet design has incorporated the standard basic dimensions for forklift handling in terms of the unobstructed access from two sides of the pallet. The openings for the forklifts are 4 inches high x 8 inches wide, with 20-inch centerline-to-centerline spacing centered on the pallet sides. The suggested design of the pallet structure, using 6-inch and 9-inch aluminum channels, provides clear-through openings with no breaks or joints to snag the fork members. The strength of these channels in welded assembly is adequate for pallet loads many times the maximum projected loading of approximately 2,000 pounds (two power supply groups plus pallet).

As noted earlier in Section 2.13.1, the forklift openings are compatible with the 4- to 6-inch wide fork members of the general-purpose lift trucks at depots and aerial ports. The openings were intentionally left narrower than the 9- to 10-inch wide fork members on powered (gas or electric) "walkie" pallet trucks to preclude their use in close proximity to C-E equipment cabinets and bays. The openings will fit the hand-powered walkie pallet trucks recommended for close aisle work. These trucks are rated at 5,000 pounds lift capacity and can be turned 90 degrees in aisles of less than 6 feet in width.

2.17.2 Pallet Design Recommendations

The pallet design dimensions shown in Figure 1-1 provide suitable openings for powered lift truck handling in transhipments and for manual walkie pallet truck handling for installation. Forklift openings should be no wider than 8 inches.

2.18 MANUAL HANDLING OF PALLETS

2.18.1 Discussion of Considerations

The requirement for an empty pallet to be movable by unaided humans is not considered a valid design bounding constraint. If other considerations lead to a pallet that can be lifted manually, appropriate hand spaces or openings in the pallet outer frame can be called out as a convenience requirement. Forklift openings, channel flanges, etc., should be adequate for pallet handling and their edges must not be sharp or ragged.

The pallet design indicated in Figure 1-1 would weigh approximately 95 pounds if made of aluminum, and of course, much more if made of conventional or stainless steel. At least two men are required for lifting such weighty items, even with convenient handles or hand holds. The use of small four-wheeled dollys is widespread in industry (and household moving) for moving boxes, pallets, and skids. Dollys would be convenient for this application, particularly for factory assembly and checkout of the equipment modules. The use of wheel casters or ball casters as permanent components of the pallets is a "nice-to-have" feature at appreciable added cost. The mobility provided by casters will be a problem when attempting to anchor the installed pallet in its location on-site.

2.18.2 Pallet Design Recommendations

It is suggested that dollys be used for manual handling of pallets in module assembly and checkout, and a manual walkie pallet truck to be used for site installation of the pallet and module assemblies. Handling convenience openings and/or handles may be added to the pallets later. Wheel or ball casters are not recommended.

2.19 PALLET LOADING

2.19.1 Discussion of Considerations

It is recognized that the center of gravity of the pallet/module will be off-center because the two racks/cabinets are planned to be mounted close to one side of the pallet. However, the enclosed slots in the pallet ensure stability in forklift truck movements, and military and commercial transport operations are fully experienced in handling items with awkward size, balance, and form characteristics. The optional use of a transport (463-L) pallet under several DCS pallets (see Chapter 2) could help to overcome such difficulties. Further, DCS pallet shipping notes can call out provision for transport tie points located so as to permit encompassing and proper constraint of the module center of gravity, e.g., per the requirements of the Air Transportability Handbook, AFSC DH 1-11.

2.19.2 Pallet Design Recommendations

Mounting points for off-center cabinets and racks should provide for adequate numbers and sizes of bolts, washers, and nuts for distributed equipment weights up to 950 pounds per cabinet, assuming cabinet heights up to 60 inches. Electric cable pass-through holes should also allow shipping restraints to be attached to the pallet to constrain the module center of gravity if a separate shipping pallet is not used.

2.20 PALLET EXTENSION

2.20.1 Discussion of Considerations

There is a requirement for operator access to the front and rear of pallet-mounted cabinets. Since the pallets are small, it will be necessary to provide suitable floor areas for walking around the cabinets. The use of blank pallets as extensions of flooring areas or aisles was noted earlier to be uneconomical compared to other available access floor systems. Such flooring systems also provide for trim panels at exposed sides of the raised area, satisfying safety and appearance criteria. Since no requirement for under-floor cooling air has been established, pallet and flooring design need make no provisions for air seals.

2.20.2 Pallet Design Recommendations

No unique design provisions are required, as the use of pallets for extended flooring areas or cooling air containment is not anticipated.

2.21 RAMPS AND STEPS

2.21.1 Discussion of Considerations

As noted earlier, the 6-inch height of the pallet falls within the limits (8 inches) for a single step riser as defined in MIL-STD-1472B, Human Engineering Design Criteria. The use of ramps solely to avoid a single step is extravagant of floor space and introduces accident hazards. However, use of wheeled carts (e.g., for test equipment) at a site may require ramps. As a site-unique requirement, ramps can be constructed of wood and bolted to the pallets in the same manner as pallet-to-pallet attachments are made. At those sites, the surfaces of the ramps must be treated with a nonskid material per MIL-W-5044, applied in accordance with MIL-W-5050. This requirement per MIL-STD-1472B goes beyond the simple use of asphalt tile or linoleum, which are recommended for working area floors; such floors do not require nonskid treatment. If access floor systems are used, the ramps designed for and included with those systems are recommended.

2.21.2 Pallet Design Recommendations

No special design requirements for attachment of ramps to pallets have been identified; the attachment bolt holes for connecting adjacent pallets should also be suitable for the attachment of ramps. Normally, it is recommended that ramps be provided as part of a separate access floor system at DCS sites.

2.22 FAMILY OF PALLETS

2.22.1 Discussion of Considerations

One single, standard-sized, universal pallet is desired; or if necessary, a small family of pallets with width and/or length variations would be acceptable. Task I has demonstrated the feasibility of a single pallet design that accommodates a wide range of current and planned 1980s DCS equipment. The candidate pallet also provides a high degree of flexibility for site configuration. For example, it is large enough to accommodate both a radio R/T unit (AN/FRC-162) and the associated second-level multiplexer unit (AN/FCC-97), yet small enough for convenient handling and grouping as desired. A pallet can be readily removed from any position in a lineup of C-E equipment cabinets and replaced; or entire bays of palletized modules can be regrouped to support new traffic requirements.

Associated C-E equipments that require two pallets (four cabinets) may be accommodated by mounting the two pallets onto a single 463-L air cargo transport pallet for handling and shipment to DCS sites for final installation. An alternative approach of using a "double" pallet (twice as large) holding four C-E cabinets introduces handling and installation difficulties. For example, where aisles are narrow, the double pallet – being 88 inches long (instead of 44 inches) – would pose lift-and-turn and insert-into-place problems. Another problem with such double pallet units is the decreased flexibility in repositioning or even redeploying simple modules of C-E equipment that are mounted and integrated into double pallet units. A possible additional problem with larger pallet and equipment module aggregates is the potential functional compromise of the entire pallet of equipment by the failure of one component. Thus the simple and basic system building blocks of small modules of associated equipment should prove to be advantageous in most respects for the initial stage of implementation of this concept.

2.22.2 Pallet Design Recommendations

The pallet design should focus on an optimum small basic pallet to accommodate two cabinets of C-E equipment.

2.23 PALLET LEVEL INDICATOR

2.23.1 Discussion of Considerations

The driving factors in determining any requirements for leveling of equipment relate to operator safety and equipment performance. No requirements pertinent to C-E equipment leveling for operator safety have been identified in OSHA, MIL-STD-1472, or the NEC handbook. Likewise, no leveling requirements arising from unclassified C-E equipment operation and performance have been noted. Rotating elements such as disks, drums, or cylinders that are level-sensitive are typically high-value precision devices and will, per standard practice, have level indicators built into their assemblies or be marked prominently with such cautions. Other devices, such as floppy disc and rigid disc memory storage units, are not critically level-sensitive in operation; manufacturers advise that ordinary office desks and counters or table tops are suitable without special leveling. In the absence of information on COMSEC equipments, it is assumed that any pallet leveling requirements can be accomplished on-site by shimming and the use of a carpenter's level or similar indicator.

2.23.2 Pallet Design Recommendations

Inclusion of a level indicator on each pallet is neither necessary nor cost-effective.

2.24 PALLET LEVELING

2.24.1 Discussion of Considerations

The rigid structure of the pallet enables the positioning of shims or pads under the bottom surfaces of the pallet to level the module. Subsequent anchoring of the pallet to the floor prevents movement and/or displacement of the shims and subsequent loss of level position. Access to the underside of the pallet, once installed in place, must be from the top, e.g., by means of removable floor panels or from an exposed side or sides of the pallet. The open channel construction of the pallet is consistent with such access requirements for placing shims or pads as necessary. The use of any liquid-bubble level will provide sufficient accuracy to determine and correct for unevenness in site floors.

2.24.2 Pallet Design Recommendations

Top and side access for shimming the installed pallets to meet leveling requirements should be provided. The pallet structural material and the shim stock must be stable and not subject to cold flow or plastic deformation with time under load.

2.25 ELECTRICAL AND MECHANICAL SAFETY OF ASSOCIATED PERSONNEL

2.25.1 Discussion of Considerations

Pallet mechanical design must be consistent with the referenced military, commercial (NEC), and OSHA documents and standards. Equipment module electrical design and assembly and installation with the pallets likewise must meet the equipment specifications and be consistent with the engineering and installation guidelines cited in TM 11-486-4, Electrical Communications Systems Engineering; CCTM 105-50-6, Technical Control Facilities; CCTM 105-50-21, Installation, General; and FM 11-487-3, Telephone Inside Plant Installation Fundamentals.

An essential consideration in human factors engineering (as discussed in Section 2.13) is the safety of personnel involved in transport, installation, operation, and maintenance of the C-E equipment on the pallet. Recognizing that good design takes into account the handling and transportability requirements and constraints, and their implications on the personnel involved, it is necessary to conduct hazard analyses of potential dangers to operations and maintenance personnel. This analysis should be performed as a part of the detailed pallet design process. A preliminary hazards analysis will develop safety criteria to be imposed on performance and maintenance specifications to promote maximum safety of both personnel and equipment. The hazards analysis considers the installed location(s) of the equipment, obstructions to full access, structural failures, inadvertent release of electrical energy, shorting of electrical/electronic equipment, RF radiation, and any other indicated potential hazards. The level of hazards identified are categorized (see MIL-STD-882 for added details and corrective requirements) as:

a. Category I – Negligible

b. Category II – Marginal

c. Category III – Critical

d. Category IV – Catastrophic

At an appropriate later date, a follow-on Fault Hazards Analysis should be conducted to verify that the proper actions have been taken in the pallet detailed design process to eliminate or minimize the hazards identified in the preliminary analysis.

2.25.2 Pallet Design Recommendations

A preliminary hazards analysis should be conducted for each variant of pallet and C-E equipment module to ensure that early consideration is given to potential design requirements. Subsequently, during the planning of the installation of the modules, a follow-on Fault Hazards Analysis should be performed to verify proper control of the potential risks to personnel and equipment. Design and fabrication of the pallet should prevent sharp or burred edges at any location posing a hazard to assembly, handling, installation, operator, and maintenance personnel.