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PASSENGER AIRPLANE CONVERSION TO FREIGHTER

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Abstract

Airfreight is an important sector of air transportation and a vital component of the global economy. About 10% of shipped goods worldwide are transported by air. Airfreight moves high-tech goods, mail, livestock and food around the world. Economic activity as measured by gross domestic product (GDP) is a primary driver of the airfreight industry.

Boeing forecasts is that world air cargo will grow at 5.3% per year (Fig 1).

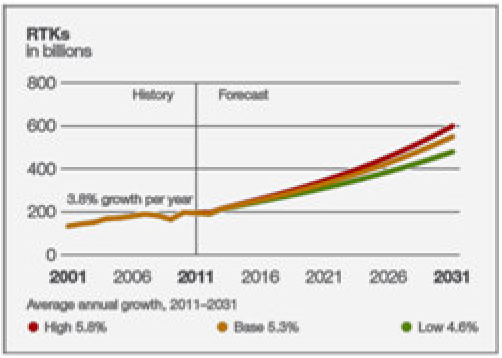

Figure 1: World air cargo forecast 2012

Growing world trade, transport of perishable and time-sensitive commodities, and the need to replace aging airplanes, creates a continuous demand for freighters. Boeing's and Airbus' market outlook suggests that the full freighters fleet will grow to about 3,200 by 2031.

This will only be partly met by production freighters. About 1,820 will be converted passenger airplanes, an economical alternative to new freighters. Short (standard) range narrow-body freighters with less than 45 tons payload, existing fleet share of 35% will retain unchanged. Long range large freighters (over 80 tons payload) share, will grow from around 30 percent today, to nearly 35 percent by 2031 while medium freighters (40 to 80 tons payload) share will reduce by 5% by 2031 (Fig 2).

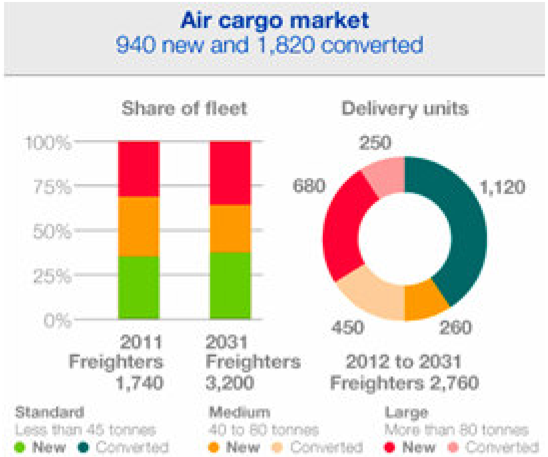

Figure 2: Current market outlook 2012-2031

Israel Aerospace Industries (IAI) Bedek Aviation Group holds Supplemental Type Certificates (STCs) for conversion of passenger aircraft to BEDEK Special Freighters (BDSF): B737-300 & -400, B747-100, -200 & -400, B767-200 with a 9g safety net and B767-300 with a 9g rigid barrier.

This paper discusses the conversion through structural, new/or modified electrical & mechanical systems and interior modifications required to cope with the requirements of freighter airplanes.

Introduction

Development of passenger-to-freighter conversion is based on a four-step program:

- Pre-conversion ground and flight tests for data collection including: wing deflections and fuselage pressurization to verify strains at critical locations, and environmental control system (ECS) performance.

- Design of modified structure and interiors, based on finite element models (FEMs).
- Development, qualification and certification of new and modified systems following the guidelines of aviation industry standards, including SAE ARP 4754 (systems), RTCA DO-160E (environmental), DO-254 (hardware), DO-178B (software) and SAE ARP 4761 (safety).
- Ground and flight tests to demonstrate airworthiness by verifying modifications compliance with the design requirements and applicable FAR/CS Part 25 regulations.

Modifications consist of (Fig 3):

- Removal of all passengers' amenities: seats, communications, entertainment systems, lavatories and galleys.
- Deactivation of all doors except L1 & R1, retained for entrance and service.
- Strengthening the main deck floor structure.
- Installation of a main deck cargo door (MDCD) hydraulically or electro-mechanically operated.
- Modification of the main deck to Class E cargo compartment with an in-flight personnel access.
- The forward & aft lower cargo compartments retain their existing Class C to enable loading of packages of dangerous goods.
- Addition of a supernumerary and crew rest compartments, adjacent to the flight deck. The added compartments include escape devices and the required installations to provide access to the main deck cargo compartment for the flight crew and supernumeraries.
- Added 9g safety net + smoke barrier, or a 9g rigid barrier to meet emergency landing requirements and to provide sealing and pressure differential, and occupant's protection in case of main deck fire.
- Installation of a floor drains system, to prevent water accumulation within the airplane structure and to prevent corrosion.
- Installation of a cargo loading system (CLS), guiding assemblies, restraints and additional seat tracks to provide additional support for the CLS.
- Modification of the air conditioning system and air distribution ducts rerouting, to accommodate freighter configuration.
- Modification of the temperature control of the main deck cargo compartment to maintain temperature at 2-4°C for perishable food transport.
- Installation of a new main deck fire/smoke detection system, meeting the 1-minute rule detection time required by the latest regulations.
- Addition of Class E shutoff valves downstream of the air cycle machines to cut air supply to the main deck cargo compartment in case of fire/smoke in the main deck.
- Replacement of flow control and shutoff valves (FCVs) by new valves with a low flow mode to allow reduced fresh airflow to the occupied areas in case of fire/smoke in the main deck.
- Installation of a new interior including lining, dado panels, honeycomb side panels, ceilings, decompression & maintenance panels, window plugs, decals and marking for the CLS.
- Installation of a new main deck lighting, and visual & audible alert system.
- Relocation of the flight data recorder (FDR) to allow access when aircraft is fully loaded with containers.
- Relocation of the primary and secondary flight controls/landing gear cables, pitot-static and hydraulic tubing to accommodate the loading of high pallets.

Figure 3: B767-200/300BDSF modifications

Regulations

Aircraft manufacturing, operation and maintenance is subject to aviation regulations, standards, procedures and/or criteria which are legally binding the civil aviation community. The widely Federal Aviation Regulations (FARs) issued by the US Federal Aviation Administration (FAA) and certification specifications (CSs) issued by the European Aviation Safety Agency (EASA) are referenced in this paper. Conversion changes a certified airplane. This change does not require a new Type Certificate (TC), but needs to be covered by a Supplemental Type Certificate (STC). The original Type Certificate (TC) plus the approved changes in type design equal a STC. The most important regulation for passenger-to-freighter conversion is FAR/CS Part 25 Airworthiness Standards, Transport Category Airplanes.

Freighter conversions are defined as a significant change at product level. The product individual changes are classified according to the FAA guidelines of the changed product rule (CPR). All changes and affected areas comply with the latest amendments (except for earlier amendments, but not earlier than the type certificate (TC) amendment level), in the following cases:

- Non-significant changes.
- The latest amendment does not contribute to safety or is impractical.
- Secondary changes of a major change.

Payload - Range Chart

To compare operational characteristics of different aircraft models, payload-range charts are used (Fig 4). Point P1 represents ferry range; zero payload and full fuel tanks.

Adding payload toward P2, reduces range (with maximum fuel capacity). P2 represents maximum takeoff weight (MTOW). To further increase payload towards P3, the amount of fuel has to be reduced, so range decreases. At P3 the sum of operating empty weight (OEW) and payload, is the maximum zero fuel weight (MZFW); no further increase of payload is possible. Reducing OEW and leaving both MZFW and MTOW unchanged, the payload-range chart of the original aircraft moves parallel to the range-axis by the amount of the OEW reduction (P3 to P3').

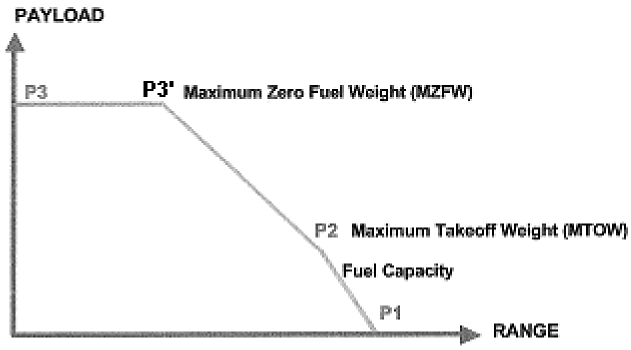

Figure 4: Payload - Range chart

Flight Deck

Freighter conversions retain the original flight deck configuration or enlarge the deck for seating of non-crewmembers (supernumeraries).

For example: B767-300 conversion. Flight deck aft wall is removed and the deck is extended to the (new) rigid cargo barrier. The left hand observer seat is removed. Three supernumerary seats are installed near the rigid barrier.

A new flush type lavatory is installed on the right hand side of the flight deck (Fig 5).

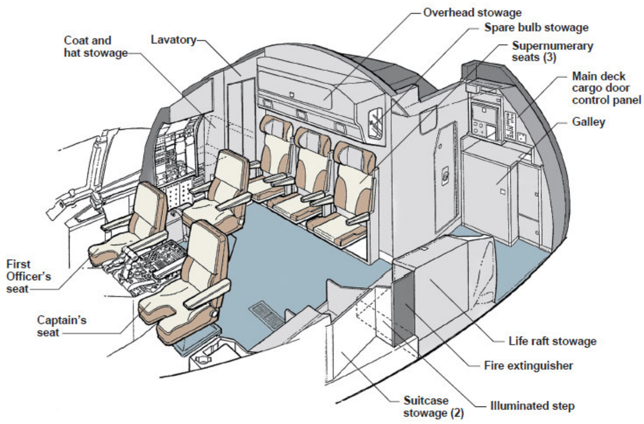

Figure 5: B767-300BDSF enlarged flight deck

Main Deck Cargo Configuration

Several main deck cargo configurations are available to optimize the volume of freight loaded into the main deck cargo compartment via a newly installed main deck side cargo door. Modularity is the key word for cargo loading, since a range of containers and/or pallets may be used (Fig 6, Table 1).

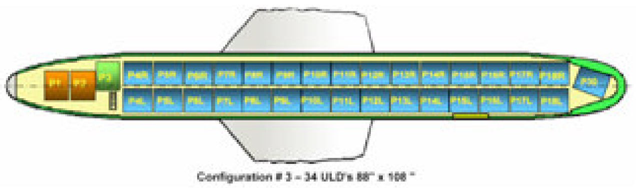

Figure 6: B747-400BDSF 34 ULD's 88" x 108"

	B737-400 BDSF	B747-400 BDSF	B767-300ER BDSF
Maximum Taxi Weight (MTW) Lbs	150,500	873,000/ 878,000	413,000
Maximum Takeoff Weight (MTOW) Lbs	150,000	870,000/ 875,000	412,000
Maximum Zero Fuel Weight (MZFW) Lbs	117,000	610,000/ 635,000	309,000
Maximum Landing Weight (MLW) Lbs	124,000	652,000	326,000
Operating Empty Weight (OEW) Lbs	69,000	357,000	183,500
Fuel Capacity USG/Range naut mi	5,311/ 1,725	53,765/ 4,100	23,980/ 3,400
Max Cargo Payload Lbs	48,000	253,000	125,500
Main Deck Pallet Positions Example: 88" x 108" x 82"	10	34	26

Table 1: Certified weight limits

Structure Modifications

Structure is modified to support the increase in design weights and high cargo loads in the main deck, while retaining aircraft external geometry, flight characteristics and performance. The changes include replacement/reinforcement of floor beams, posts, seat tracks, intercostals and floor panels. Addition of new tension ties and frames reinforcements is also part of structure modifications. Some of the new floor beams are machined from aluminum plate to enhance structural integrity. Fuselage frames are also reinforced.

To meet operational targets of cargo capacity and payload revenue, customers can choose between a 9g safety net and 9g rigid barrier designed to prevent movement of containers and meet emergency landing requirements. The 9g rigid barrier allows the operator to load an additional pallet/container due to its shape. A large cutout is performed on the left hand side of the aircraft and replaced by reinforced surrounding structure and the main deck cargo door via segmented hinges (Fig 7).

Figure 7: B747-400BDSF cargo door cut-out

Structure modifications substantiation methodology is common to all conversions and includes:

- Load: analysis ensures no change in the basic flight envelope, no increase in landing gear loads. Weight and center of gravity limitations are introduced to ensure that original design loads are not exceeded.
- Flutter: substantiation by a comparative dynamic analysis of a complete aircraft models, before and after conversion, to show no or negligible differences in the relevant frequencies and modes.
- Damage Tolerance: AC 91-56, AC 25-571 and the structure repair manual (SRM) are used to comply with FAR/CS 25.571. A fatigue spectrum is developed for the freighter versus passenger configuration.
- Finite Element Analysis: significant structural details of the converted airplane are analyzed with a highly accurate loads distribution. The analysis includes various parameters such as internal loads, mechanical constraints, 9g forward crash condition, gear loads, flight envelope, main deck floor loads and decompression loads. Internal pressure tests with strain gages instrumentation provide finite element model validation (Fig 8).

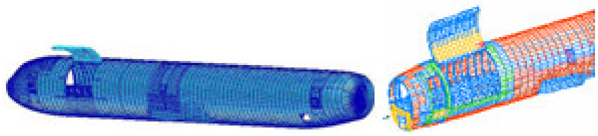

Figure 8: B767-300BDSF / B737-400BDSF finite element model (FEM) with MDCD open

To determine center of gravity location with reference to the landing gear, the aircraft is first weighed in a level attitude on the wheels and then at different attitudes. This pre-conversion process allows to derivate the center of gravity location (Fig 9).

Figure 9: B737-400 center of gravity and ground vibration test (GVT) evaluation

Main Deck Cargo Door (MDCD)

Main deck cargo door (MDCD) is typically an outwards and upwards opening side door. An upward opening door ensure an easy access to the main deck, reduces the risk of damaging the door or its hinges and to some extent protects the interior from precipitation during ground operations. An isolated electrical or hydraulic circuit controls door opening and closing.

Manual operation of the door is normally provided as a backup in case of a system failure. Several catastrophic accidents have demonstrated the need for visual inspections of door locking mechanism and provisions to prevent depressurization when the door is not fully closed and locked. To ensure pressure equalization across the door prior to opening, a pressure relief door is fitted. Current door designs allow operation in winds up to 40 knots.

The MDCD has been certified by the FAA to FAR 25.783 amendment 25-88 and by EASA to JAR 25.783 including NPA 25-301 (similar to FAR 25.783 Amdt 25-114). Therefore the MDCD design meets latest requirements FAR 25.783 Amdt 25-114 from May 3, 2004. The MDCD is installed on the left hand side of the fuselage forward of the wing (B737, B767) or aft the wing (B747) and is hinged at the top.

The door is operated through three mechanisms: lock, latch and lift. Each mechanism is mechanically independent, but electrically or hydraulically sequenced with the other mechanisms in the opening and closing cycles (Fig 10).

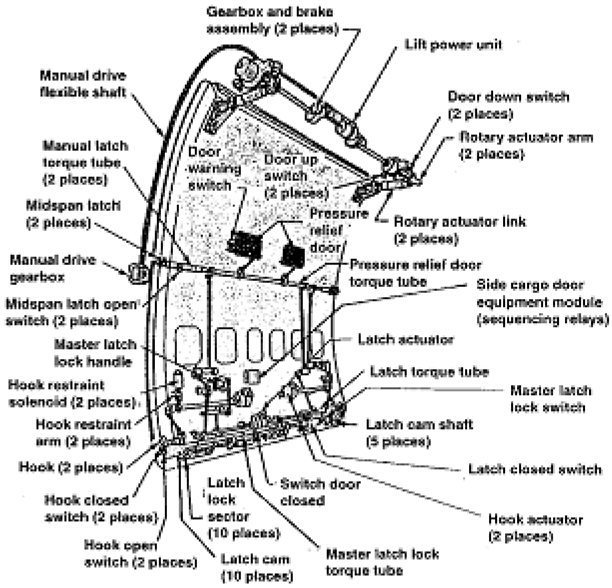

Figure 10: B747-400BDSF MDCD

The B737 MDCD is hydraulically operated. B747 and B767 MDCD mechanism is electrically operated via two control switches on the door control panel: the first switch operates the lock and latch mechanisms while the second switch operates the lift mechanism. Electrical sequencing of the lock, latch and lift actuators are accomplished by limit switches and relays. The MDCD and other operational doors have a master caution & warning and EICAS caution message if left open or unlocked. An aural warning inhibits when decision speed (V_1) is reached. In addition to the indication lights available on the MDCD control panel and flight deck, reporting a potential unsafe condition of the door, a white flag can be seen at each of the view ports, if the locking units have reached their required position (Fig 11).

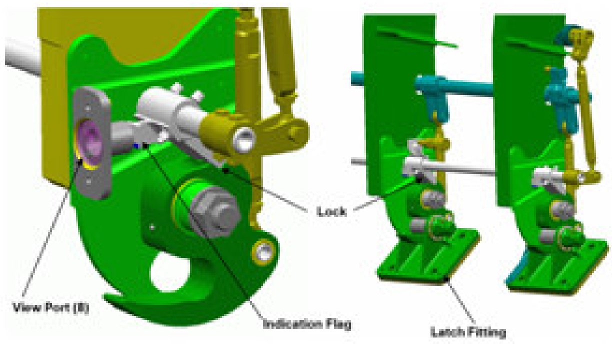

Figure 11: MDCD lock & latch mechanism, view port & indication flag

Environmental Control System

The environmental control system (ECS) is modified to accommodate special freighter configuration by removing items unique to the passenger configuration (main deck sidewall outlets) and adding items unique to the freighter configuration (fire protection related valves) (Fig 12).

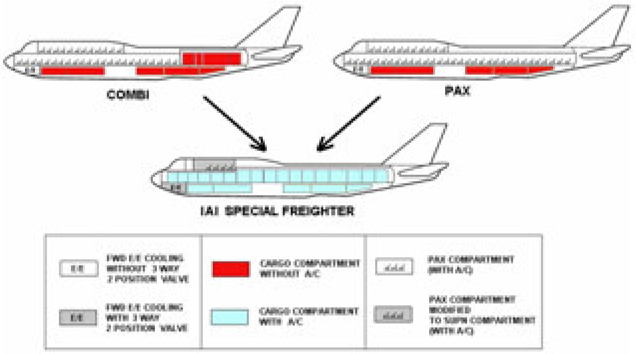

Figure 12: B747-400BDSF ECS

The design approach is to maintain same (or better) airflow rate, temperature control, duct pressure and noise levels and to meet FAR 25.831 requirements of airflow and temperature control.

The modified system maintains flight deck and main deck temperature between 19˚C (66˚F) and 29˚C (84˚F), in case of normal temperature selection. Main deck temperature of 2˚C (38˚F) to 19˚C (66˚F) can be selected in case of perishable goods.

The ECS modifications consist of the following:

- Sidewall ducts and associated outlets are removed.
- Entire main deck air distribution system is replaced by a new overhead air distribution ducting.
- Addition of main smoke mode:
  - main deck ventilation shut down by a Class E shutoff valves.
  - air conditioning pack activation to provide sufficient (reduced airflow) fresh air to the occupied areas.
- Addition of a new air conditioning system that includes air heater for the supernumerary compartment.
- Simplified forward electronic equipment (E/E) cooling system to match freighter's requirements.

The ECS is simplified to provide fresh air only. Cabin air re-circulation system and associated control logic and switches are removed. For each conversion, the air distribution system is balanced and tested to satisfy the defined criteria.

Fine tuning of the system is performed by introducing screen restrictors thus balancing the airflow delivered to the occupied areas, to the main deck and to the lower cargo compartment and electronic bay.

Ventilation

Freighters evolve a problem that is not an issue on a passenger plane: main deck cargo compartment fire and smoke. FAR Part 25 requires that smoke evacuation from the cockpit area must be "readily accomplished, starting with full pressurization and without depressurizing beyond safe limits". Fire suppression on Class E cargo compartment requires complete stoppage of airflow to the cargo area in order to minimize oxygen concentration, while still supplying fresh air to the occupied areas, in order to replace smoke in the cabin and sustain a pressure differential across the smoke barrier. As a consequence, modification of the air-conditioning system is necessary. During normal operation, aircraft cabin air conditioning is fed by engine bleed through the air cycle machine. Air is supplied from the mix manifold separately to the main and flight cabins. Three possible modification alternatives to accommodate fire/smoke regulations:

- Adding isolation valves to each main deck duct. These valves shut down airflow in a fire situation to prevent air from entering the main deck.
- Replacing flow control & shutoff valves (FCV) located upstream of the air-conditioning packs, with "smoke mode" FCVs, allowing just a small amount of fresh airflow to the occupied areas.
- Optional: opening ram air ventilation directly into the flight cabin area, while shutting down air supply to the airplane (all flow valves closed). The airplane is then depressurized and the ram air inlet supplies fresh air only to the occupied areas. Air and smoke are drawn overboard through the overboard extraction

valve. By manipulating cabin outflow valves, a positive pressure differential across the smoke barrier can be established, helping to keep the occupied areas smoke free.

Main Deck Fire Protection

Freighter fire protection consists of fire detection and fire extinguishing/suppression systems:

- Detection
  - Engine fire and overheat.
  - APU fire.
  - Forward electronic equipment cooling system smoke.
  - Wheel well overheat.
  - Wing leading edge overheat.
  - Tail cone overheat.
  - Main & lower cargo compartment smoke.
  - Lavatory smoke detector (option).
- Extinguishing/suppression
  - Engine fire.
  - APU fire.
  - Main & lower cargo compartment fire.

Common to all conversions; all of the above systems remain unchanged except for the addition of a new main deck fire protection system consisting of a smoke detection system and fire extinguishing/suppression.

The main deck smoke detection system is a dual loop AND logic that meets the 1-minute rule. The system 2-LRUs (Line Replaceable Unit) architecture consists of a cockpit control panel and FAA TSO-C1c approved smoke detectors ("duct" or "ambient") set to provide an alarm at light transmissibility of 97% (3% obscuration rate). The entire electronics is built in the cockpit control panel.

Photoelectric detectors are used to measure light attenuation, reflection, refraction and absorption of certain wavelengths (Fig 13).

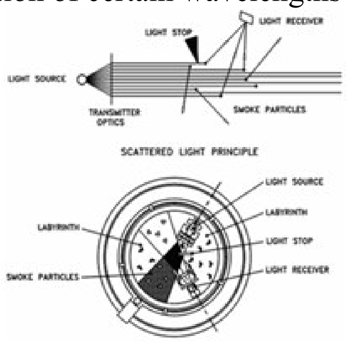

Figure 13: Photoelectric smoke detector architecture

B737-400BDSF incorporates multi-criteria (MCR) smoke detectors include dual optical chamber, two temperature sensors and a humidity sensor (Fig 14).

Figure 14: Siemens PMC11 multi-criteria (MCR) smoke detector

The dual optical chambers allow identification of fire type (open or smoldering) and adjust the sensitivity accordingly. Temperature criteria and humidity criteria combined with optical signals, adjust detector's sensitivity to detect smoke and to prevent deceptive signals due to high humidity variation. The performance of a smoke detector is optimized by adjusting detection logic according to environmental conditions, and smoke properties. Environmental conditions analysis allows smart detection process and thus, significant reduction of false alarms, compared to conventional detectors (Fig 15).

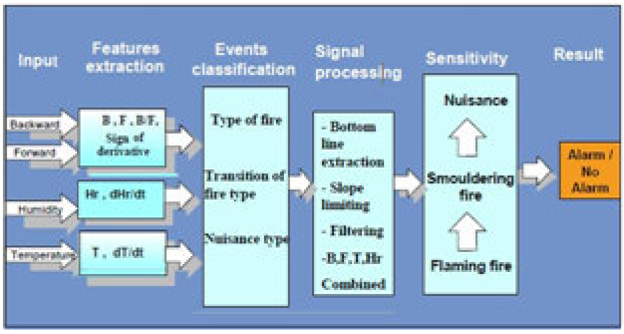

Figure 15: MCR signal processing algorithm

IAI Bedek, in collaboration with Siemens (France) Airborne Systems, developed state-of-the-art cargo smoke detection systems, for main & lower cargo compartments. The systems provide:

- Early detection (warning) of fire/smoke at a temperature significantly below structural integrity degradation.
- Functionality test procedure.
- Effectiveness through the entire operation configurations and conditions.

- Comply with 25.1301 function and installation, and 25.1309 safety requirement.

Considering the probability for a fire event to be less than 1.7 E-07 per operating hour (OH), system reliability complies with safety requirements of FAR/CS 25.1309 (Table 2).

Fault Conditions	Classification Severity	Requirements (per OH)
Total loss of smoke detection in combination with a fire	Catastrophic	< 1.00 E-09
Un-indicated loss of smoke detection capability without fire	Major	< 1.00 E-05
Spurious warning of smoke in a cargo compartment	Major	< 1.00 E-05
Total loss of smoke detection in a cargo compartment zone without fire	Minor	< 1.00 E-03

Table 2: Smoke detection system functional hazard analysis (FHA)

B737-400BDSF main smoke detection system consists of twenty, FAA TSO C1d approved multi-criteria PMC11 smoke detectors, mounted within cavities on the ceiling panels and a cockpit control panel, located on the P5 aft overhead panel. The system is integrated into the existing aircraft fire detection to provide the standard fire alerts and fault indications via the fire warning and master caution lights and annunciator system. It contains a Built-In Test Equipment (BITE) capability for self-checking (Figs 16 & 17).

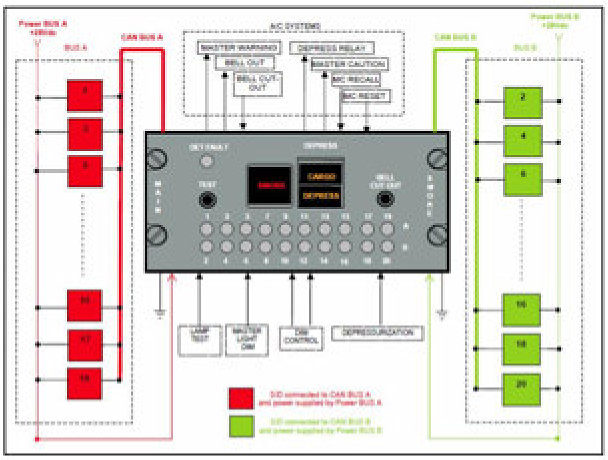

Figure 16: B737-400BDSF main deck smoke detection system layout

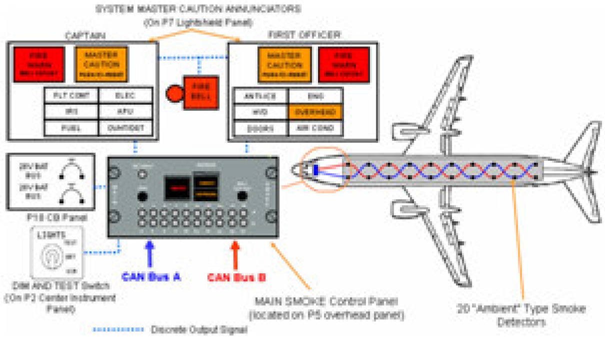

Figure 17: B737-400BDSF main deck smoke detection system integration

Smoke detection tests were conducted according to the guidelines of FAA AC 25-9A, to demonstrate detection time anywhere within the cargo areas and through the entire aircraft flight envelope. Each test was conducted by generating a small amount of smoke at several locations. Kidde Aerospace smoke generator were used to produce smoldering smoke according to AC 25-9A.

Following the smoke detection tests, a smoke penetration test was conducted, to demonstrate sealing-proofing of occupied areas. The test also supports demonstration of no inadvertent operation of smoke detection for adjacent compartments; smoke is detected only in the compartment where it originates (Fig 18).

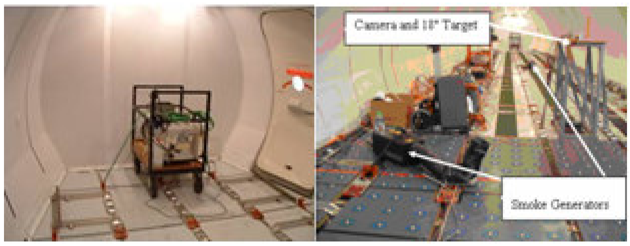

Figure 18: Smoke detection and penetration tests

Although FAR/CS 25.857 uses the term "fire extinguishing system", the FAA requires a "fire suppression system" that does not necessarily extinguish fire, but rather suppresses it to ensure safe landing. Currently, the most effective and most commonly used suppression agent is Halon. Although production and usage of Halon is restricted by international agreements due to its effect on the ozone layer, continued use for aircraft fire suppression is supported by the FAA and the US Environmental Protection Agency.

There are different approaches to Halon concentration levels. According to FAA Airworthiness Directive, a minimum initial concentration of 5 percent is required throughout the compartment to suppress combustion to controllable levels, thereafter, the system must sustain a minimum of 3 percent for 60 minutes to prevent re-ignition or spreading of combustion, and for airplanes certified for extended-range twin-engine operations (ETOPS), the fire-suppression system must be able to sustain a 3 percent concentration of Halon within the compartment for a maximum of 180 minutes. However, according to FAA Amendment 25-93, the often-quoted Halon concentration of 3 percent is not a requirement, but is typically used.

A fire-suppression installation typically consists of agent (Halon) bottles, tubing, suppression nozzles, electronic units and a flight deck control panel. Depending on airplane model and its configuration, fire-suppression and detection systems may add up to 300 pounds (136 Kg) to the empty weight of an airplane.

Electrical / Avionics Changes

Aircraft systems changes affect the electrical systems which are modified accordingly. The affected systems include (among others) ECS, smoke detection, communication, lighting, and indications. Electrical system components are removed, modified or changed to support all changes that include: circuit breakers, switches, wire bundles, indications, etc. The wiring design and installation is performed in accordance with Process Specifications which are equivalent to Boeing standards to ensure satisfying quality.

Wires for modified systems are same standard as the existing or an alternative compatible type, in accordance with Boeing D6-54446 Standard Wiring Practices Manual.

The circuit protective devices are compatible with the actual electrical load and wire gage. Six inches clearance between new and modified wires and between wires connected to equipment installed inside of the fuel tanks are kept. The existing wire bundles, located along left side of the aircraft are relocated and rerouted to bypass the main cargo door cutout.

Flight Controls

Flight control cables are rerouted to accommodate 96 inch height containers while fully retaining their functionality. The rerouting is supported by a series of tests performed on each rerouted cable system to ensure same ratio between cockpit input displacement and cable-end displacement before and after conversion. The tests also allowed to ensure losses within the system remain acceptable compared to their pre-conversion levels.

Every cable is tested from the pilots' hand grip or foot-hold, e.g. stick, pedal, lever, handle, etc., to a location downstream of the proposed modification. The cockpit control is gradually loaded and the loads are monitored. The load is resisted as far as possible along the cable, depending on the type of test (proof or operational) and control system involved by either of two methods:

- Resistive load integrated into the cable.
- Reaction load introduced through the cable.

During the ground test performed after conversion, the loads (forces and moments) are continuously monitored not to exceed the allowable limits. Load levels are prescribed by FAR/CS 25.397 and 25.405. The loads refer to pilot’s grip position location on the column, pedal, lever, etc. Displacement gauges measure the control travel (linear or angular). 100% of pilot’s limit loads is applied to comply with the requirements of FAR/CS 25.681 and 25.683, and to produce cables slack conditions, to show compliance with FAR/CS 25.683 and 25.855. Compliance is fulfilled also when cockpit control stops are reached under less than 100% of limit load (Fig 19).

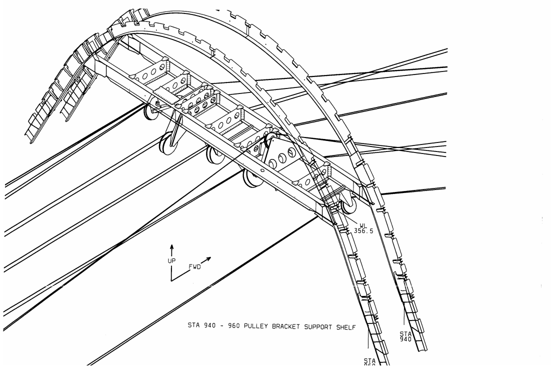

Figure 19: B747-400BDSF pulley brackets relocation

Water & Waste

The conversion includes simplification of the basic water & waste system by replacement of potable water tank with a smaller tank. Only a limited quantity of water is necessary for freighters. Simplification of the waste system is performed by removal of half of the basic vacuum waste system (Fig 20).

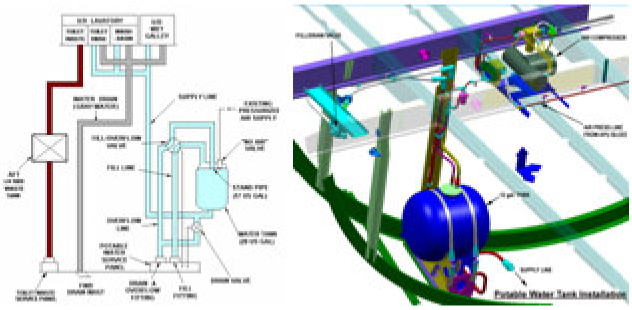

Figure 20: B767-200BDSF water system

A new flush type waste system with an associated service panel can be installed whereas a portable water tank is installed above the lavatory sink for hand washing purpose. This design approach ensures significant weight saving, simplified installation and therefore simplified servicing & maintenances (Fig 21).

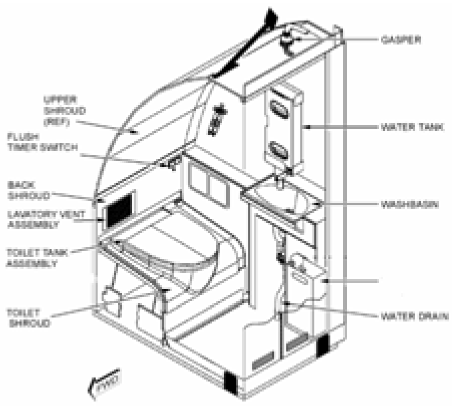

Figure 21: B767-300BDSF new flush type toilet

Oxygen Systems

The oxygen system is modified to provide oxygen to the crew and to the supernumeraries at each user inhalation location. The system is based on two oxygen cylinders located in the forward cargo compartment and gaseous diluter demand masks available at each flight deck occupant/supernumerary station. A portable oxygen system is also provided in the lavatory and for access to the main deck in case of sudden decompression or cargo fire (Fig 22).

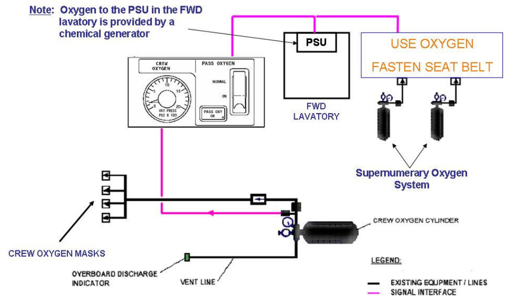

Figure 22: B737-400BDSF oxygen system

Unit Load Devices

Rapid loading and unloading can be achieved by utilizing loads. Unit load devices (ULDs) include aircraft pallets and containers, which interface directly with the cargo handling and restraint system. ULDs ensure that cargo is moved safely, quickly and cost effectively. An aircraft container is a completely enclosed ULD. A pallet is a platform with standard dimensions, on which goods are secured with a net (Fig 23).

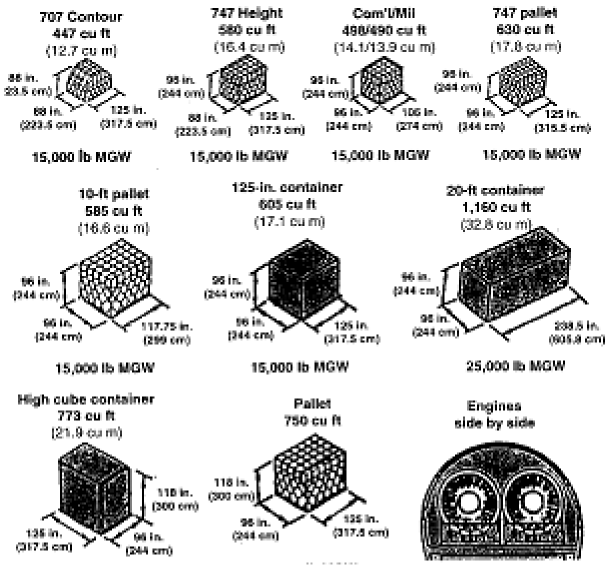

Figure 23: Main deck ULD examples

Main Deck Cargo Loading System (CLS)

A typical cargo loading system (CLS) consists of necessary equipment to provide movement, guiding and restraint of cargo. Power drive units

(PDUs) may be installed to move ULDs semi-automatically. These items can be attached either directly or via tray assemblies and floor fittings to seat tracks and floor structure. System selection depends, to a certain extent, on how good the ULDs layout with its required restraint installations fits floor structure and seat tracks (Figs 24 & 25).

Figure 24: Cargo loading system B747-400BDSF (LH), B737-400BDSF (RH)

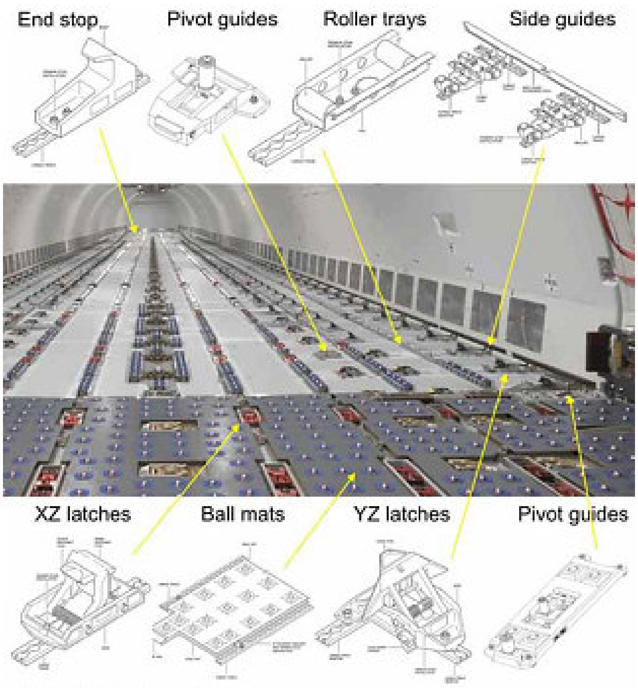

Figure 25: Cargo loading system (CLS)

Tray assemblies provide moveable restraint for various parts of the CLS like locks and rollers. Rollers allow free movement of ULDs along tracks in both directions. Brake rollers restrict the movement of ULDs to one direction. They prevent unintended movement of ULDs in cargo compartments with a sloping floor, particularly towards the doorway area (Fig 26).

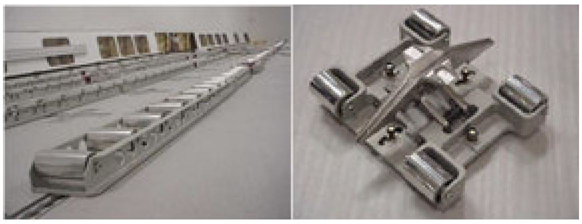

Figure 26: Trays & rollers

Pallet locks provide restraint for pallets and containers. Restraint requirements are found in NAS 3610. The mechanism of longitudinal/vertical restraint locks can be retracted below the roll plane to enable loading and unloading. Tray-mounted locks can be moved along the tracks and locked to them by shear pins. End stop assemblies provide longitudinal and vertical restraint for cargo pallets and containers at the beginning and end of a ULD row. They may be retractable to ease unloading. Outboard guide rails can be installed throughout the aircraft on both sides of the door to protect the fuselage from damage and may contain side locks. Side locks are used to provide vertical and transversal restraint. They are mounted either directly or via fittings onto existing structure. Centerline guide assemblies are installed along the aircraft centerline. They guide and restrain ULDs that are loaded side-by-side along the centerline (Fig 27).

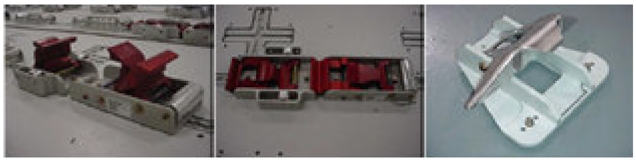

Figure 27: ULD restraints

Doorsill protection assemblies are installed at the opening of the cargo door. They are attached to seat tracks by tie down studs and are positioned by shear plungers. These units are hinged to enable upwards folding when not in use. Rollers and caster assemblies are mounted on the doorsill protectors to provide friction-reduced travel of containers. A hinged side guide is mounted on the outside edge of the doorsill protector. The side guide is raised during use to guide containers into the cargo door (Fig 28).

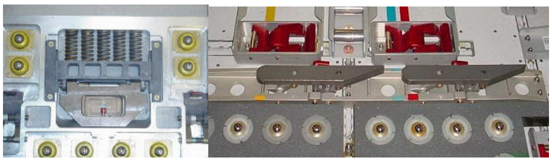

Figure 28: Doorsill protection

Ball mats are aluminum panel assemblies consisting of freely rotating balls protruding above the surrounding surfaces. They are used to enable omni directional movement of units passing over them, especially in the cargo door area and where shifting or rotating of ULDs is necessary (Fig 29).

Figure 29: Ball mat assembly

Compared to purely manual loading, PDUs make ground operations more efficient. PDUs add considerable weight to the OEW and require power during ground operations. There are floor mounted and track mounted PDUs. The latter are small enough to fit into trays and are lighter, but have to be provided at a greater numbers. Quality of rubber coating of the small rollers is essential for satisfactory operation. To allow ULD movement in all directions and rotation necessary in door areas, there are steerable floor-mounted PDUs. Alternatively, a set of PDUs in perpendicular layout can be installed. A centralized control unit is necessary to ensure efficient and safe operation and only PDUs needed to move ULDs at their actual position are powered. Spacing of PDUs is a tradeoff between the number and weight of all PDUs. Tray mounted PDUs are typically spaced at around 30 inches. Floor mounted PDUs may be spaced wider. If spacing is too wide, badly warped ULDs with bent base edges may stall as PDUs lose contact with the ULDs during transport. In wet conditions, a poor ULD contact with the PDUs may cause conveying difficulties (Fig 30).

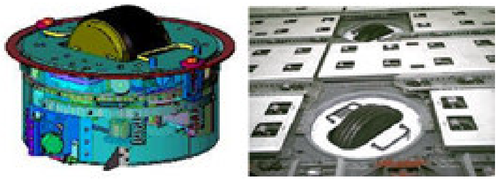

Figure 30: Power drive unit (PDU)

Main Deck Floor Drain

A floor drain system is provided for the main deck. The floor drain is connected to the existing forward and aft drain masts. The crew lavatory and galley drain (gray water) is retained. The main deck cargo compartment floor is sealed and water dams are installed along the side walls, aft bulkhead and forward at the anchor beam, to prevent water seepage (Fig 31).

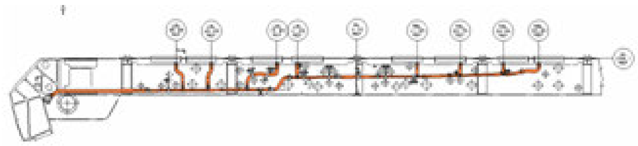

Figure 31: B737-400BDSF main deck floor drain

Interior & Cabin Safety

The interior modifications of the main deck consist of:

- A new cargo lining.
- Vent grilles in the dado panels for main deck ventilation flow.
- Dome lights flush mounted on the ceiling for compartment illumination.
- A new dry galley, including a storage cabinet (Fig 32).

All non-metallic materials meet the applicable requirements of FAR/CS 25.853 and 25.855 as demonstrated by flammability testing (FAR Part 25 Appendix F). Passenger emergency equipment including life rafts and aft door slides are removed. The existing emergency equipment in the flight deck retain unchanged. TSO approved 4-man life rafts are installed in flight deck. Two TSO approved cabin attendant life vests are retained in their stowage positions for use by supernumeraries. TSO approved portable ELT is installed on inboard galley wall. 2.5 lbs fire extinguisher is installed on the 9g rigid barrier, adjacent to the galley.

Additional equipment for in-flight entry into the main deck cargo compartment: portable oxygen bottle with full face mask is installed on the 9g rigid barrier. A decompression vent panel is installed in the floor under the empty cart stowage compartment of galley G1. The compartment is blocked by bars and is placarded accordingly.

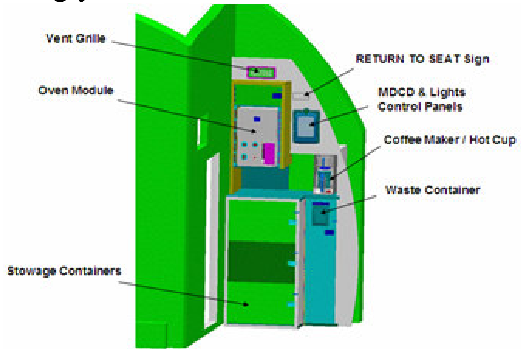

Figure 32: B767-300BDSF new galley

Emergency Equipment

The FARs requires a number of emergency equipment items. Several already exist, but some major items need to be added. 9g rigid barrier is designed to resist the 9g longitudinal loading of main deck cargo compartment per FAR/CS 25.561 (Fig 33).

Figure 33: 9g rigid barrier and 9g safety net

Allowable of material are required to prove the ability of the barrier to withstand the pressure due to load under 9g emergency landing condition.

Specimen's tests are performed for bending, shear and compression to evaluate the design values in compliance with FAR/CS 25.613(a)(b) requirements (Fig 34).

Figure 34: 9g rigid barrier shear & bending tests

Rotor Burst

Design precautions are taken to minimize hazards of uncontained engine and auxiliary power unit (APU) rotor failure. Modified items potentially affected by rotor burst are flight controls and electrical wires routed in the main deck floor and/or ceiling. All flight controls have a backup system, allowing a continued safe flight and landing. Electrical wiring is located in raceways under the main deck floor beams, away from the risk zone. The design should meet the requirements of FAR/CS 25.903(d) and AC 20-128A Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure.

Method of substantiation consists of a geometrical study demonstrating that relocated electrical bundles still maintain the physical separation distance from their redundant systems to avoid rotor burst damage (Fig 35).

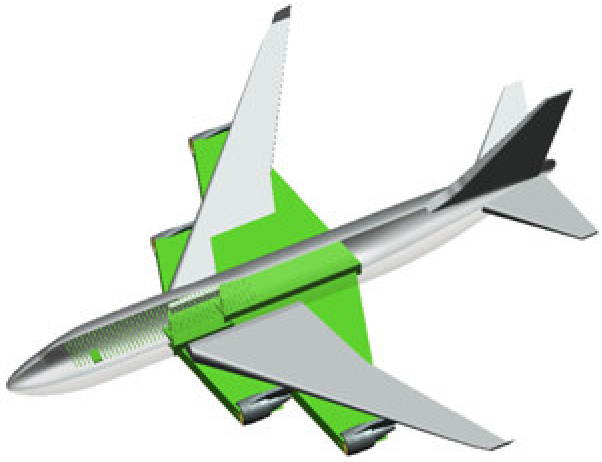

Figure 35: Rotor burst analysis