NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594
January 30, 2015

Group Chairman's Factual Report

STRUCTURES

DCA13MA081

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References

1. Telair Weight and Balance Control and Loading Manual, Report Number 25-55-66 Revision L, Main Deck Cargo Handling System, System Number: 193100-331/-332/-334/-335/-336/-337/-338/-339/-4051/-4053/-4055/-407/-4071, Aircraft: Boeing 747-400SF.
2. Boeing 747-400BCF, Weight and Balance Control and Loading Manual, Boeing Document Number D043U544-XXX1 Revision 2.
3. Boeing 747-400F, Weight and Balance Control and Loading Manual, Boeing Document Number D043U542-MASTER dated July 31, 2003 and September 22, 2005.
4. National Airlines Cargo Operations Manual Revision 8 Issued September 17, 2012.
5. National Airlines Weight and Balance Manual Revision 6 Issued October 2, 2011.
6. Transportability Approval for the Mine Resistant Ambush Protected (MRAP) – All-Terrain Vehicle (M-ATV) – File Number DP 33-09, November 17, 2009
7. Internal Air Transport Certification (ATTLA) – 2009.08.32 Revision 1, October 9, 2009
8. Internal Air Transport Certification (ATTLA) – 2007.07.18.01, August 6, 2009
9. Boeing Presentation 747-400 BCF MRAP Tie Down Assessment for NTSB, August 2014
10. Boeing 747-400 Frangible Cargo Sample Calculations, August 15,2014
11. Telair Study M-ATV Vehicle Restraint Analysis (with tie down straps), June 3, 2014
12. Telair Study Cougar Vehicle Restraint Analysis (with tie down straps), June 3, 2014
13. Telair Study M-ATV Secured to 9G Forward, November 20, 2014
14. Federal Aviation Administration Type Certificate Data Sheet A20WE
15. Federal Aviation Administration Supplemental Type Certificate ST00459LA

A. ACCIDENT INFORMATION

Accident #:	DCA13MA081
Location:	Bagram Air Base, Afghanistan
Date:	April 29, 2013
Time:	1527 Local Time
Airplane	Boeing 747-400 Series BCF, N949A

B. STRUCTURES GROUP

Chairman:	Brian K Murphy National Transportation Safety Board (NTSB) Office of Aviation Safety (AS-40) Washington, DC
Member:	Rick Mayfield The Boeing Company Air Safety Investigator Seattle, Washington
Member:	Alfredo Gumbs Jr. National Airlines (NAL) Chief Loadmaster/Cargo Operations Orlando, FL
Member:	Steven Fox Federal Aviation Administration (FAA) Senior Aerospace Engineer (ANM-120S) Renton, WA

C. SUMMARY

On April 29, 2013, about 1527 local time, a Boeing 747-400, N949CA, operated as National Airlines[1] flight 102, crashed shortly after take-off from the Bagram Air Base (OAIX), Bagram, Afghanistan. All 7 crewmembers on board were fatally injured and the airplane was destroyed from impact forces and post-crash fire. The 14 Code of Federal Regulations (CFR), Part 121 Supplemental cargo flight was destined for Dubai World Central - Al Maktoum International Airport (OMDW), Dubai, United Arab Emirates.

[1] National Air Cargo Holdings was the holding group for two subsidiaries, National Air Cargo Group, Inc. dba National Airlines (based in Orlando, Florida) and National Air Cargo, FZE (based in Dubai, UAE). National Airlines operated both passenger (B757) and cargo (B747-400) operations. For the cargo operations, National Air Cargo was responsible for load planning, cargo/pallet build up, and aircraft loading of National Airlines' B747-400, while National Airlines transported the cargo.

D. DETAILS OF THE INVESTIGATION

D.1. Aircraft Description

N-number:	N949CA
Airplane Serial Number:	25630
Airplane Manufacturer:	The Boeing Company
Model:	747-428
Airplane Year:	1993
Airworthiness Certificate:	Standard
Approved Operations:	121 supplemental
Aircraft Type:	Fixed Wing Multi-Engine
Engine Type:	Turbo fan
Airplane Category:	Transport
Number of Engines:	4
Type Certificate	A20WE
Supplemental Type Certificate	ST00459LA

The certification basis for N949CA was per 14 Code of Federal Regulations (CFR) Part 25 of the Federal Aviation Regulations (FAR), effective February 1, 1965, as amended by Amendments 25-1 through 25-59 except as noted in Section X - 747-400 of TCDS A20WE[2] (Approved January 10, 1989) Transport Aircraft. Furthermore, N949CA is a 747-400SF (Special Freighter), or optionally known as a 747-400BCF (Boeing Converted Freighter), which is a 747-400 Series passenger airplane that has been modified in accordance with FAA-approved Boeing Service Bulletin 747-00-2004 to operate in a freighter configuration. These aircraft remain as 747-400 Series aircraft for documentation purposes on TCDS A20WE and with regard to the applicability of airworthiness directives. Because of the magnitude of this design change, the certification basis for the changed aspects was required to be established and documented in accordance with section 21.101 (Changed Product Rule). All general information in TCDS A20WE for the 747-400 Series remains applicable to an airplane operating in the 747-400SF configuration, except as noted in Section XIII (747-400SF Major Design Change) of TCDS A20WE.

D.2. Wreckage Debris

The airplane impacted the ground about 590 feet northeast of the departure end of runway 03. The wreckage was spread over 394 feet along a heading of 75 degrees. The airplane forward of about body station (STA) 2060 (Figure 1) located in section 46 was highly fragmented and consumed by fire. Airplane debris was recovered about 4,500 feet downwind from the departure end of runway 03 in the vicinity of taxiway Charlie. Twelve pieces of structure were recovered in the runway, three were identified as being located aft of the aft pressure bulkhead (APB) and one was identified as being from the E8 rack containing the cockpit voice recorder

[2] Refer to reference 14.

(CVR) and flight data recorder (FDR) located forward of the APB and aft of the L5 door on the left hand side (pilot) of the airplane.

D.3. Fire Damage

All of the structure forward of about STA 2060 was consumed by fire (Figures 2 & 3). This includes the wings, fuselage sections 41, 42, 44, and section 46 forward of about STA 2060.

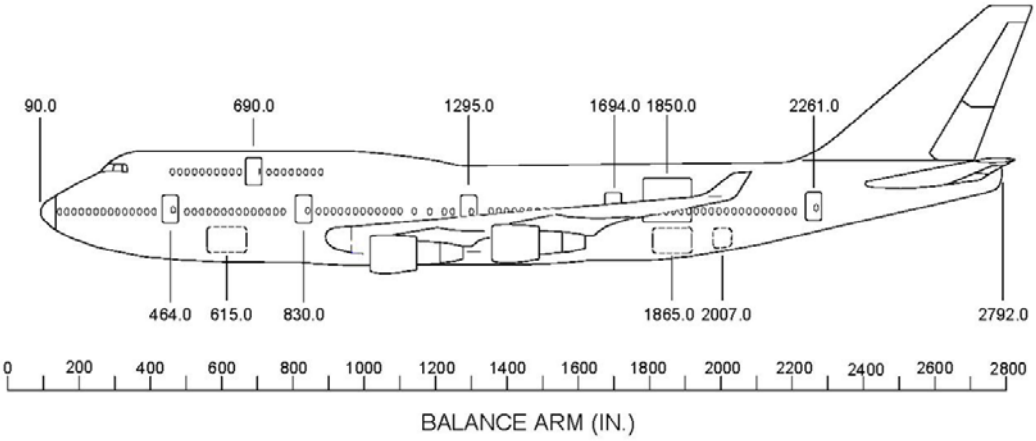

Figure 1 - Body station (STA) and balance arm (B.A.) [3]

Figure 2 – N949CA Crash Site Aerial View

[3] The balance arm (B.A.) is a true measure in inches from the reference datum 90 inches forward of the airplane nose. B.A.'s are equivalent to body stations (STA).

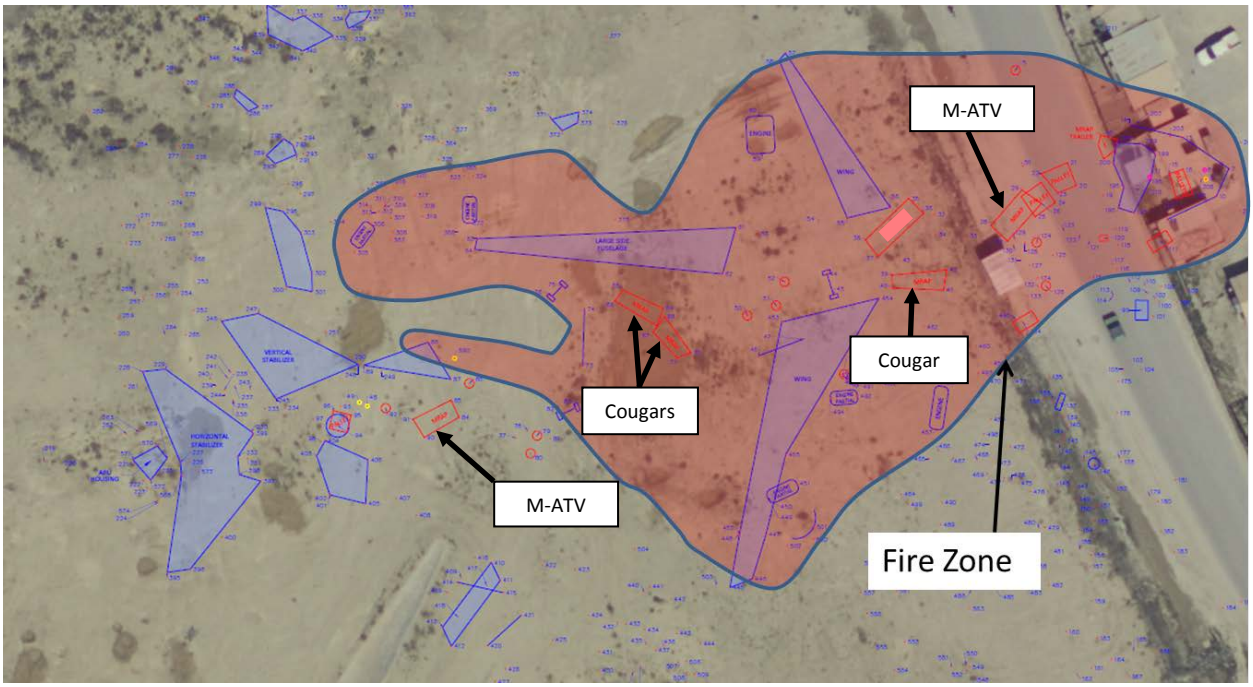

Figure 3 – N949CA Wreckage Debris & Fire Damage

D.4. Structure

D.4.1. Fuselage Section 46

Portions of six section 46 fuselage skin panels aft of the fire damage were identified and documented at the accident site (Figure 4).

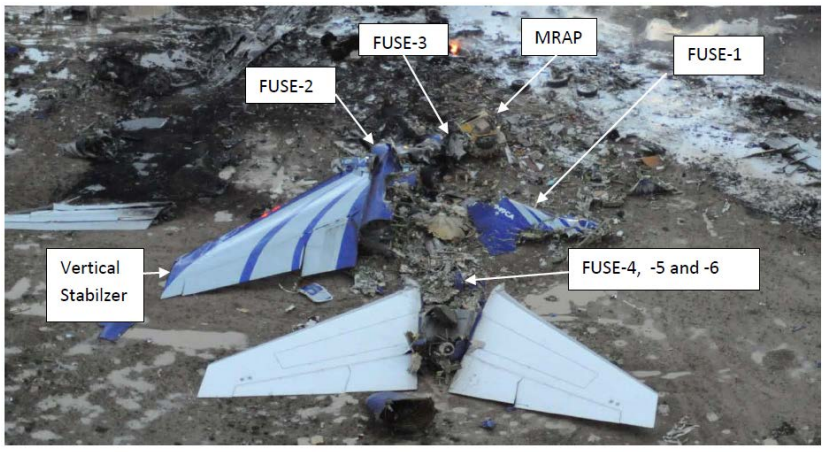

Figure 4 - Fuselage Section 46 Skin Panel Locations

FUSE-1 includes a deactivated and intact R5 door (Figures 5 & 7). The skin panel section also contained a section of the APB.

The FUSE-2 skin panel also contained a portion of the APB and exhibited fire damage (Figures 6 & 8). The fire damage was from about stringer 22L to about stringer 1 between STA 2320 and STA 2360. The FUSE-2 skin contained the E-8 rack that housed the FDR and CVR.

The FUSE-3 skin panel section was impaled on the left side of the aft most MRAP[4] (Figure 6).

FUSE-4 and FUSE-5 were found next to and partially on top of each other near the bottom of the large impact crater that was approximately 30 feet in front of the horizontal stabilizer. The stringer stiffeners and frames common to these skin sections were flattened and had a smeared appearance (Figures 5 & 6).

FUSE-6 (Figures 5 & 6) was also found at the bottom of the large impact crater. This section of skin exhibited evidence of buckling, but did not have the flattened appearance of FUSE-4 and FUSE-5 (Figures 5 & 6).

All of the examined fracture surfaces exhibited features consistent with overstress failures with no evidence of fatigue.

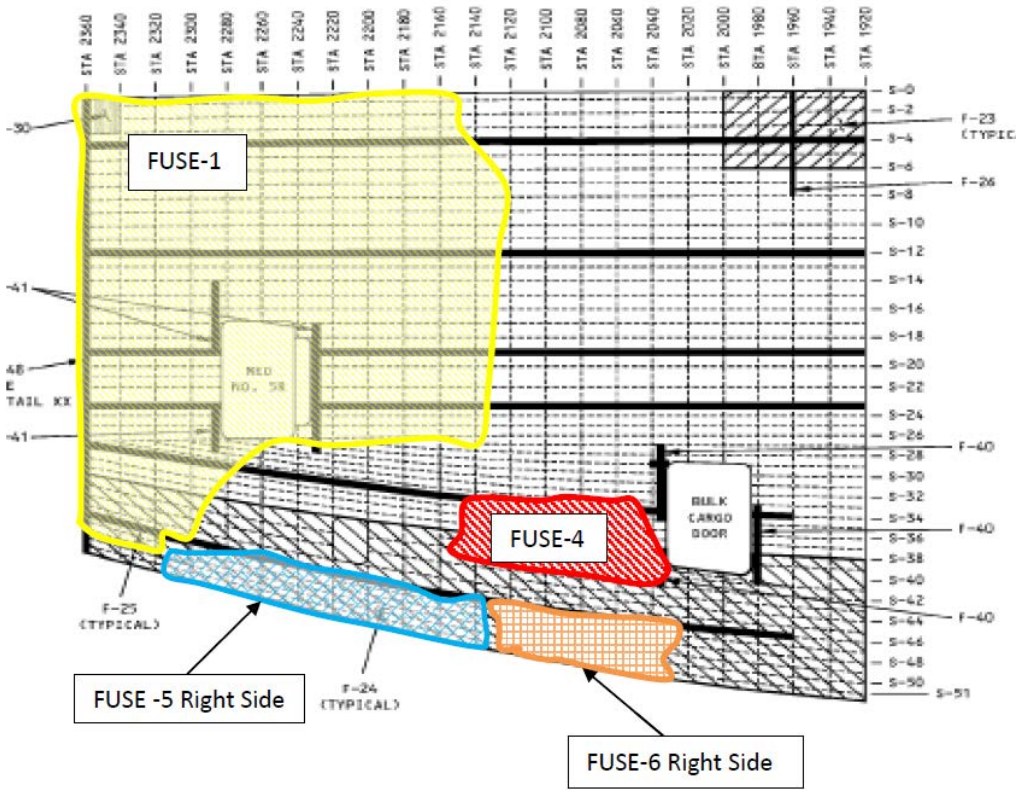

Figure 5 - Right Hand Major Skin Panel Sections FUSE-1, -4, -5, and -6

[4] MRAP - Mine Resistant Ambush Protected vehicle.

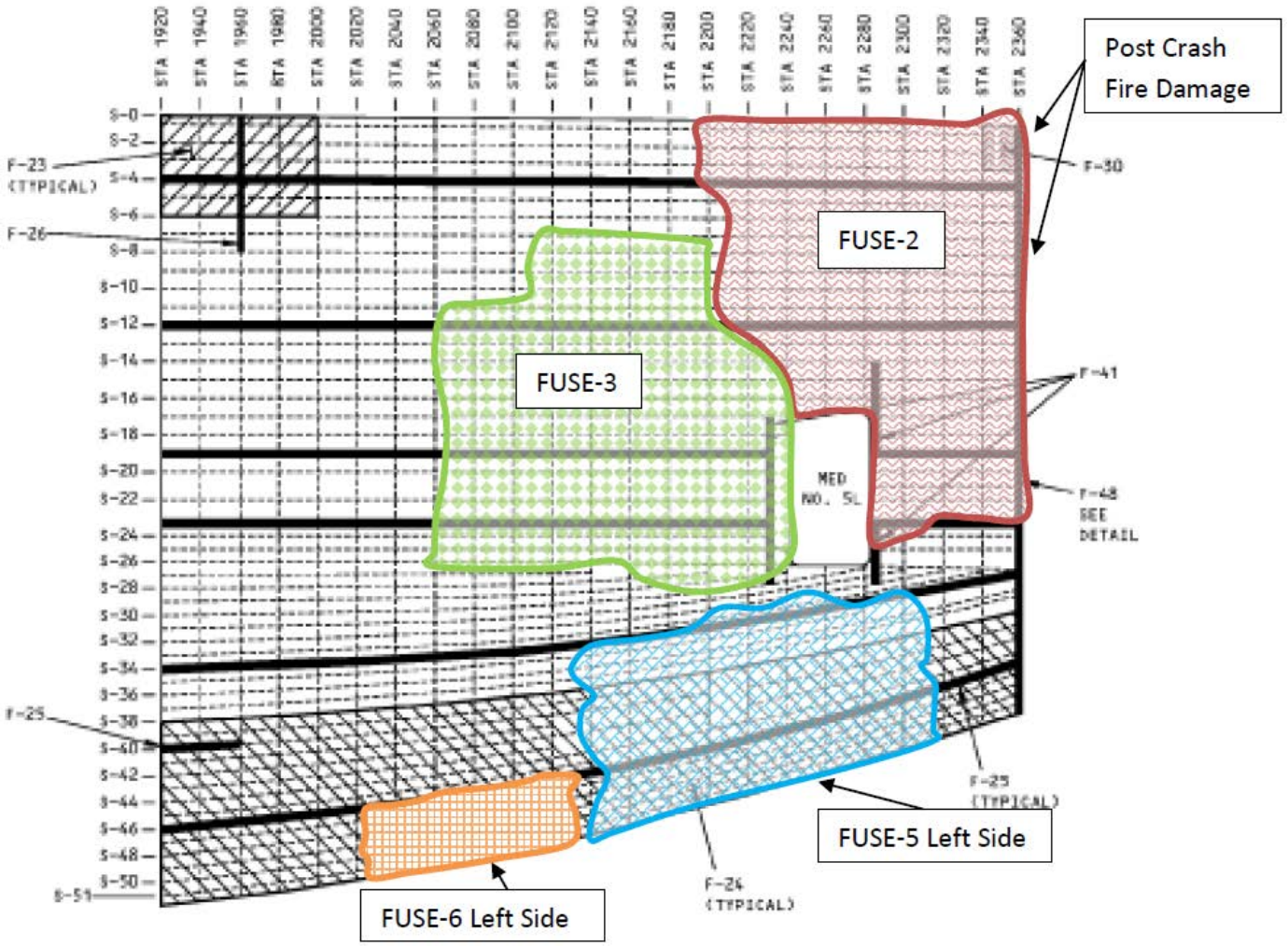

Figure 6 - Left Hand Major Skin Panel Sections FUSE-2, -3, -5, and -6

Figure 7 - FUSE-1 Panel Section

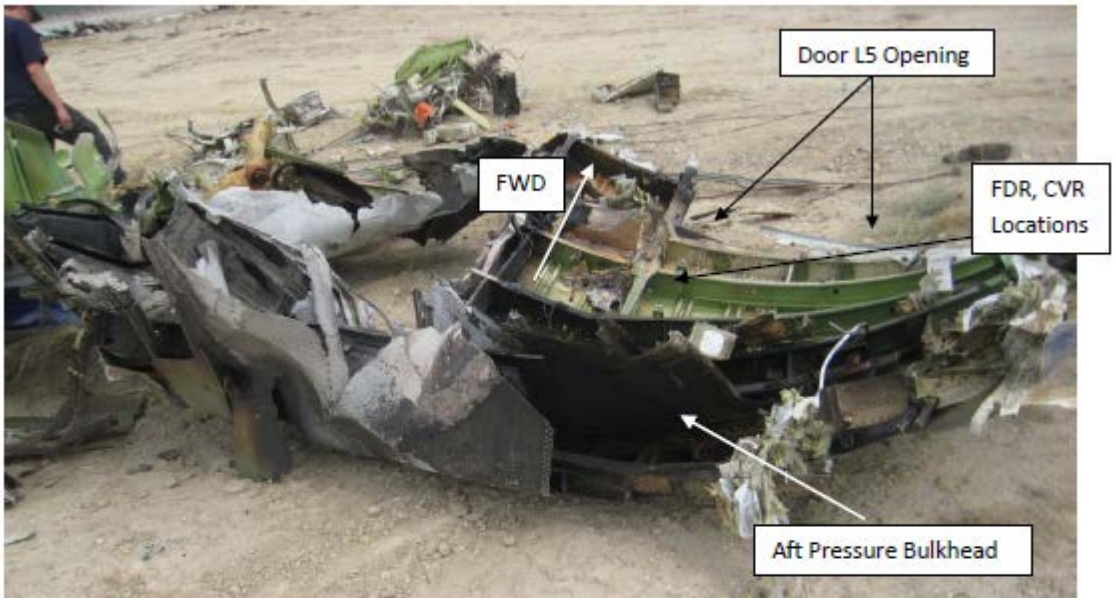

Figure 8 - FUSE-2 Panel Section

D.4.2. Fuselage Section 48

Fuselage section 48 extends from the APB at STA 2360 aft to STA 2775 (Figure 1). A large section of section 48 remained attached to the vertical stabilizer from about STA 2412 aft to about STA 2484. At STA 2412 the frame was deflected aft and the skins and stringers were present from about stringer 9L to stringer 17R. At STA 2436 the frame was deflected aft and the skins and stringers were present from about stringer 12L to stringer 17R. At STA 2460 the frame was deflected aft and the skins and stringers were present from about stringer 13L to stringer 17R. At STA 2484 the frame was deflected aft and the skins and stringers were present from about stringer 13L to stringer 17R. From STA 2484 aft to STA 2658 the skins, stringers and frames were present from stringer 11L to 11R. The skins, stringers and frames below these regions were destroyed. The APU compartment from STA 2658 to STA 2775 broke away cleanly from the forward section of section 48 and was located just aft of the horizontal stabilizer in the debris field.

All of the examined fracture surfaces exhibited features consistent with overstress failures with no evidence of fatigue.

D.4.3. Aft Pressure Bulkhead

Five sections of the APB were identified at the accident site (Figures 9 & 10). The aft pressure bulkhead is dome shaped and curved aft. Three of these sections, APB-3, - 4 & -5, were still attached to the faceplate "Y" chord and section 46 outer skin panels. APB-1 & -2 were found not connected to any fuselage structure.

The 5 major sections of the APB were recovered as depicted in Figure 9.

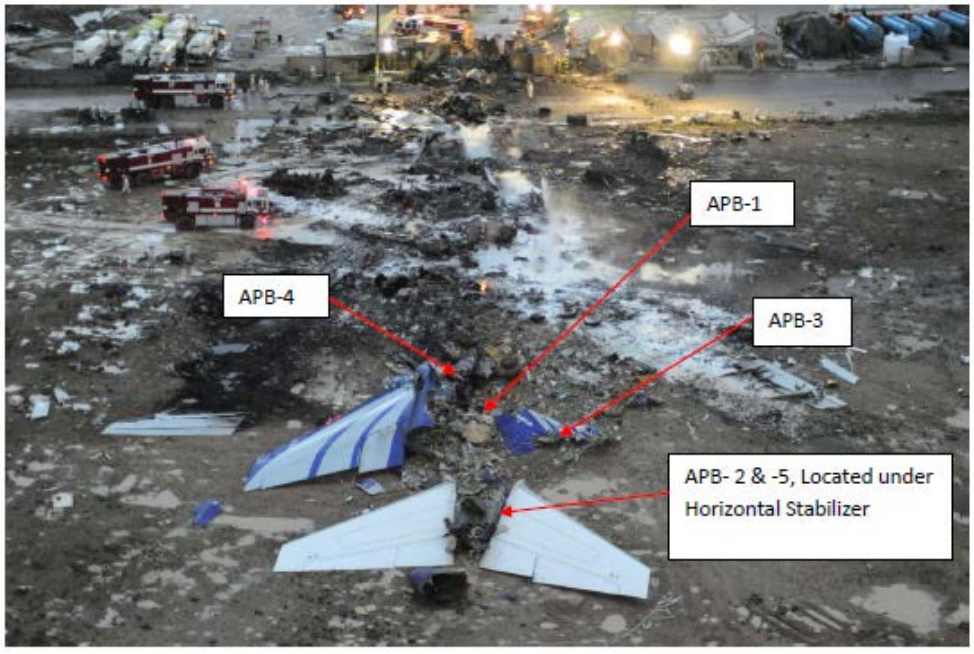

Figure 9 – Five APB sections

Section APB-1 was found on top of a pile of section 46 wreckage that was in an impact crater located approximately 30 feet forward of the horizontal stabilizer (Figure 11). APB-1 had a large crease just below the center dome. The upper half, above the center of the APB, was deformed aft. APB-2 was found under the horizontal stabilizer with the stiffeners deformed flat. APB-3, -4 and -5 were still attached to their respective STA 2360 Y chord and section 46 fuselage skins. APB-3 was attached to a large section of the right hand section 46 skin panel (Figure 12). APB-3 was deformed forward. The forward deformation was greater at the lower waterline levels and less pronounced near the crown.

APB-4 was attached to a portion of the left hand section 46 skin panel (Figure 13). It was also deformed forward similar to APB-3. APB-5 was bent aft from the skin panel to about the top of the APU cutout and the remainder of the section was bent forward (Figure 14). APB-5 was located under the horizontal stabilizer near APB-2.

All of the examined fracture surfaces exhibited features consistent with overstress failures with no evidence of fatigue.

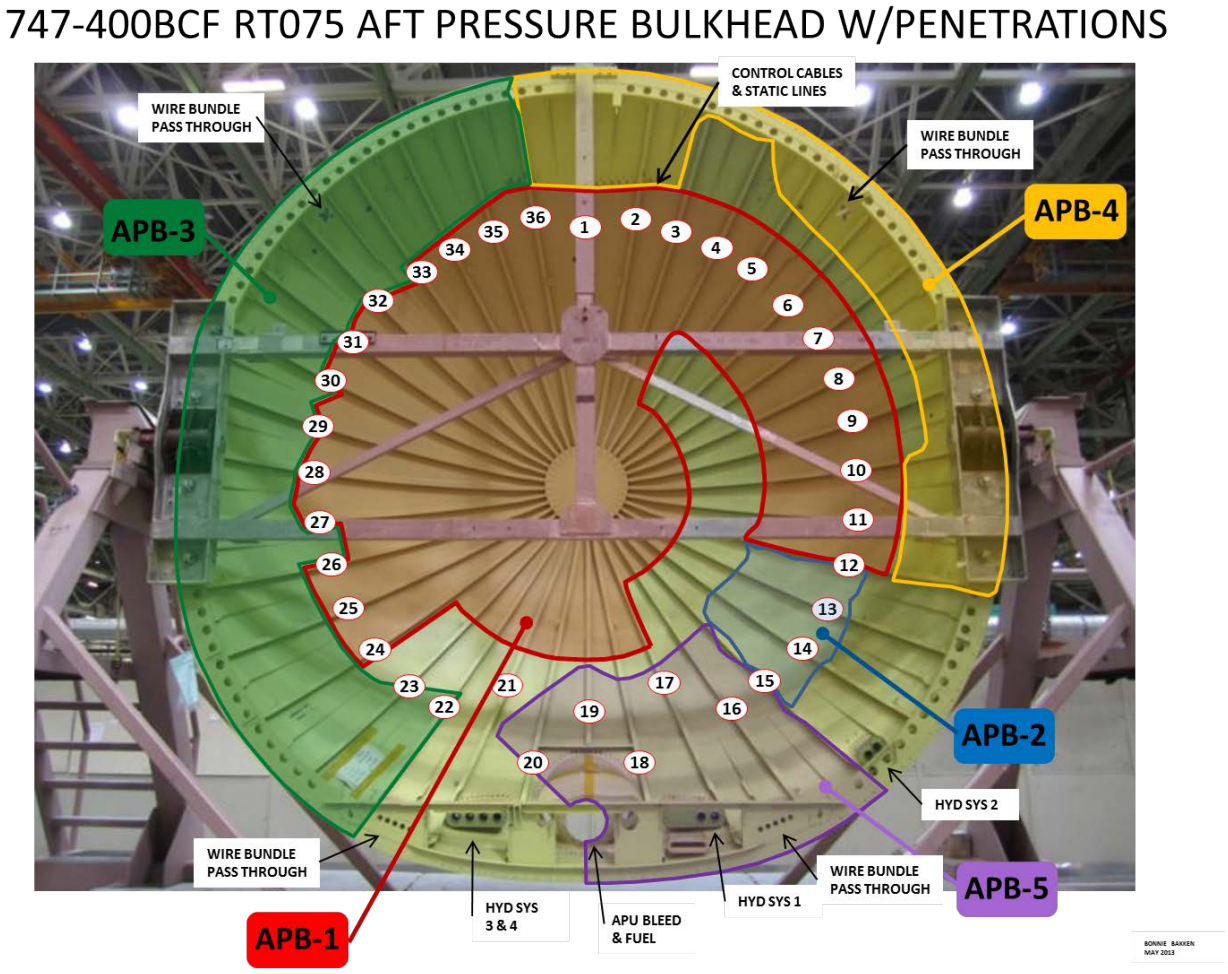

Figure 10 - APB, View Looking Aft

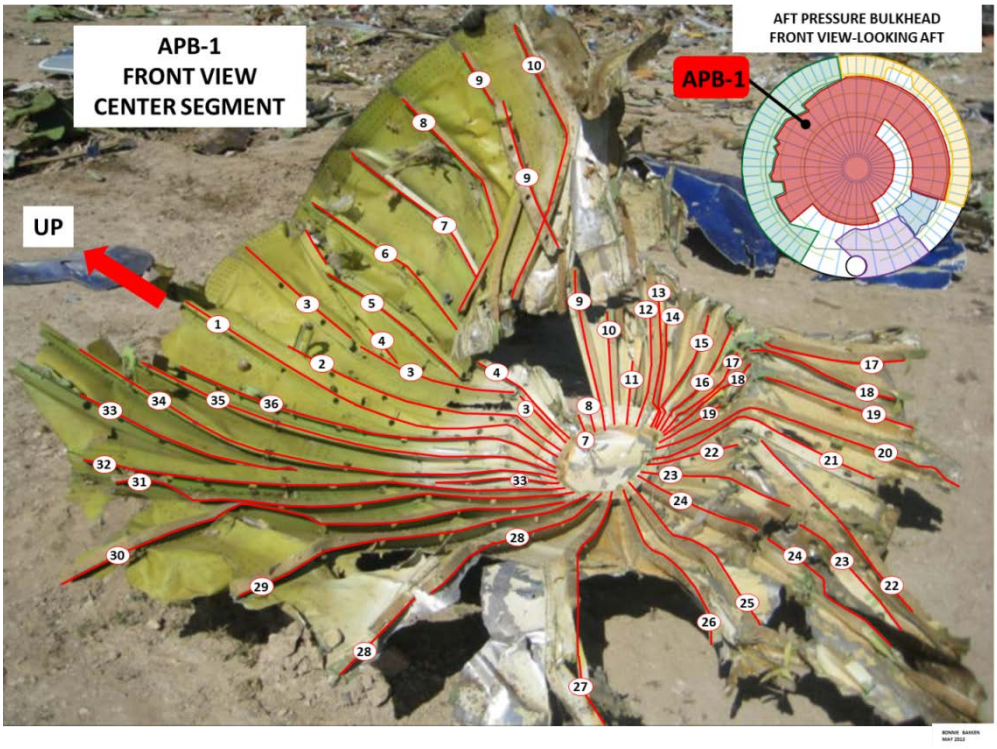

Figure 11 - APB-1, View Looking Aft

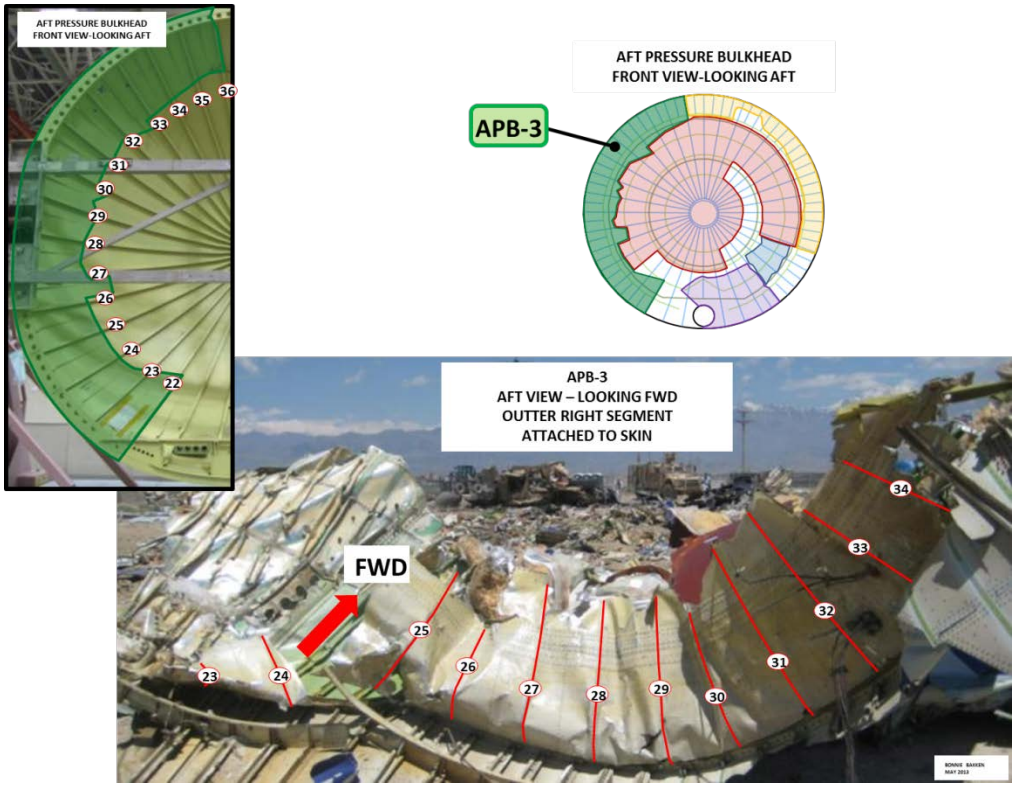

Figure 12 - APB-3, View Looking Forward

Figure 13 - APB-4 View Looking Aft and Outboard

Figure 14 - APB-5 View Looking Aft

D.5. Telair Cargo Restraint System

N949CA was equipped with the Telair main deck cargo handling system, pursuant to supplemental type certificate (STC) ST00459LA[5]. The cargo restraint equipment includes pallet locks, side guide restraints, centerline guide restraints and retractable and fixed end stops. The restraining system locks unit load devices (ULD) against forward, aft, vertical or lateral movement. All restraining equipment is equipped with integrated components that support the conveying capabilities of the cargo handling system. All restraining equipment is installed in seat tracks or floor fittings or within other cargo components.

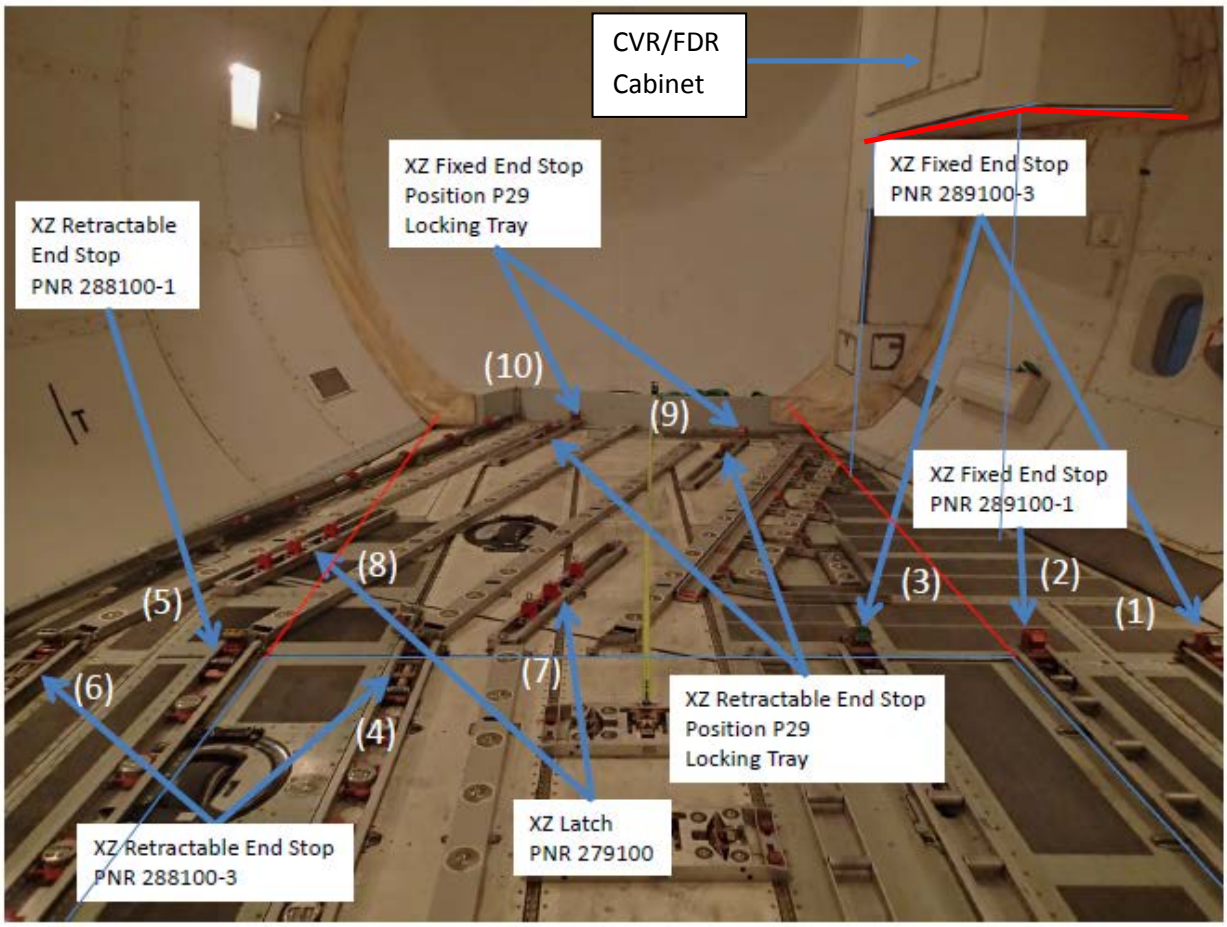

Figure 15 – National Exemplar 747-400 BCF cargo end stop hardware locations

[5] Refer to reference 15.

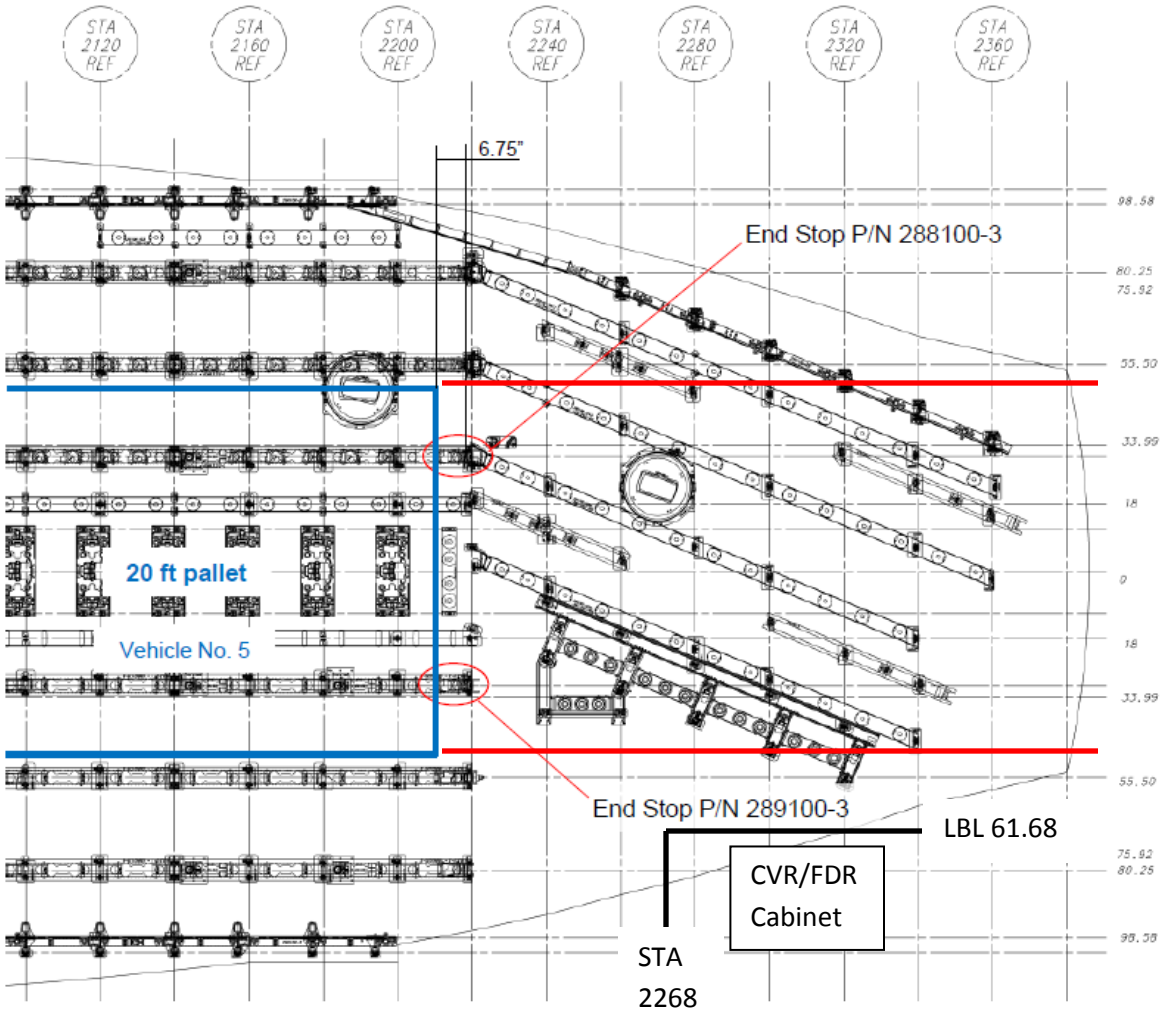

Figure 16 – 20 Foot Pallet and Main Deck Plan View

The fixed end stop and black housing in position 1 were recovered still mounted and secured to about a 40 inch section of silver aluminum roller tray (Figures 15 & 17). The roller tray was fractured about 40 inches forward of the aft end and about 5 inches forward of the power drive unit (PDU). The fixed end stop located in position 2 was recovered still mounted to the black housing and was no longer mounted to a silver aluminum roller tray (Figures 15 & 18). The fixed end stop located in position 3 was recovered separated from the black housing and the housing was no longer attached to the silver aluminum roller tray (Figures 15, 16 & 19). The housing fractured on the right hand side where the fixed end stop attaches to the black housing.

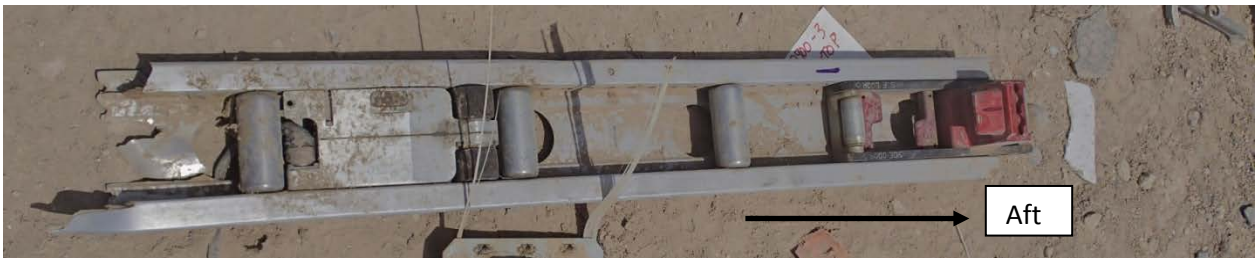

Figure 17 – N949CA Fixed End Stop (1) (part number 289100-3)

Figure 18 – N949CA Fixed End Stop (2) (part number 289100-1)

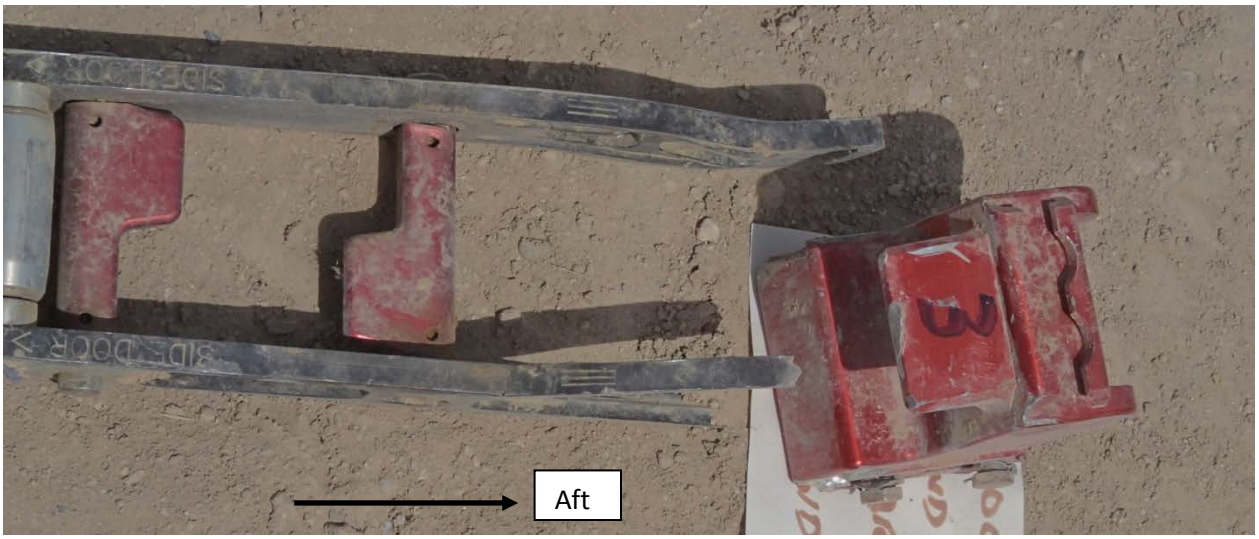

Figure 19 – N949CA Fixed End Stop (3) (part number 289100-3)

The black housing of the retractable end stop in position 4 was recovered fractured at the aft end with no retractable end stop attached to the housing (Figures 15, 16 & 20). The

retractable end stop was not recovered in the wreckage debris. In position 5 the retractable red end stop was recovered in the down position attached to the black housing (Figures 15 & 21). The assembly was not attached to the silver aluminum roller tray. In position 6 the retractable red end stop was recovered in the up position and secured to the black housing (Figures 15 & 22). The assembly was attached to about 20 inches of the silver aluminum roller tray. The roller tray was fractured at the forward end.

Figure 20 – N949CA Retractable End Stop Tray (4) with Missing End Stop (part number 288100-3)

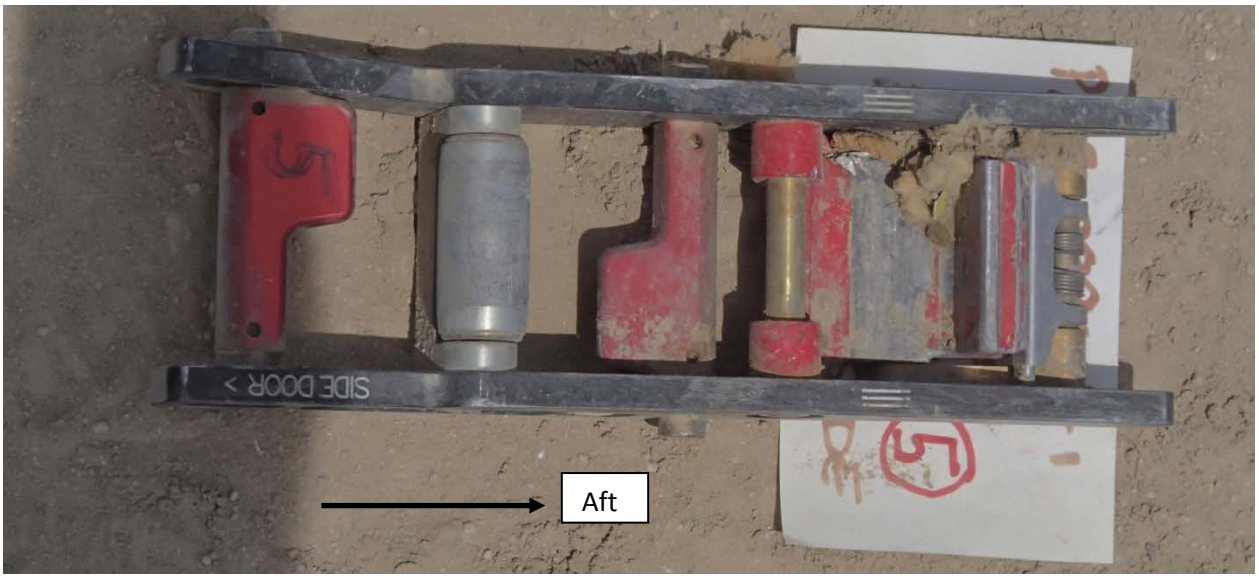

Figure 21 – N949CA Retractable End Stop (5) (part number 288100-1)

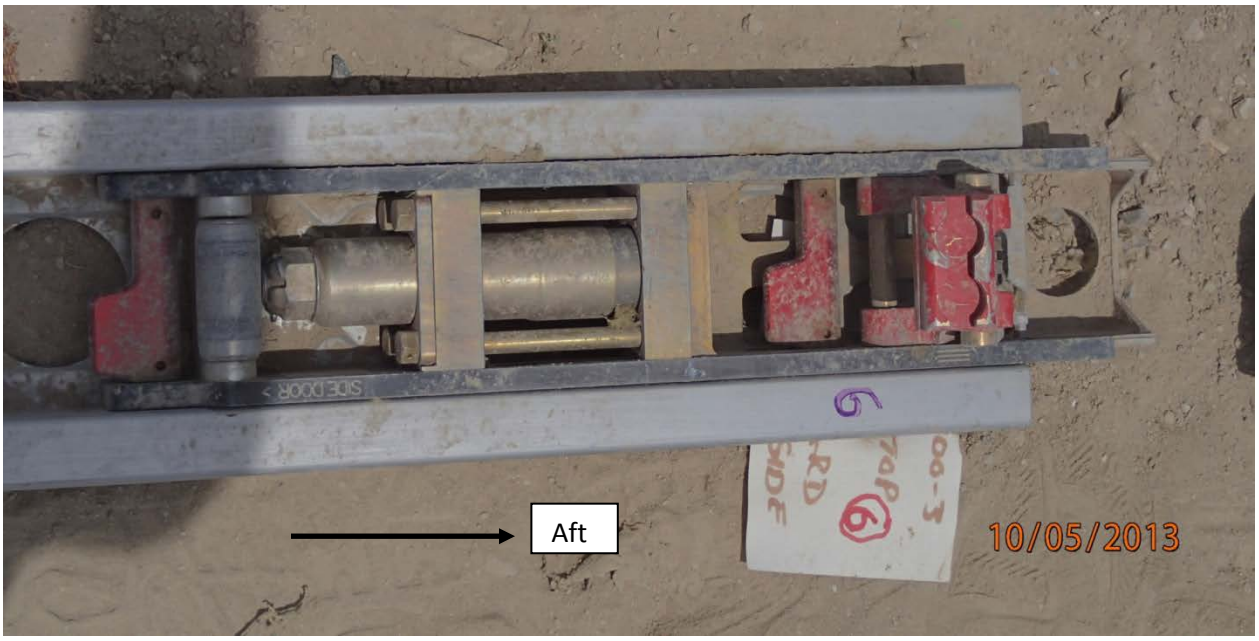

Figure 22 – N949CA Retractable End Stop (6) (part number 288100-3)

In position 7 the silver aluminum lock tray was fractured about 22 inches from the forward end in the location of the aft retractable end stop (Figures 15 & 23). The forward retractable end stop was in the up position, the middle was in the down position and the position of the aft retractable end stop could not be determined due to it being separated from the silver aluminum lock tray. In position 8 the entire assembly comprised of the silver aluminum lock tray and the 3 retractable end stops was recovered intact. The aft retractable end stop was in the up position and the middle and forward stops were in the down position (Figures 15 & 24). The assemblies in positions 7 and 8 are interchangeable and a determination of which was located on the left versus right hand sides of the airplane was not possible (Figures 15, 23 & 24).

Figure 23 - P29 Forward Lock Tray (7) retractable end stops (part number 279100)

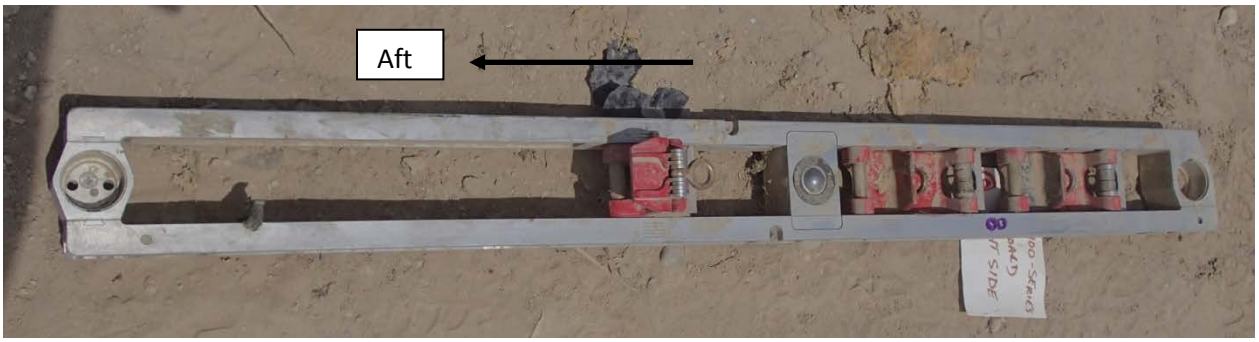

Figure 24 - P29 Forward Lock Tray (8) retractable end stops (part number 279100)

In position 9 (Figures 15 & 25) the entire assembly was recovered with the forward retractable end stop in the down position (Figure 25). The silver aluminum lock tray was fractured about 44 inches from the forward end or about 7 inches from the aft end in the location of the aft roller. Material from the upper forward edge of the fixed end stop where the single stud and double stud attachment points are located was ground away. The upper surface of the silver aluminum lock tray also had diagonal scratches going from right to left on a 45 degree angle when viewed from the front looking aft. In position 10 the entire assembly was recovered with the retractable end stop in the up position and the fixed end stop attached and in place (Figures 15 & 26). The silver aluminum lock tray was fractured on the right hand side when viewed looking aft about 6 and ½ inches forward of the aft end of the tray. In position 9 the entire assembly was recovered with the forward retractable end stop in the down position. The assemblies in positions 9 and 10 are interchangeable and a determination of which was located on the left versus right hand sides of the airplane was not possible.

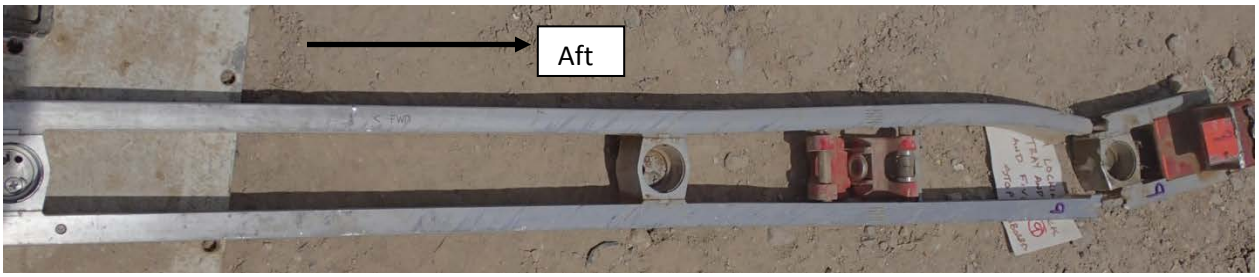

Figure 25 - P29 Aft Lock Tray (9) fixed and retractable end stops

Figure 26 - P29 Aft Lock Tray (10) fixed and retractable end stops

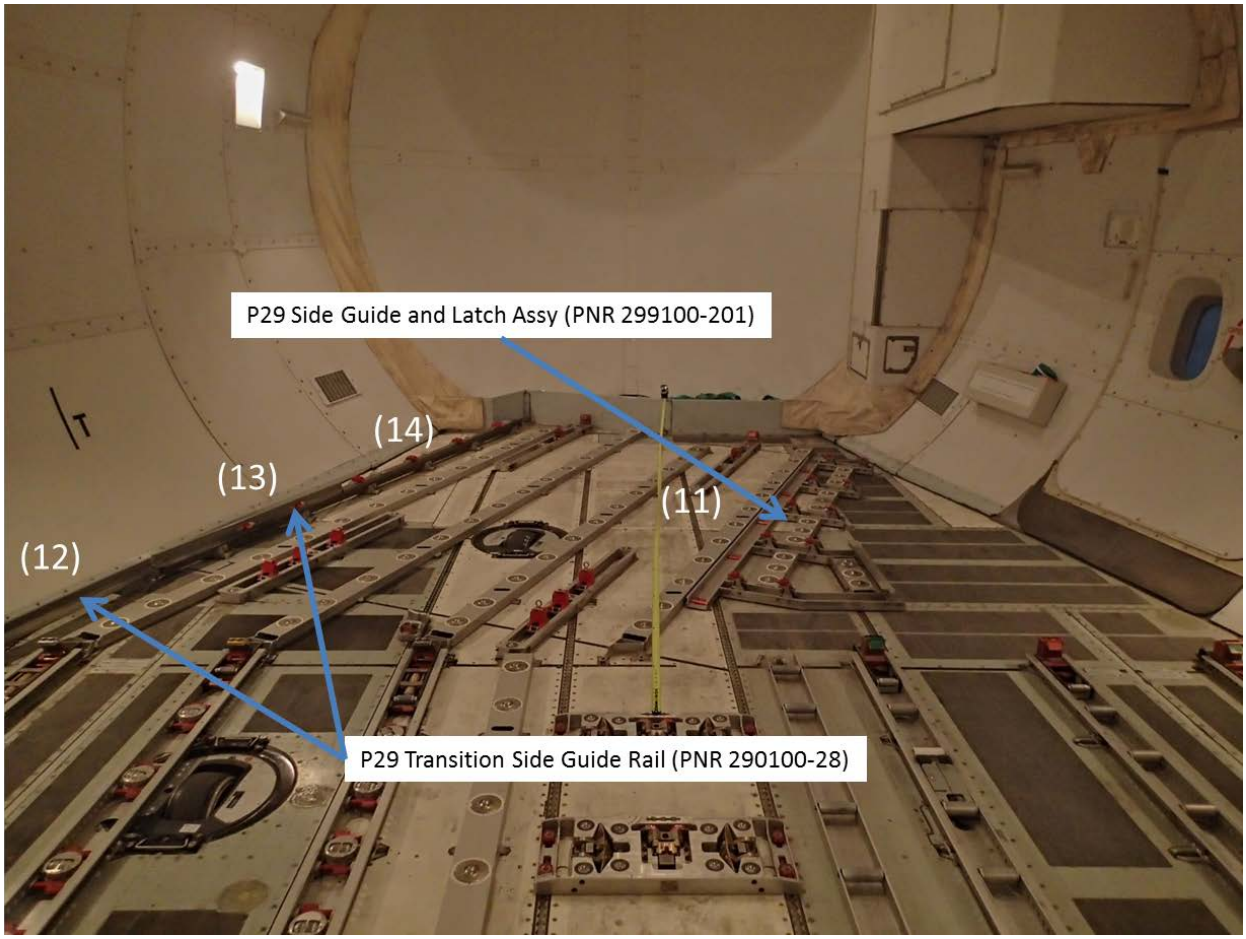

Figure 27 - National Exemplar P29 RH & LH Side Guide Rails

The P29 side guide and latch assembly was recovered in the wreckage with 9 out of the 10 lateral and vertical restraints in place. The forward end of the side rail was fractured about 12 inches aft of the forward end. The restraints have been numbered 1A and 1B in the forward location to 5A and 5B in the aft position for the purposes of this report. The A position is the inboard restraint and B position is the outboard restraint. In position 1, the retractable restraint 1A was in the down position and in position 1B the restraint had separated from the track assembly. The track in position 2 separated from the side rail assembly and both stops 2A and 2B were in the down position. In position 3 restraint 3A was in the down position and 3B was in the up position. In position 4 restraint 4A was in the up position and stop 4B was missing. In position 5 the track was separated from the side rail assembly and restraint 5A was in the up position and 5B was in the down position.

Figure 28 - N949CA P29 LH Side Guide Rail (11)

The RH side P29 side guide rail movable arm, item 12 (Figures 27 & 29), remained attached to the forward end of the fixed side guide rail item 13 (Figures 27 & 30). The lug used for attaching the movable section of the side guide rail to the fixed forward side rail via a quick connect pin was fractured on the movable guide rail side. The aft fixed side guide rail was fractured 57 and ½ inches from the forward end creating items 13 and 14 (Figures 27, 30 & 31).

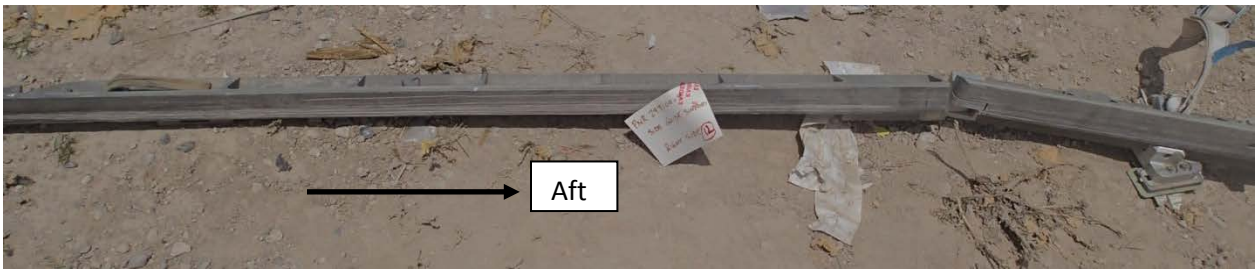

Figure 29 - N949CA P29 RH Transition Side Guide Rail (12)

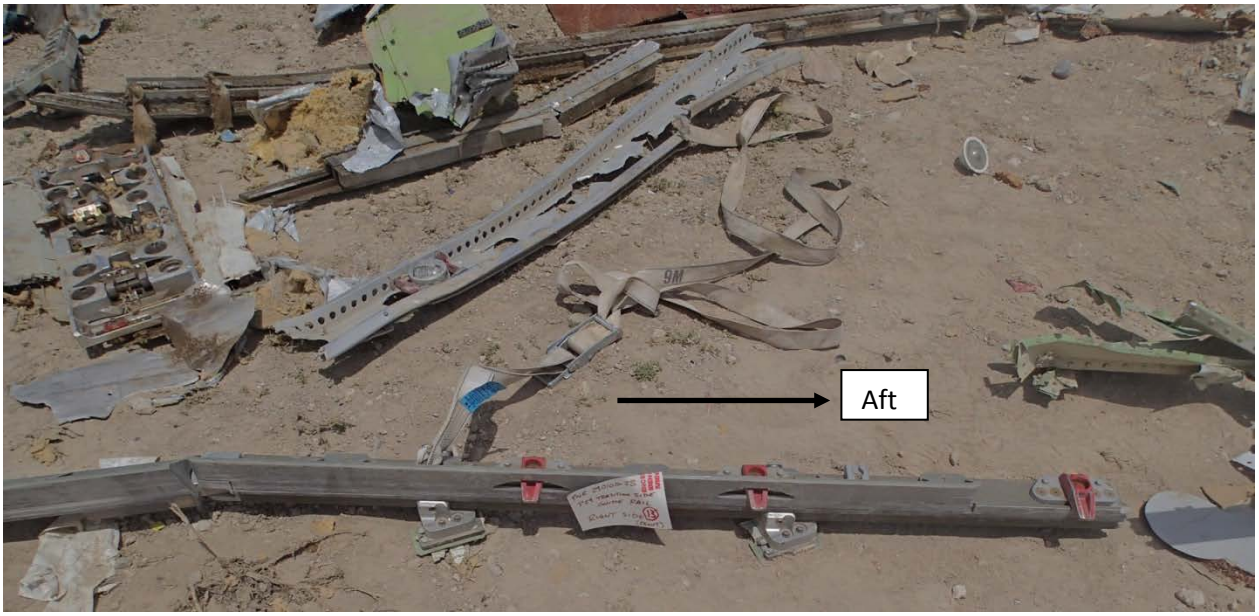

Figure 30 - N949CA P29 RH Transition Side Guide Rail (13)

Figure 31 - N949CA P29 RH Transition Side Guide Rail (14)

All of the examined fracture surfaces exhibited features consistent with overstress failures with no evidence of fatigue.

D.6. Main Deck Loading

The airplane was loaded at Camp Bastion Afghanistan with five vehicle and pallet combinations (Figures 32, 33 & 34) weighing a total of 176,678 LBS on G code pallets measuring 96 inches in width by 238.5 inches in length. The two M-ATV's and pallets were approximately 107 inches in height and the three Cougar and pallet combinations were approximately 121 inches in height. The main deck cargo was as listed in Table 1 (Figures 35 thru 38).

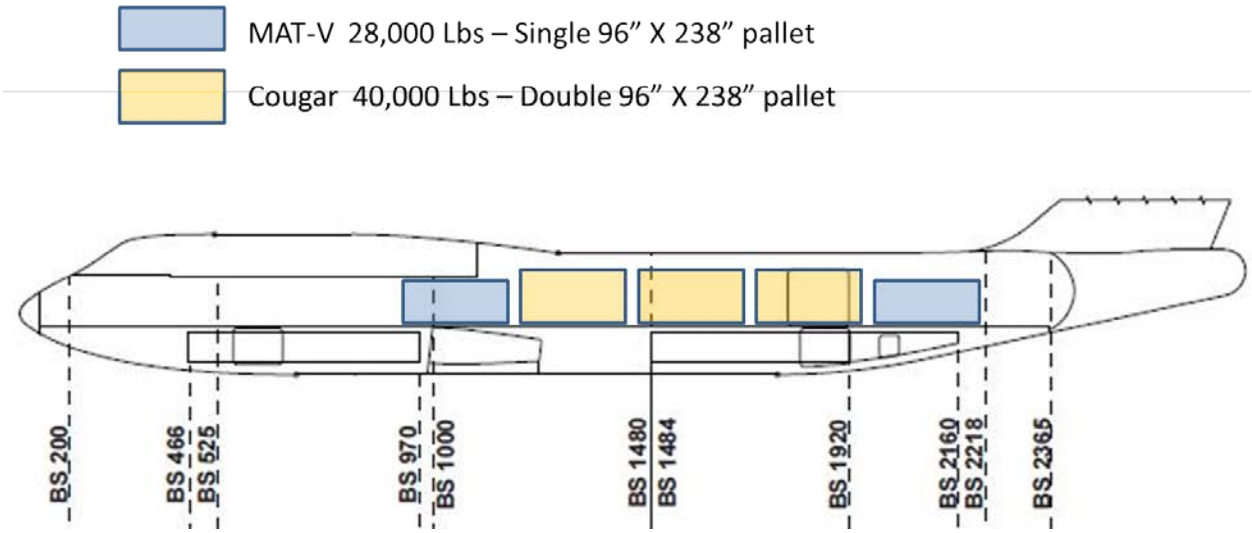

Figure 32 - N949CA M-ATV and Cougar locations[6]

[6] Refer to the Operational Factors Factual Report, Sections 6.3 and 6.4 for loading description.

Figure 33 –M-ATV on a single 20 foot G code pallet

Figure 34 - Cougar on two 20 foot G code pallets

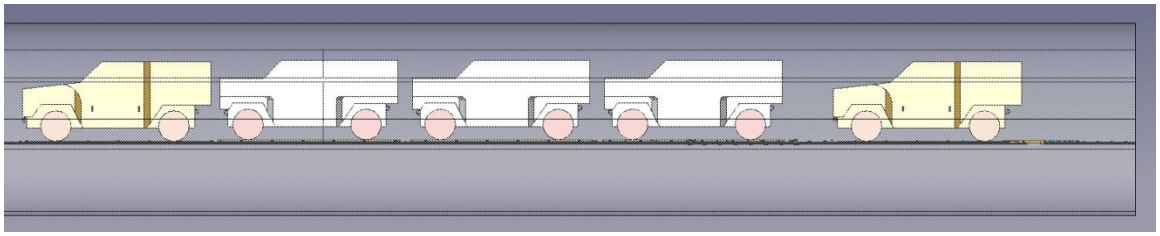

Figure 35 – Illustration MRAP's on pallets inside 747 side view

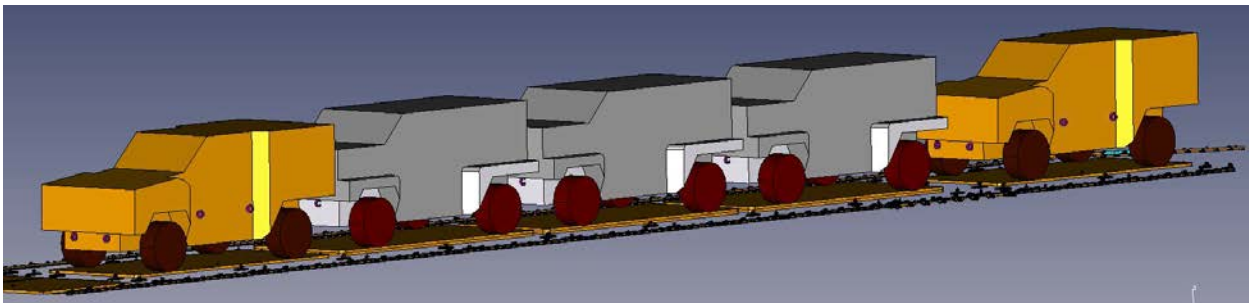

Figure 36 – Illustration of MRAP's on pallets, ISO view (1)

MAINDECK CARGO						
ITEM	ACTUAL WT Kg[7]	REPORTED WT Kg[8]	CG B. A.[9]	START B.A.	STOP B.A.	COMMENTS
Fly Away Kit	460	460	220	200	240	Metal bin
463L Pallet[10]	1829	1829	282	238	326	Tools
463L Pallet	1985	1985	379	335	423	436L pallets
463L Pallet	1503	1503	476	432	520	Freight
Coupled 463L	1440	1440	634.5	526	743	Generator
463L Pallet	1243	1243	798	744	852	Turret
M-ATV[11]	12614[12]	12110	1029	909.75	1148.25	MRAP
Cougar[13]	18646[14]	17220	1281	1161.75	1400.25	MRAP
Cougar	18434[15]	17199	1533	1413.75	1652.25	MRAP
Cougar	18030[16]	16780	1785	1665.75	1904.25	MRAP
M-ATV	12584[17]	12090	2092	1972.75	2211.25	MRAP
	1463	1463	798	744	852	Freight

Table 1 – Main Deck Cargo Loading – Refer to Figures 39 thru 40

[7] 1.0 KG is equivalent to approximately 2.2 LBS.

[8] The original reported weights did not include the weight of the pallets, shoring material and the tie down chains.

[9] Balance Arm, refer to Figure 1 and reference 2 section 1-00-041.

[10] 88 inches by 108 inches.

[11] M-ATV – **M-ATV** is an MRAP (Mine Resistant Ambush Protected) vehicle developed by the Oshkosh Corporation of Oshkosh, Wisconsin for the MRAP All-Terrain Vehicle (M-ATV) program, refer to references 6 and 7.

[12] 27,809 LBS

[13] The **Cougar** is a South African-designed United States MRAP and infantry mobility vehicle structured to be resistant to landmines and improvised munitions, refer to reference 8.

[14] 41,107 LBS

[15] 40,640 LBS

[16] 39,749 LBS

[17] 27,743 LBS

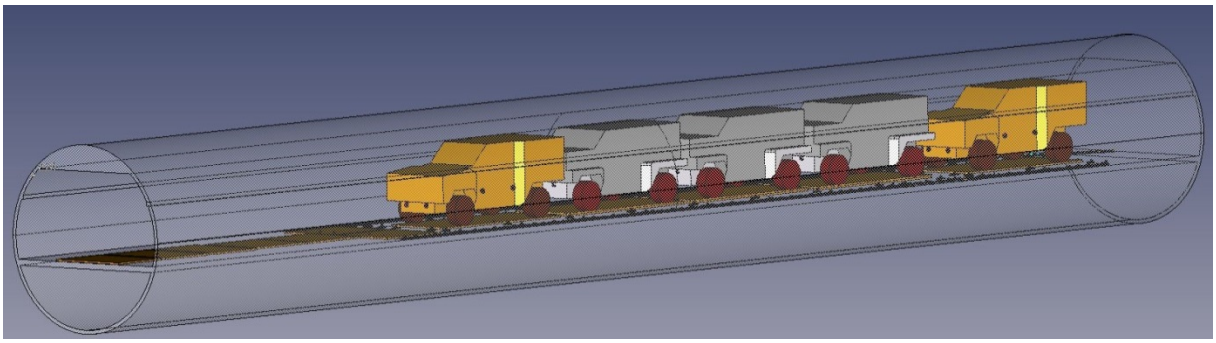

Figure 37 – Illustration of MRAP's on pallets inside a 747 fuselage, ISO view (2)

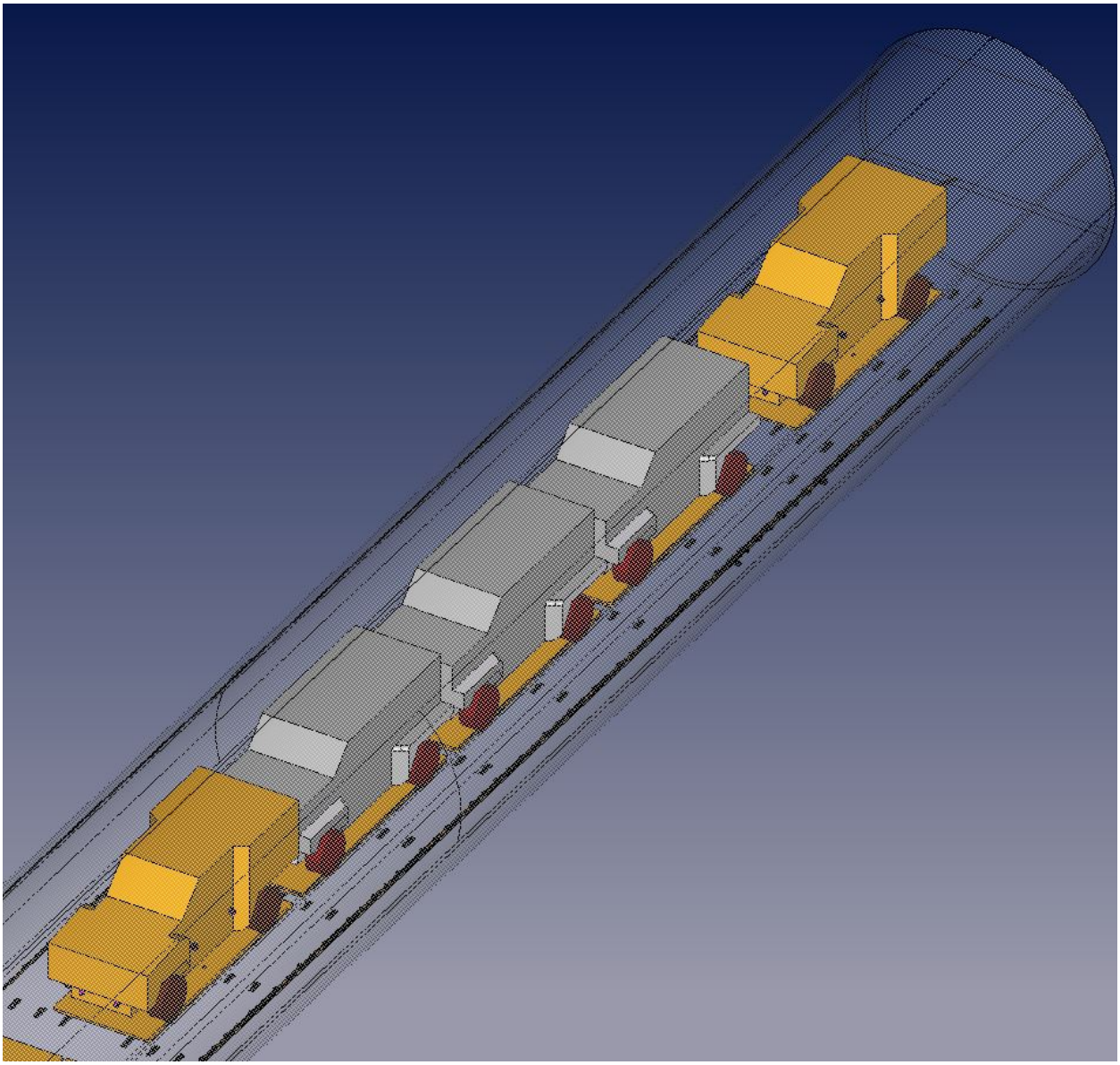

Figure 38 –Illustration of MRAP's on pallets inside a 747 fuselage ISO view (3)

The MRAP vehicles and pallets on board the accident airplane were taller than 96 inches and qualified as tall rigid cargo (TRC)[18] subject to the airplane manufacturer and the main deck cargo handling system manufacturer restrictions and safeguards for such cargo. TRC is defined as cargo that is in excess of 96 inches tall and will not break apart during an emergency landing event (a 777 engine is an example of TRC).

In an emergency landing event, TRC must be stopped before it impacts the upper deck divider at B.A. 800. This will protect all of the upper deck occupants on the airplane.

To ensure this, a sufficient volume of cargo must be loaded forward of the TRC. In an emergency landing event, this cargo will redistribute and fill up the main deck cargo volume between the B.A. 158.5 barrier and the TRC. This volume of cargo will stop the TRC impacting the upper deck divider at B.A. 800.

Per the Boeing and Telair weight and balance manuals, the most forward position for TRC that is 118 inches tall is B.A. 1220. The most forward position for TRC that is 110 inches tall is B.A. 902. All cargo in excess of 110 inches tall between B.A. 902 and B.A. 1220 must be frangible cargo. These height restrictions will ensure at least a 16 inch clearance between that TRC and the airplane structure overhead.

Because the M-ATV and pallet combination is TRC it must be restrained for 9G's forward, or frangible cargo must be employed to prevent the TRC from impacting the upper deck passenger compartment during an emergency landing.

D.7. Aft M-ATV

The aft M-ATV was located from B.A. 1973 to 2211. The M-ATV was substantially damaged but was not consumed by fire. Pieces of the main deck interior panels were recovered from inside the M-ATV and orange and green paint transfers consistent with the orange paint on the CVR and the FDR cases and the green primer used on unpainted airplane structure were identified on the rear portion of the aft M-ATV. The paint transfer marks are consistent with airplane structure located aft of the M-ATV's tie down position (Figures 39 thru 42).

[18] Refer to reference 1 Section 3.2 pages 18, 55 and 56, reference 2 Section 1-00-001 page 5, section 1-64-901 page 1 and section 1-69-121 and reference 3 section 1-64-123 and section 1-69-120.

Figure 39 - MATV versus E8 Cabinet Positional Reference

Figure 40 - Orange Paint Transfer (1) to M-ATV

Figure 41 - Orange Paint Transfer (2) to M-ATV

Figure 42 - Airplane Green Primer Paint Transfer on M-ATV

The right (first officers side) interior liner between the APB and airplane side of body interior lining and the lower APB cargo liner splice strap were found on the right hand side of the aft M-ATV trapped underneath the collapsed M-ATV structure(Figures 43 thru 45).

Figure 43 - Trapped APB Liner Material (1)

Figure 44 - Trapped APB Liner Material (2)

Figure 45 - Trapped APB Liner Material (1) & (2) reference Figures 39 & 40

D.8. Tie Down Straps

70 total sections of strapping were recovered aft of the last M-ATV and were torn at varying lengths. Twelve 5,000 LB straps of varying length were found attached to 6 sections of the cargo system side guide rail. The straps were submitted to the NTSB Material's Laboratory for examination.[19] Four straps (Figures 46, 47, 48 & 49) were found attached to seat tracks. The double stud fitting shown in Figure 46 was installed in the right butt line (RBL) 75.9 seat track, between STA 1920 and STA 1940 There are no seat track allowables[20] for this track at this location per the Boeing Weight and Balance Control and Loading Manual. Figure 47 shows a part consistent with floor panel 814B6554-100. This would place the tie down location shown in Figure 43 on RBL 89.67 at approximately STA 2220. In Figure 48, the T/SL mark is a pallet mark on the left sidewall at the aft end of the side by side pallets (approximately STA 2218). The seat track appears to be the left butt line (LBL) 89.67 seat track at this location. There are seat track allowables[21] for these tracks at these locations per the Boeing Weight and Balance Control and Loading Manual. It was not possible to determine the location of the fourth seat track and strap combination (Figure 49).

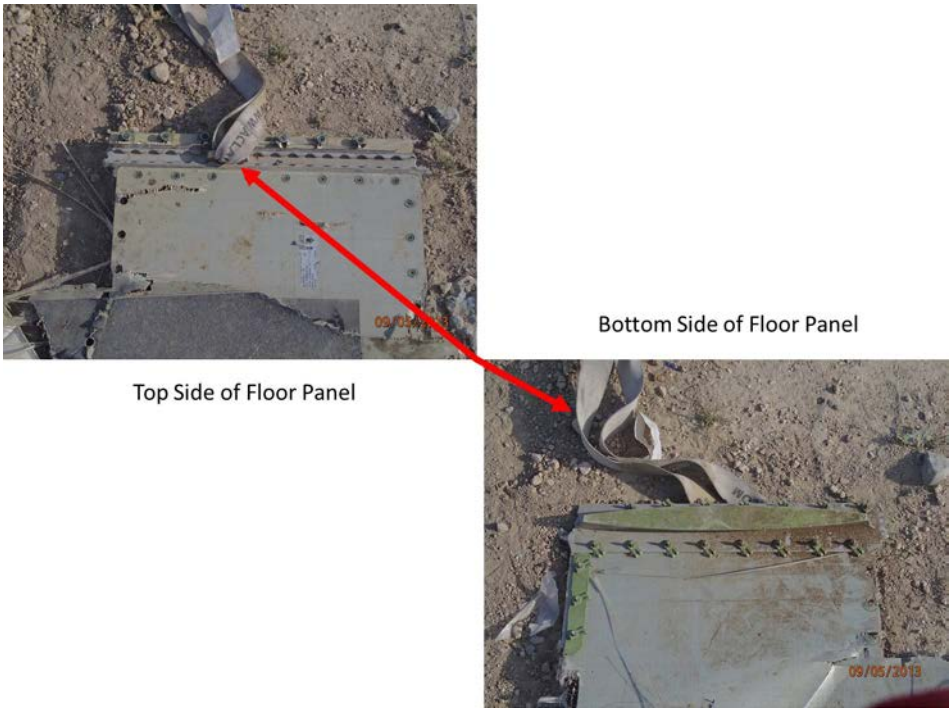

Figure 46 - Seat Track with attached Strap (1)

[19] Refer to NTSB Materials Laboratory Report 14-066.

[20] Refer to reference 1 13.2.4 page 107 and reference 2 section 1-68-951 page 4.

[21] Refer to reference 1 13.2.4 page 107, reference 2 section 1-68-901 page 10 and section 1-68-951 page 4.

Figure 47 - Seat Track with attached Strap (2)

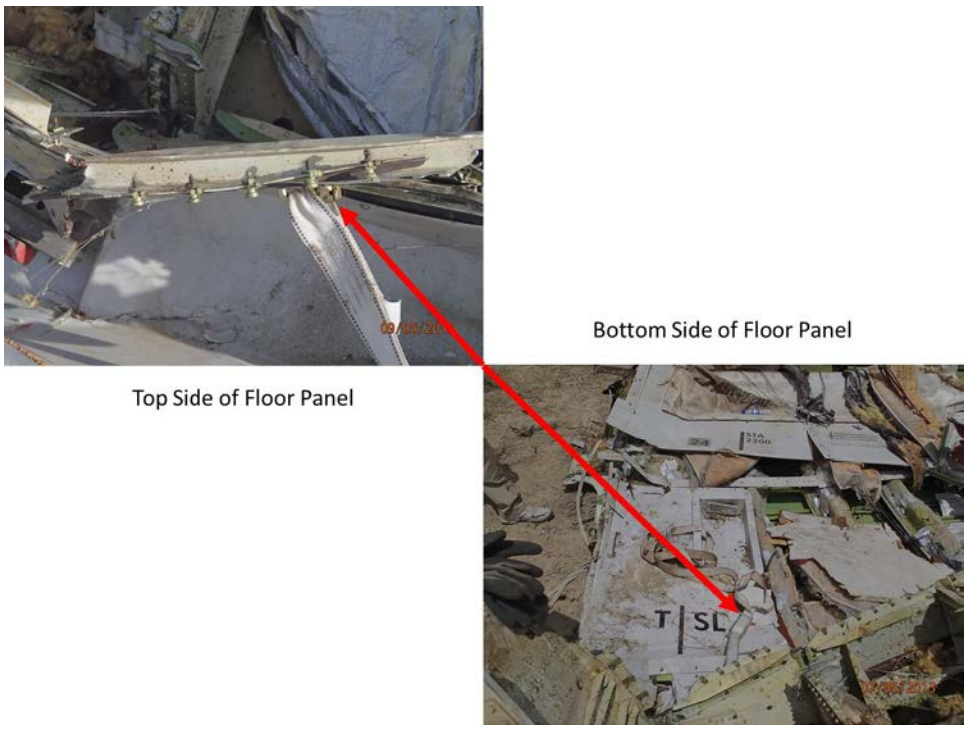

Figure 48 - Seat Track with attached Strap (3)

Figure 49 - Seat Track with attached Strap

D.9. Runway Debris

Twelve items were recovered from the runway following the accident in the vicinity of Taxiway C which was near the point of takeoff rotation. Eleven were identified as airplane structure and one was identified as being part of an MRAP. Of the eleven pieces of airplane structure, five were matched to specific parts of the airplane. The identified items included: 1) two small pieces of fuselage skin with blue National Airlines paint (Figure 50); 2) a green stanchion from the E8 CVR/FDR rack (Figure 51); 3) a bracket reinforcing a hydraulic line penetration in a fuselage frame located at body station 2377 (Figures 52 thru 54); 4) a body station 2377 frame intercostal; and 5) a section of tubing from hydraulic system 2 hydraulic line (Figure 55). The MRAP part was identified as being part of an antenna installation located on the rear upper left corner of a M-ATV (Figures 56 & 57). The rear M-ATV was missing its entire antennae assembly. The recovered piece of the antennae assembly was consistent with those installed on the accident M-ATVs.

Figure 50 - Fuselage Skin Pieces recovered from the Runway

Figure 51 - E8 CVR/FDR Stanchion Recovered from the Runway

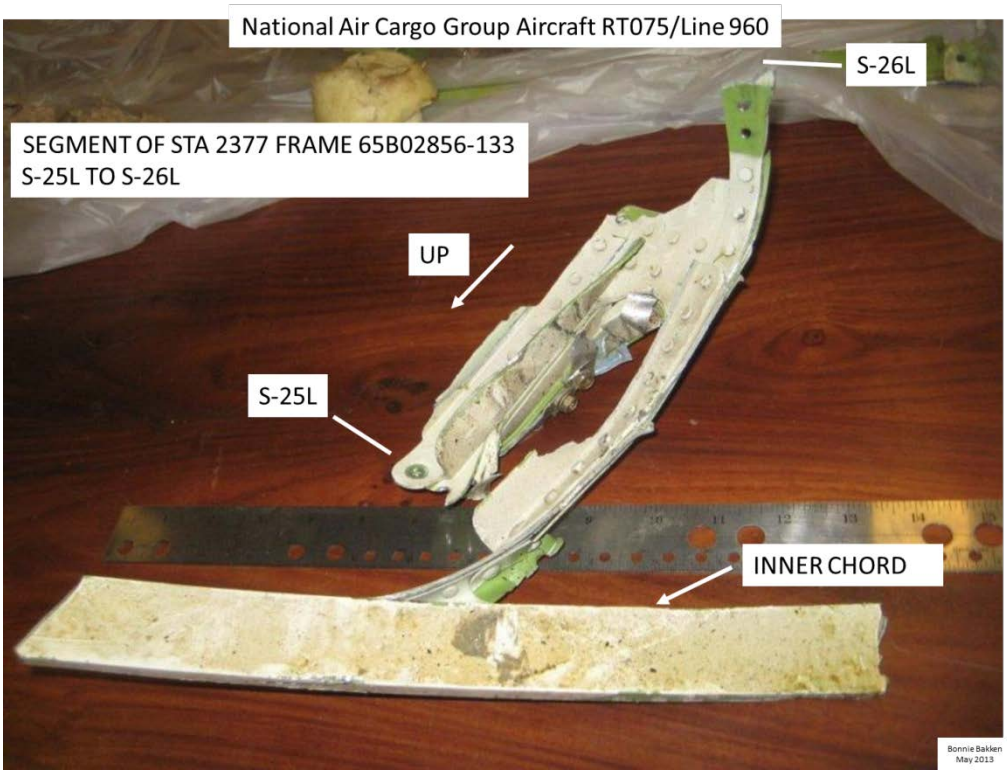

Figure 52 - BS 2377 Frame Penetration Bracket

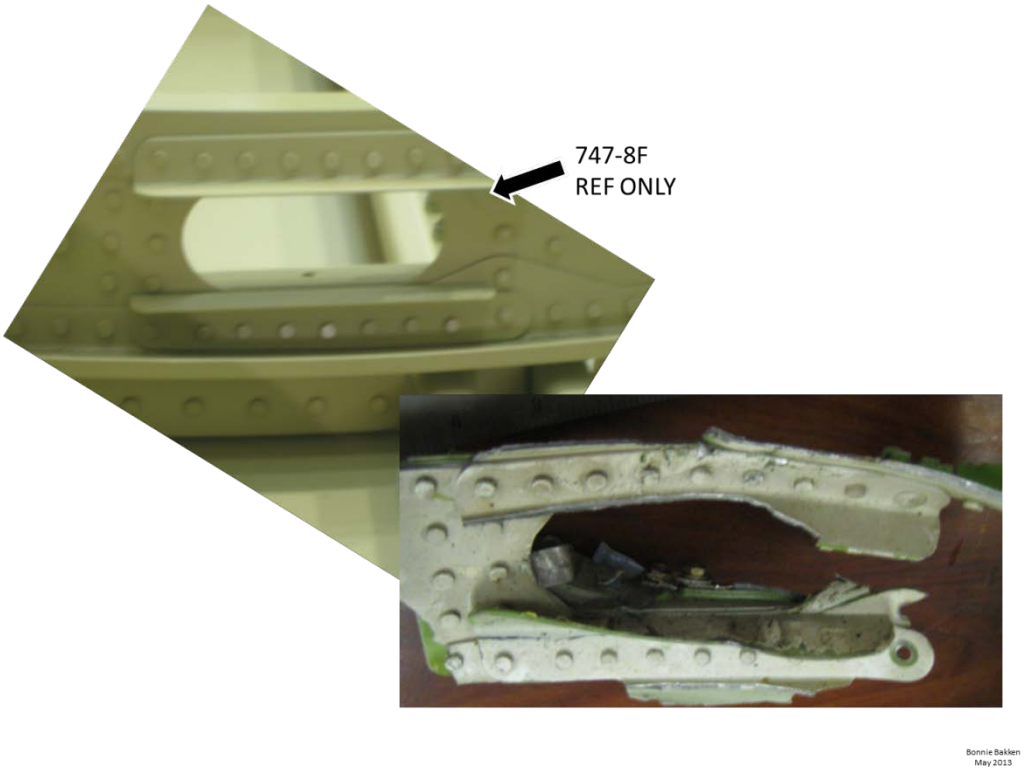

Figure 53 - BS 2377 Penetration Bracket & 747-8F Exemplar

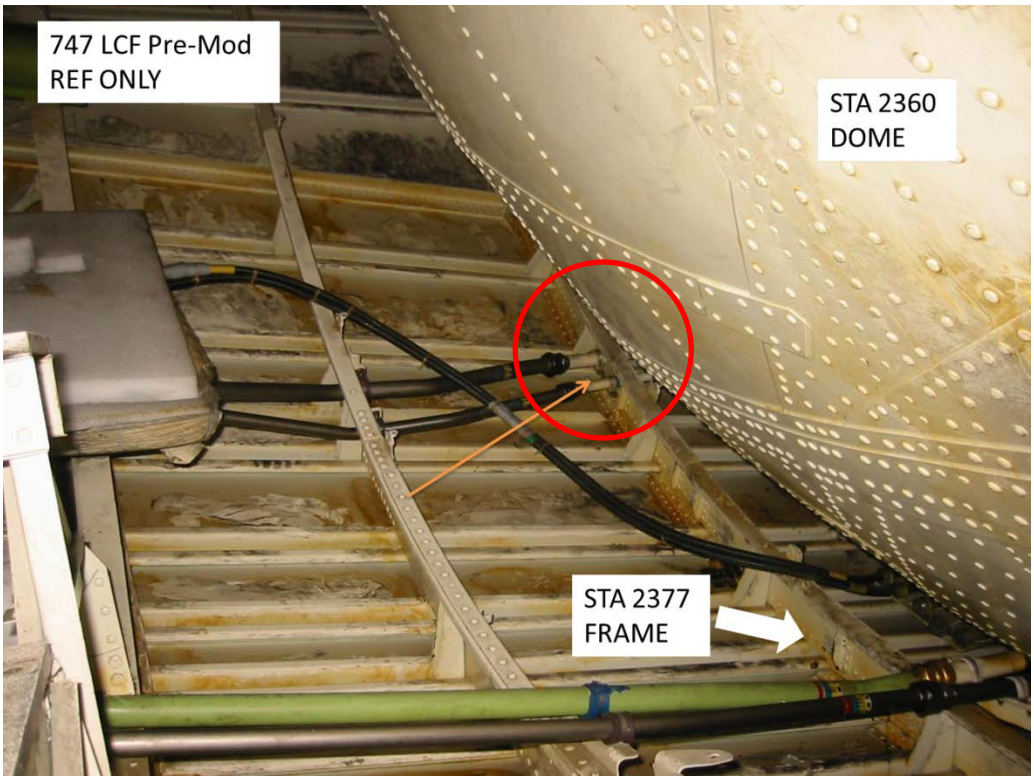

Figure 54 - BS 2377 Frame Hydraulic System 2 Penetration

Figure 55 - Hydraulic System 2 Hydraulic Line

Figure 56 - M-ATV Antennae Component Recovered from the Runway

Figure 57 - M-ATV Exemplar Antennae

D.10. Witness Marks

Multiple sections of the main deck interior panels had evidence of contact with an MRAP tire. There was also evidence of contact between the aft M-ATV and the airplane's structure located aft of its reported tie down position. In addition, there was also evidence of contact between one of the 238.5 inch aluminum pallets that the MRAP's were secured to and the red cargo floor restraints and the roller trays[22].

The APB interior liner had evidence of contact with an MRAP tire. There was a quarter tire witness mark from about the 9 o'clock to about 12 o'clock positions on the APB liner (Figure 58). The liner is comprised of 4 near equal quarter sections. The lower right quarter panel (viewed aft) was not identified in the wreckage. The estimated center of the 44 inch MRAP Michelin tire witness mark was located on the APB right upper quarter panel, about 50 inches from the top edge, about 15 inches from the lower and about 14 inches from the left edge when viewed looking aft. The tire imprint was consistent with a tire being parallel to the APB and located 81 and ½ inches above the main deck cargo floor. The spare tire on the aft most M-ATV is mounted parallel to the rear bumper of the vehicle and the bottom of the tire is located about 59 and ½ inches above ground level. This measurement was for the shored and secured configuration on the pallet, however, the spare tire on the aft accident

[22] The M-ATV's were loaded on one 96 x 238.5 inch G code pallet and the Cougars were loaded onto two sandwiched 96 x 238.5 inch G code pallets.

M-ATV was rotated about 90 degrees from its original position parallel to the ground and no longer in its upright vertical position (Figure 59).

Figure 58 - APB Cargo Liner Tire Witness Marks

Figure 59 - M-ATV tire rotated 90 degrees forward

Panel 411U2535-30 (Figure 61) from the CVR and FDR E8 rack also had tire witness marks. Ceiling panels 453U7135-1 (Figure 60), 845B3110-26 (Figure 62) and one other

panel with no part number identification but with an interior cabin light and grounding wire attached to it, had tire witness marks on them (Figure 65). There was evidence of multiple contacts between panel 845B3110-26 and a Michelin tire at opposing 90 degree angles (Figures 62 & 63). Another unidentified panel with tire witness marks was also recovered in the area of the aft M-ATV and the vertical stabilizer (Figure 64).

Figure 60 – Ceiling Panel 453U7135-1

Figure 61 – CVR/FDR Panel 411U2535-30

Figure 62 – Ceiling Panel 845B3110-26

Figure 63 - M-ATV Tire Tread Imprint

Figure 64 – Unidentified Panel

Figure 65 – Unidentified Panel with Interior Light Fixture & Grounding Cable

There were red paint transfer marks and material smearing on the bottom of a 20 foot aluminum G code pallet that was used for staging and loading the MRAP's. The pallet was recovered aft of the last M-ATV in the crater adjacent to the vertical stabilizer. The marks began at the forward edge of the pallet, common to a fracture, and moved aft in a right to left direction at a 103 degree angle relative to the plate centerline for about 3 feet. The witness marks then changed to a 30 degree left to right direction for about 4 feet. There were red paint transfer marks along both the 3 and 4 foot sections (Figures 66 &67). The material smearing was present on both the 3 and 4 foot sections and measure about 4 inches in width (Figure 66 & 67). There were two 4 inch circular witness marks with 1 and ¼ inch circular indentations in their center along the 4 foot section at about 20 and 48 inches from the beginning of the 30 degree witness mark. The caster trays are constructed from a 4 inch aluminum channel and house 1 and ¼ inch roller bearings in a 4 inch diameter plastic fixture (Figure 68). The aft end of the plate was curled down and back forward onto the surface of the plate containing the witness marks (Figure 69).

Figure 66 - 20 foot G code Pallet Witness Marks

Figure 67 - 20 foot G code Pallet Red Paint Transfer Marks & Material Smearing.

Figure 68 - Roller Bearing Witness Mark at 48 Inches

Figure 69 - Curled Deformation of a Partial G code Pallet

The upper collar fitting of the jack screw assembly had a longitudinal witness mark and material smearing exposing the bare aluminum under the green primer (Figures 70, 71 and 72). The jack screw is located aft of the APB and attached to the fuselage structure about 3 feet above the main cargo floor and the fitting was positioned about 8 feet above the main cargo deck floor (Figures 73, 74 and 75). The aft side of the M-ATV was about 8 feet 8 inches (104 inches) tall (Figures 39, 73 and 7571).

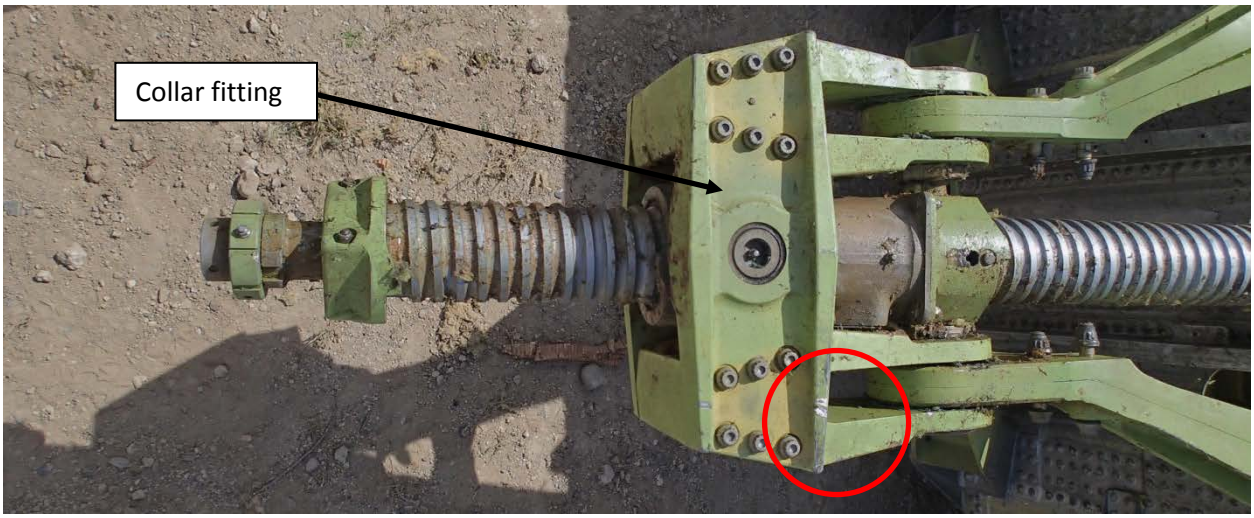

Figure 70 - Jack Screw Collar Fitting Witness Mark

Figure 71 - Jack Screw Collar Fitting Witness Mark Close-up

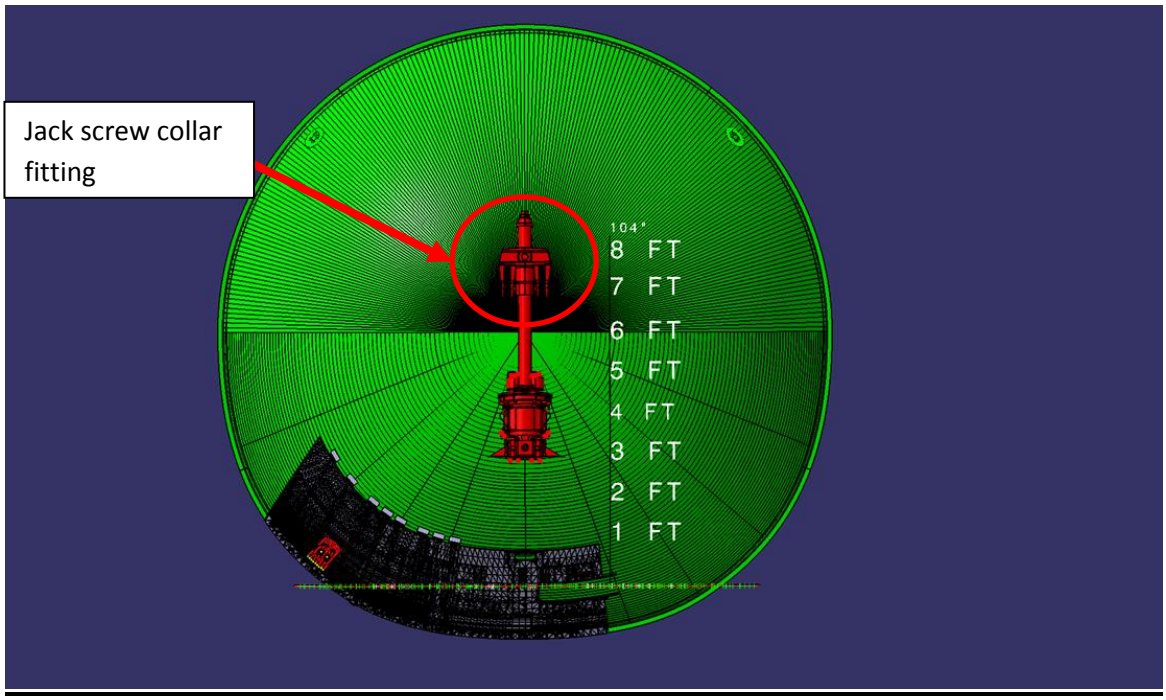

Figure 72 – Aft Pressure Bulkhead and Jackscrew viewed looking aft

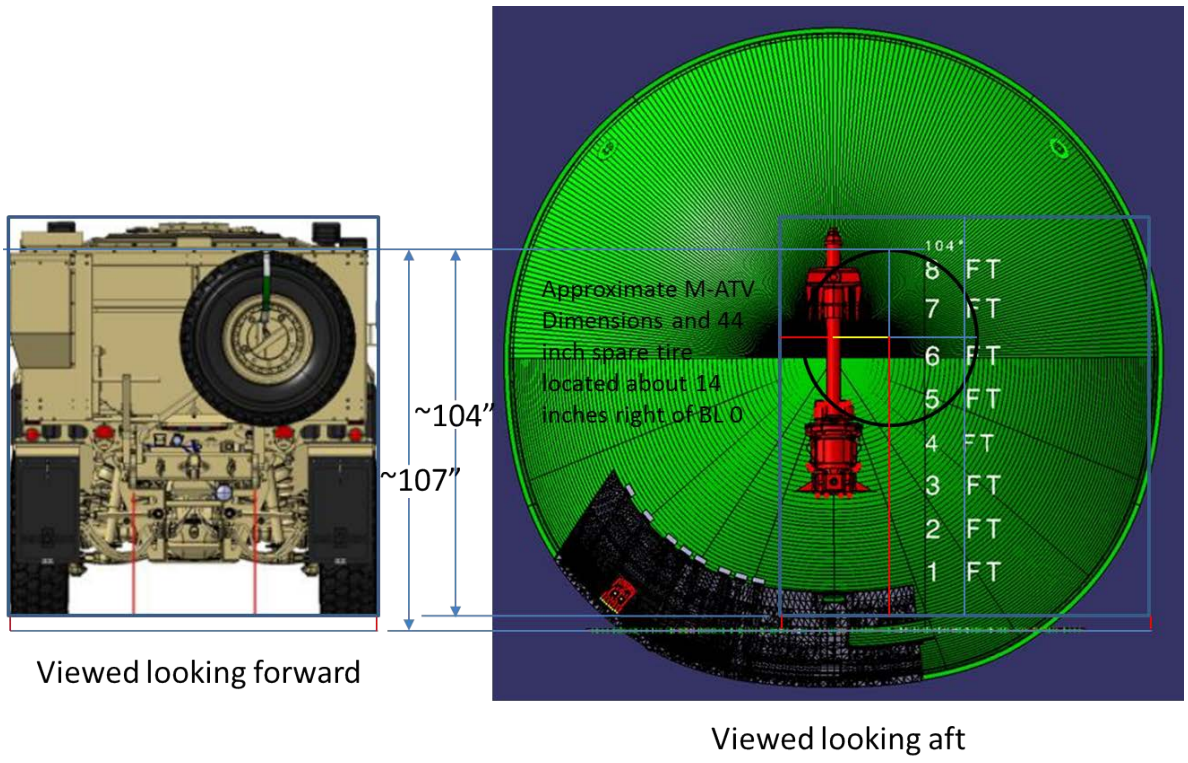

Figure 73 – Aft Pressure Bulkhead, Jackscrew and M-ATV viewed looking forward & aft

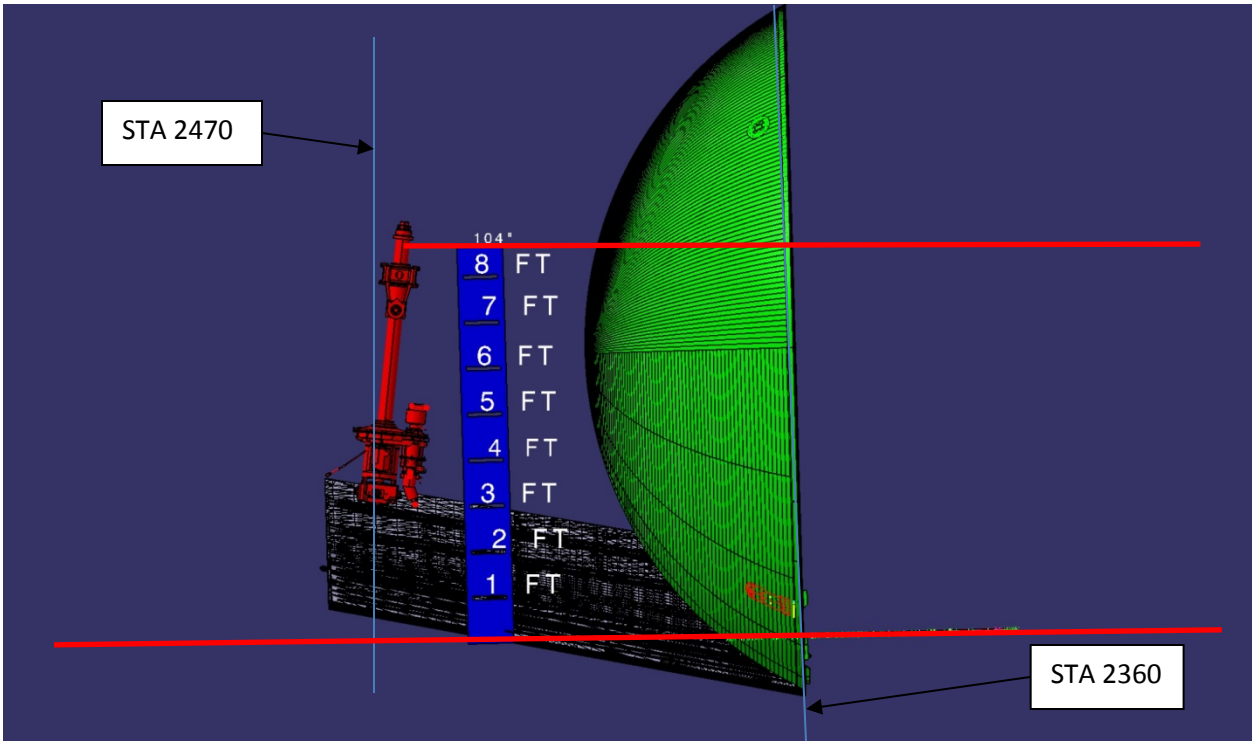

Figure 74 – Aft Pressure Bulkhead and Jackscrew side view

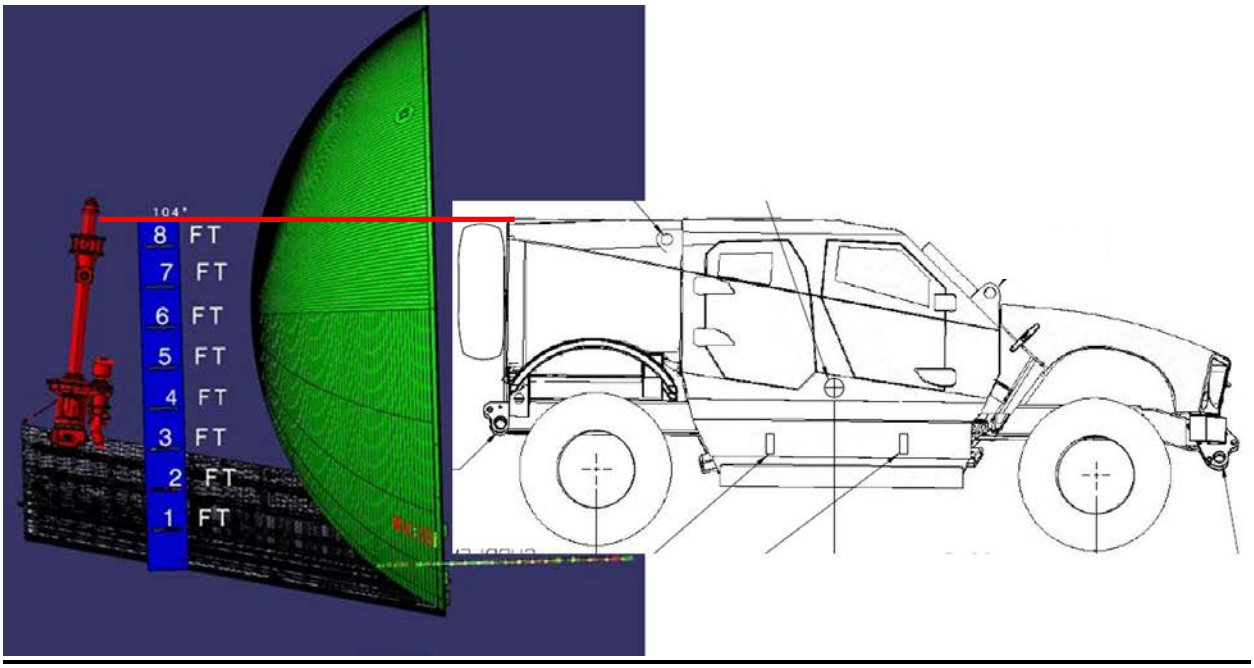

Figure 75 – Aft Pressure Bulkhead, Jackscrew and M-ATV side view #1

-ATV side view #3

The aft edge of the aft M-ATV was located at about STA 2218. The APB ties into the fuselage structure at STA 2360. Black tire transfer marks were located at STA 2412, aft of the original starting location and aft of the APB located at STA 2360 and the green dorsal fairing support structure just forward of the frame at STA 2412 (Figures 76, 77 and 78).

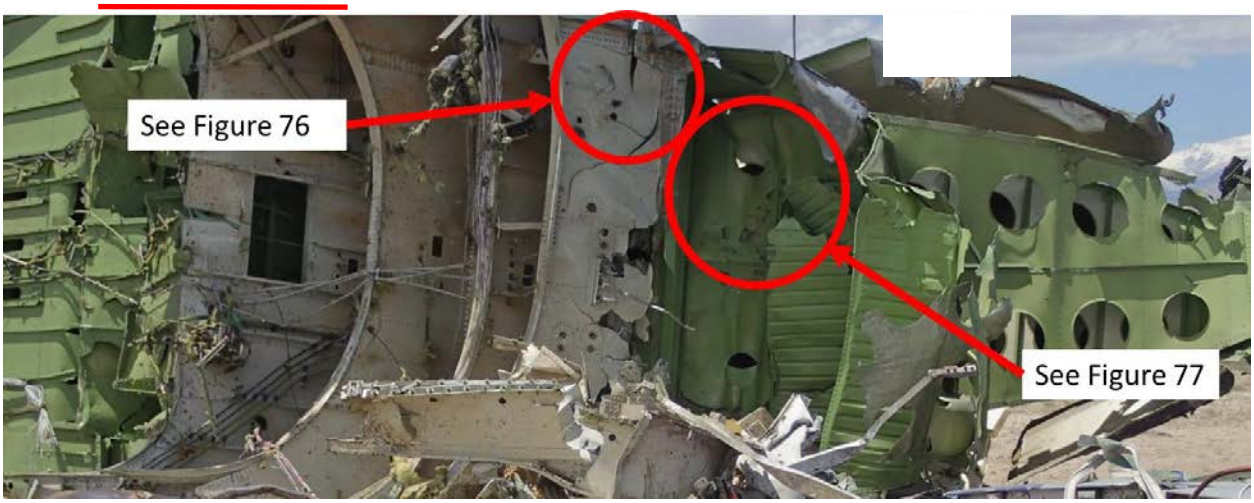

Figure 76 - Lower Side of the VTP Structure with Black Tire Transfer Marks at STA 2412

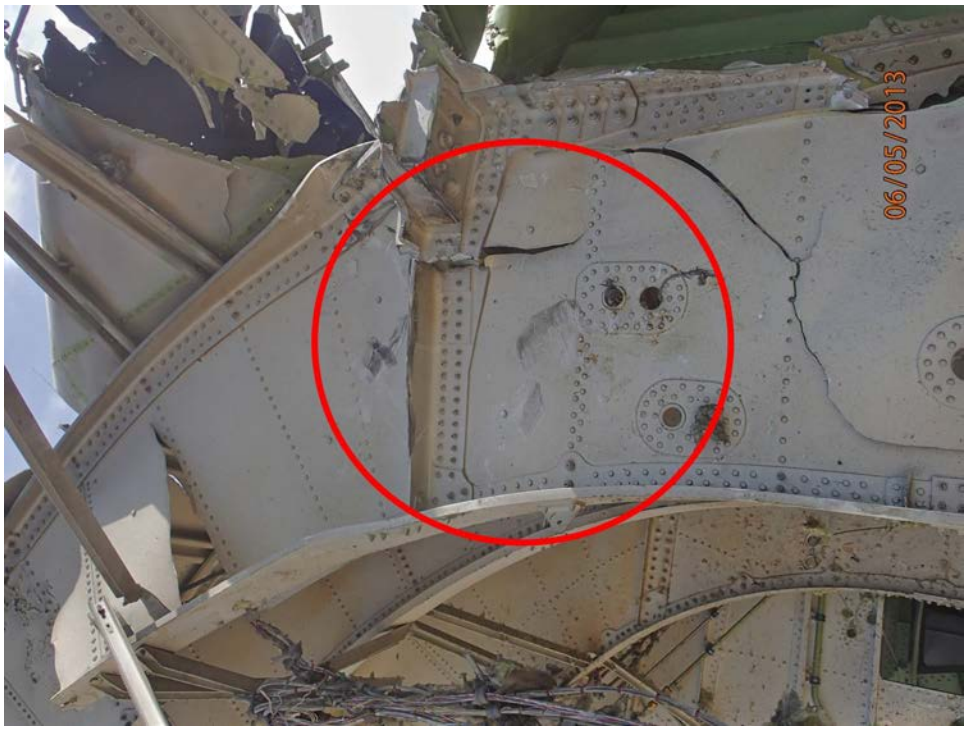

Figure 77 - Frame at STA 2412 Black Tire Transfer

Figure 78 - Vertical Stabilizer Dorsal Internal Structure with Black Tire Transfer

D.11. Weight and Balance and Loading Control

Per 14 CFR Part 21 it is required that an Airplane Flight Manual (AFM) be provided by the type certificate (TC)[23] and or Supplemental Type Certificate (STC)[24] holder to the owner of the airplane and that the airplane be operated in accordance with that AFM per 14 CFR Part 91. In addition, per 14 CFR Part 121 it is required that the air carrier certificate holder or operating certificate holder have in its manual the methods and procedures for maintaining the aircraft weight and center of gravity within approved limits. Furthermore, per these requirements it is required that the airplane be operated in accordance with the airplane manufacturer's and the main deck cargo handling system manufacturer's FAA approved Weight and Balance and Loading Control manuals[25].

D.12. National Airlines Strap Calculations

National Airlines (NAL) developed and used their own procedures and guidance[26] for tie-down strap calculations. NAL stated that they developed their procedures based on the Boeing and Telair Weight and Balance Manuals.

[23] Refer to reference 14.

[24] Refer to reference 15.

[25] Refer to references 1, 2 and 3.

[26] Refer to references 4 and 5.

There were five MRAP's loaded onto N949CA, two 12 ton M-ATV's and three 18 ton Cougars, as described in Table 1. All of the MRAP's were greater than 96 inches high and thus they all qualified as TRC. The MRAP's were not, however, loaded in accordance with the Boeing and Telair TRC requirements.

Based on the NAC employee witness statements the two M-ATV's were tied down using 24 straps and the three Cougar's were tied down using 26 straps[27] While on scene in Afghanistan the NAL Chief Loadmaster performed the following example strap calculations (Table 2 & Figure 79) for a 27,566 LBS (12,500 kg) or about a 12 ton M-ATV. The following load factors were used to calculate the required number of straps; 1.5G forward, 1.5G aft, 1.5G lateral and 2.2G vertical[28]. The strap allowable load was 5,000 LBS (2,267 KG). NAL incorporated an additional safety factor of 75% in their strap calculations and reduced the strap allowable load to 3,750 LBS (1,700 KG). The NAL guidance further assumed that all of the straps were installed at 30 degree angles when measured relative to both the airplane centerline and the airplane floor. They further assumed that all of the floor attachment points were capable of reacting 3,750 LBS (1,700 KG) in all three directions, forward and aft, lateral and vertical, simultaneously.

The Boeing and Telair manuals defined individual tie down allowable loads for single and double stud attach fittings inserted into the cargo system side rails, end stops, center guides, pallet lock tie down rings and the available seat tracks. These manuals defined allowable loads that can be applied to the attach fittings in terms of 0, 30, 60, and 90 degree increments when measured relative to both the airplane centerline and airplane floor. These allowable loads vary in magnitude from an allowable load of 0 LBS up to 5,000 LBS. The full capability of the attach fittings varies depending on the measured strap angle and the location of the attach fitting on the airplane. It was incorrect for NAL to assume that every fitting had the capability to react 3,750 LBS (1,700 KG) in every direction. For example the NAL guidance stated the following with regard to seat tracks,

> *"The total load of supplemental tie down attached to any 20-inch stretch of seat track must not exceed 5,000 LBS. A tie down is only as strong as its weakest link. Therefore a 5,000 LB strap with a single stud D-ring attached to seat track has a maximum load of 2,500 LBS vertical or 2,000 LBS non-vertical. If a double stud attachment or D-ring is used, the tie down is good for 5,000 LBS vertical, but only 4,000 LBS at any other (angle)"*[29].

The most any seat track attachment can react is 2,769 LBS per the Boeing Weight and Balance Manual. Boeing and Telair guidance also stated that each tie down fitting may only be used to react load in one direction, forward, aft, side or vertical. A tie down fitting may not be used to react load in multiple directions as described by NAL in this example.

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[27] The LM will check the cargo before departure to ensure all the nets, straps and chains are tightened. Any items that are found to need additional restraint will be secured before departure. Special attention should be paid to items loaded on top of nets, pipes and small items. Refer to reference 4 section 12.4 page 10-26.

[28] Reference 4 cites a vertical load factor of 2.6G on all aircraft, refer to section 12.13 page 10-33.

[29] Refer to reference 4 section 4.2 page 6-6.

Using the NAL guidance 12 straps were required to restrain a vehicle with an estimated weight of 27, 566 LBS (12,500 KG) in both the forward and aft directions. Per the NAL Cargo Operations Manual each of these straps, 12 forward and 12 aft, were considered to be able to react 3,750 (LBS) (1,700 KG) each for a total of 45,000 LBS (20,400 KG) in both the forward and aft directions (Figures 80 & 81). Based on the NAL manual these 24 forward and aft straps could also be used to restrain 3,750 LBS (1,700 KG) (Table 2) each in both the lateral and vertical directions. In order to restrain the vehicle from moving laterally, the manual requires that a minimum of 12 of the 24 forward and aft straps are to be utilized in each direction, to the left and to the right (Figures 82 & 83). and At least 24 straps could be used to restrain the vehicle in the vertical direction (Figure 84). These calculations also assumed that an infinite number of tie down points existed on the MRAP's. At the time of the accident there were only four approved tie down points on each MRAP[30], two on the front bumper and two on the rear bumper.

$$\#of\ straps^{31} = \frac{weight * Load\ Factor\ (LF)}{1{,}700\ kg}{}^{32}$$

If strap angle is not 30 degrees you may not use it for vertical restraint					
Strap Allowable Load 2,267 kg			2,267 kg x 75% = 1,700 kg		
Required Restraint Load			Required Number of Straps		
Forward	1.5 x 12,500 kg =	18,750 kg	18,750 kg / 1,700 kg =	11	12
Aft	1.5 x 12,500 kg =	18,750 kg	18,750 kg / 1,700 kg =	11	12
Left	1.5 x 12,500 kg =	18,750 kg	18,750 kg / 1,700 kg =	11	12
Right	1.5 x 12,500 kg =	18,750 kg	18,750 kg / 1,700 kg =	11	12
Vertical	2.2 x 12,500 kg =	33,750 kg	33,750 kg / 1,700 kg =	19.8	20

Table 2 – National Airlines on scene Example Tie Down Strap Calculations

[30] Refer to references 6, 7 and 8.

[31] The total strap number is rounded up to the next highest even number.

[32] Refer to reference 4 section 12.13 page 10-33.

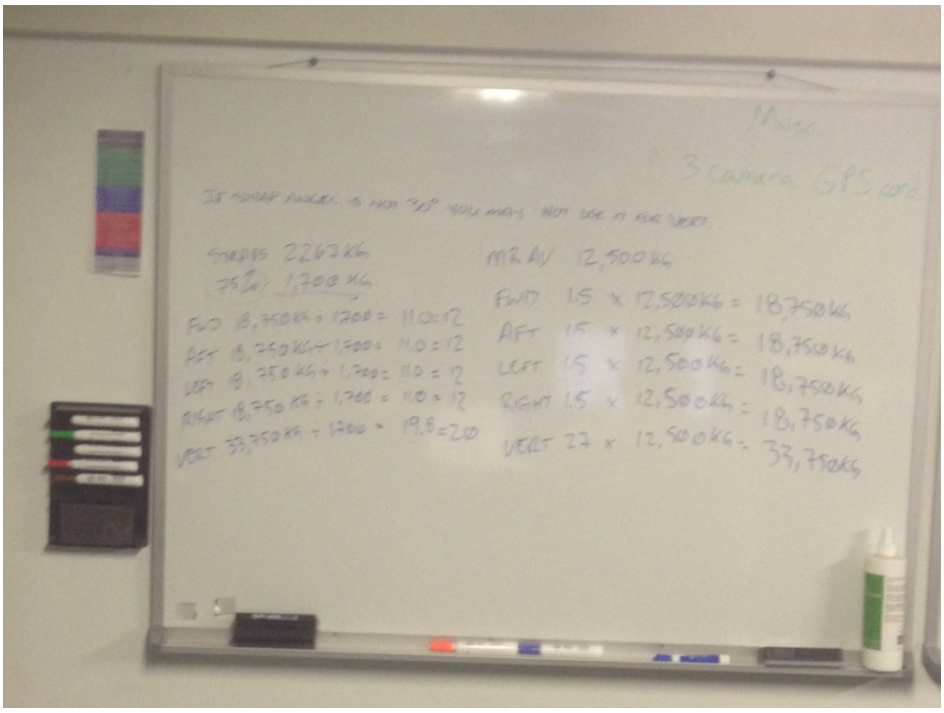

Figure 79- National Airlines Tie Down Strap Calculations[33]

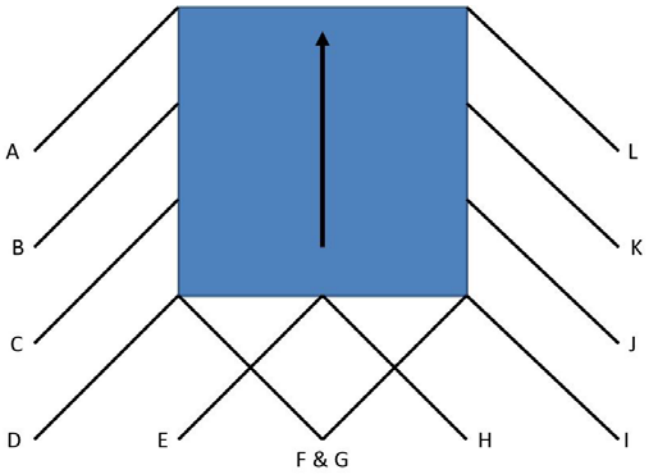

Figure 80 - NAL Forward Restraint Example Calculation (12)

[33] Calculations provided by NAL Chief Loadmaster while on scene in Afghanistan.

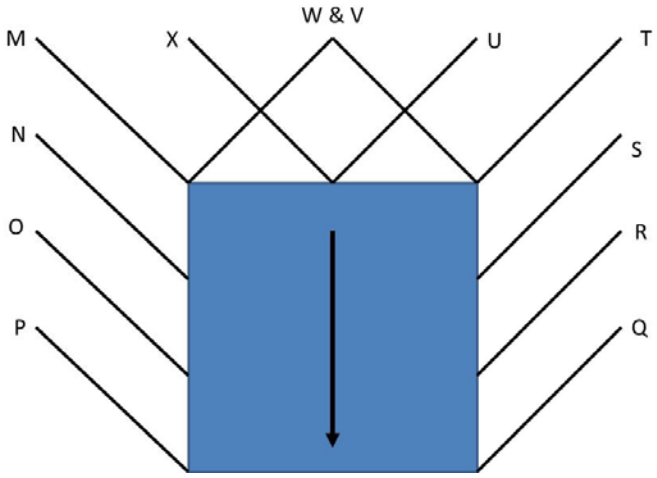

Figure 81 - NAL Aft Restraint Example Calculation (12)

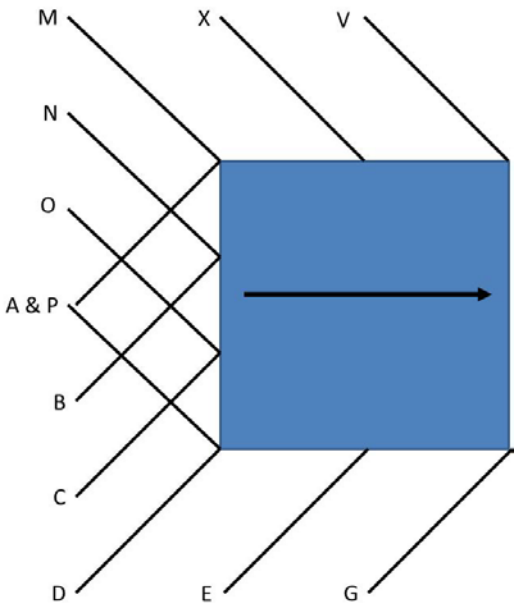

Figure 82 - NAL Lateral Restraint Example Calculation (12)

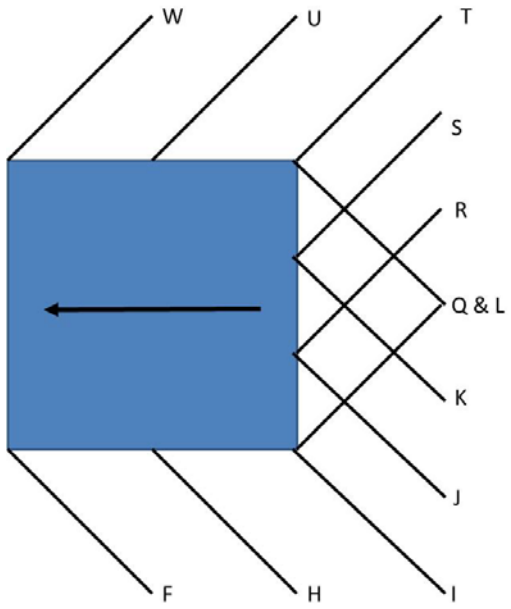

Figure 83 - NAL Lateral Restraint Example Calculation (12)

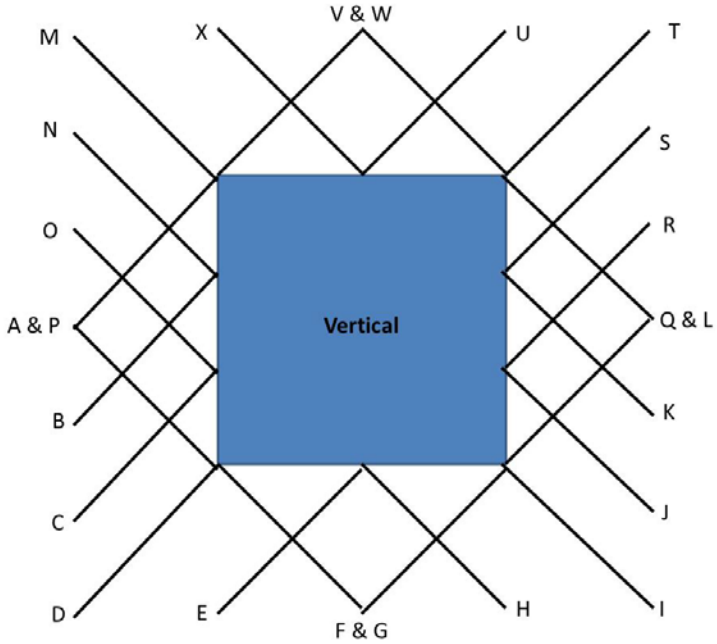

Figure 84 - NAL Vertical Restraint Example Calculation (24)

According to the National Air Cargo (NAC) employees located at Camp Bastion that loaded the vehicles onto the accident airplane twenty-four 5,000 LB rated straps were used to

secure each of the two M-ATV's and twenty-six 5,000 LB rated straps were used to secure each of the three Cougars.

While on the ground at Bagram, there was a discussion recorded on the CVR amongst the crew concerning cargo movement that occurred sometime during the flight into Bagram. The crew discussed a broken strap, with one utterance that was unclear and sounded like "strap" or "trap" or possibly "track". The crew further discussed some straps that had loosened and a load movement of "a couple inches". The Captain commented about heavy cargo not having a "lock" (the loads on this flight did not use floor locks to secure the pallets). The MRAPs were centerline loaded floating cargo. Straps were used to secure the MRAPs to the main deck.

During a subsequent meeting after the investigation team returned from Bagram, the NAL Chief Loadmaster used the following revised vehicle weights, load factors for his strap calculations. The weight of the cargo to be restrained in each direction is detailed in Table 3. For the revised calculations NAL used the following load factors to calculate the load to be restrained 1.5G forward, 1.5G aft, 2.0G side and 2.5G up[34].

	Vehicle	Weight (LBS)	Forward (LBS)	Aft (LBS)	Lateral (LBS)	Vertical (LBS)
1st	M-ATV	27,809	41,713	41,713	55,618	69,522
2nd	Cougar	41,107	61,660	61,660	82,214	102,767
3rd	Cougar	40,640	60,960	60,960	81,280	101,600
4th	Cougar	39,749	59,623	59,623	79,498	99,372
5th	M-ATV	27,743	41,614	41,624	55,486	69,357

Table 3 - National Airlines Factored Vehicle Weights

[34] Reference 4 cites G loads of 1.5G (forward, aft, lateral) and 2.6G vertical, refer to section 12.13 page 10-33.

The strap allowable was 5,000 LBS. Incorporating a NAL safety factor of 75% the strap allowable was reduced to 3,750 LBS.

$$\#of\ straps^{35} = \frac{weight * Load\ Factor\ (LF)}{5{,}000\ lbs * 0.75}\ ^{36}$$

	Vehicle	Minimum # of Forward Straps	Minimum # of Aft Straps	Minimum # of Left Straps	Minimum # of Right Straps	Minimum # of Up Straps	NAL Total Number of Straps
1st	M-ATV	12.00	12.00	16.00	16.00	20.00	32
2nd	Cougar	18.00	18.00	22.00	22.00	28.00	46
3rd	Cougar	18.00	18.00	22.00	22.00	28.00	46
4th	Cougar	16.00	16.00	22.00	22.00	28.00	44
5th	M-ATV	12.00	12.00	16.00	16.00	20.00	32

Table 4 – National Airlines Strap revised Calculations

The revised NAL calculations again assumed that all of the straps were installed at 30 degree angles to both the airplane centerline and the airplane floor and that the floor attachments were all capable of reacting 3,750 LBS in all three directions, forward and aft, lateral and vertical, simultaneously. The Boeing and Telair manuals defined individual tie down allowable loads for single and double stud fittings inserted into the cargo system side rails, end stops, center guides, pallet lock tie down rings and the available seat tracks.

Using the NAL guidance 12 straps were required to restrain the 1st vehicle, an M-ATV weighing 27,809 LBS, in each of the forward and aft directions. In addition, 12 straps were required to restrain the aft vehicle, another M-ATV weighing 27,743 LBS, in each of the forward and aft directions. Per the NAL Cargo Operations Manual each of these straps, 12 forward and 12 aft, were considered to be able to react 3,750 LBS each for a total of 45,000 LBS in both the forward and aft directions (Figures 85 & 86). This value was greater than the NAL required values of 41,626 LBS and 41,527 LBS. Based on the NAL Cargo Operations Manual these 24 forward and aft straps could also be used to restrain 3,750 LBS in both the lateral and vertical directions. This statement was contrary to the airplane manufacturer's and the main deck cargo handling system manufacturer's Weight and Balance Manual requirements.

In order to restrain the vehicle from moving laterally to the left 12 of the forward and aft straps were utilized along with 4 additional straps. These 16 straps would provide 60,000 LBS of lateral restraint. This value was greater than the NAL required values of 55,502

[35] The total strap number is rounded up to the next highest even number per NAL guidance.

[36] Refer to reference 4 section 12.13 page 10-33.

LBS and 55,370 LBS. (Figures 87 & 88). According to the NAL Cargo Operations Manual these 32 straps could all be used to restrain the vehicles in the vertical, forward, aft and lateral directions. This approach was contrary to the airplane manufacturer's and the main deck cargo handling system manufacturer's Weight and Balance Manual requirements.

Based on the NAL guidance 69,377 LBS and 69,212 LBS needed to be reacted for each of the M-ATV's in the vertical direction. Using the NAL guidance the 32 straps will provide 120,000 LBS in the vertical direction (Figure 89). This value was greater than the NAL required values of 69,377 LBS and 69,212 LBS. Per the NAL Cargo Operations Manual and the Cargo Operations Manager the M-ATV's could be carried by attaching 32 straps (Table 4) to each vehicle and to any part of the airplane as long as the attachment points were separated by 20 inches or more. The strap angles and airplane attach fitting allowables are not considered in their guidance. This was contrary to both the airplane manufacturer's and the main deck cargo handling system manufacturer's Weight and Balance Manual requirements.

Following the same procedure the NAL Cargo Operations Manager determined that two of the cougars would require 46 straps and the lighter of the three Cougars would require 44 straps to be secured to the airplane using NAL guidance.

Per the Bagram Operations Special Report the two M-ATV's were tied down using 24 straps and the three cougars were tied down using 26 straps. As a result, the two M-ATV's and three cougars were not tied down in accordance with NAL guidance which was contrary to the airplane manufacturer's and the main deck cargo handling system manufacturer's Weight and Balance Manual requirements. The NAL guidance did not take into account strap angles or fitting allowable loads. The NAL guidance also incorrectly assumed that an infinite number of tie down points existed on the MRAP's. At the time of the accident there were only four approved tie down points on each MRAP[37], two each on the front and rear bumpers.

[37] Refer to references 6, 7 and 8.

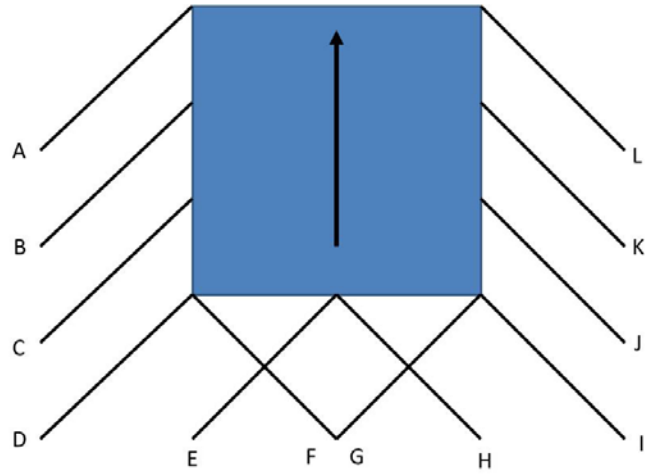

Figure 85 - NAL Straps Needed to Restrain Forward Loads (12)

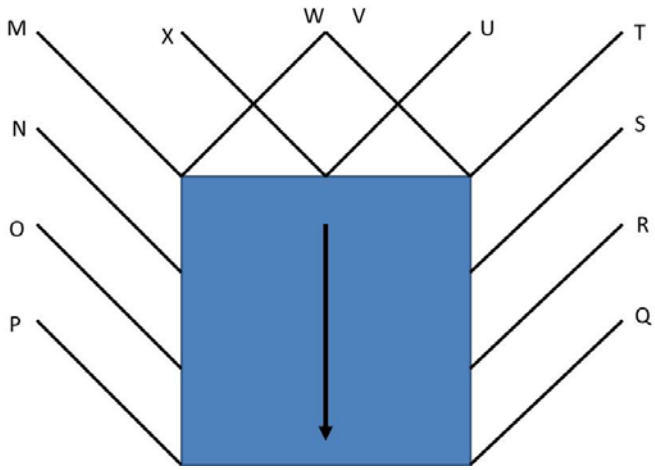

Figure 86 - NAL Straps Needed to Restrain Aft Loads (12)

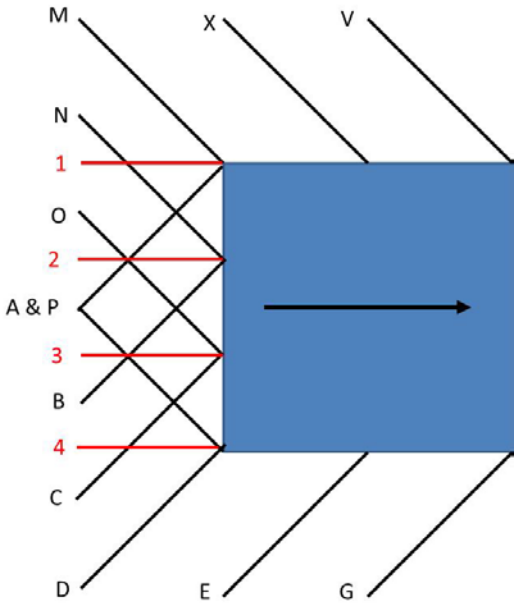

Figure 87 - NAL Straps Needed to Restrain Right Loads (16)

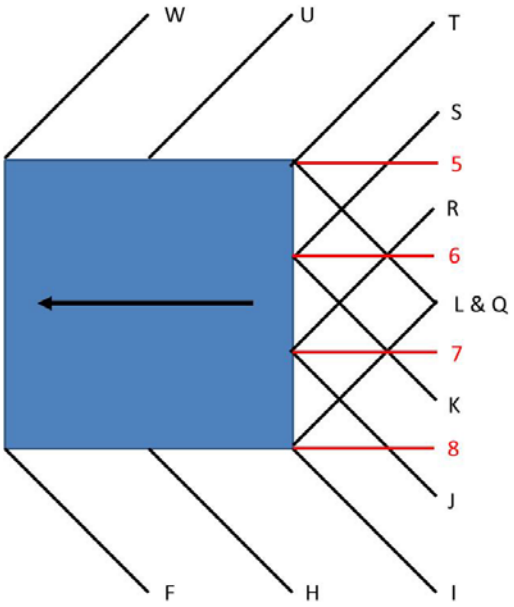

Figure 88 - NAL Straps Needed to Restrain Left Loads (16)

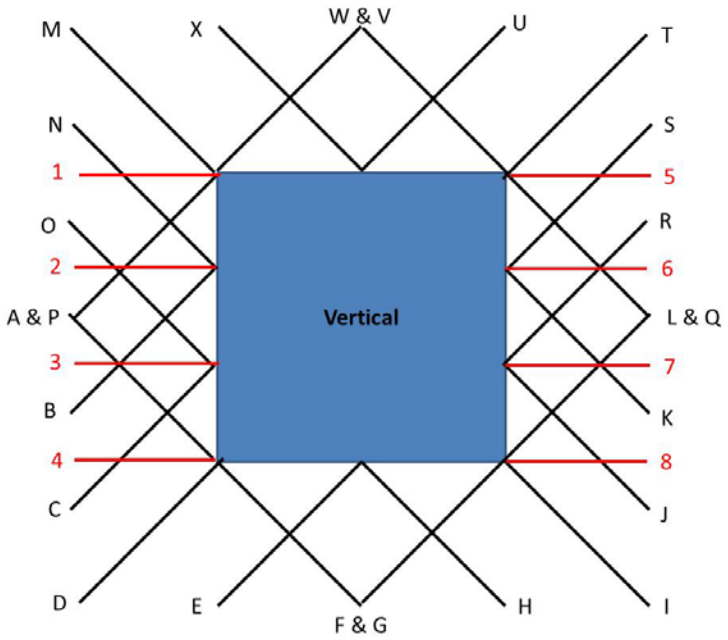

Figure 89 - NAL Straps Needed to Restrain Vertical Load (32)

D.13. Tie Down Studies

The airplane manufacturer, Boeing, and the main deck cargo handling system manufacturer, Telair, performed studies to determine how many MRAP's could be transported safely using their respective weight and balance manuals. Their analyses assumed that only four tie down points existed on each of of the MRAP's,. two each on the front and rear bumpers. For the purposes of their studies it was assumed that vertical restraint could be achieved by strapping over the top of the MRAP.

D.13.1. Boeing

For their analysis an M-ATV was assumed to be centerline loaded as TRC[38] that exceeded 96 inches in height and that frangible cargo rather than the additional tie downs would be used for the 9G forward restraint. The volume of the cargo forward of the TRC was calculated and it was determined that the volume was sufficient to stop the TRC from moving forward.

Per their guidance for TRC Boeing concluded that frangible cargo needed to be loaded in positions A1, A2, B1, CL and CR and that a M-ATV could be centerline loaded as far forward as position H, B.A. 1281 (Figure 90), provided there was enough access to the required number of attachment points. They also concluded that there could be as many as 12 size M code pallets of combined frangible and rigid cargo loaded forward of the M-ATV

[38] Refer to reference 2 Section1-64-901 and section 1-69-121.

and pallet combination in positions D thru H. The use of frangible cargo would be in lieu of restraining the M-ATV for 9 G's forward.

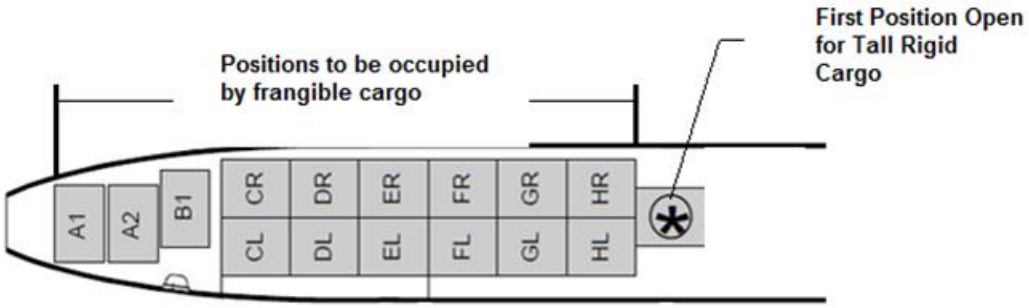

Figure 90 - Frangible and rigid Cargo Positions[39]

Per the guidance in their weight and balance manual Boeing determined that the cumulative effective volume of the cargo in positions A thru H to be 7,655 CU FT. The maximum allowable weight of cargo that can be stopped by a volume of 7,655 CU FT is 148,703 LBS and greater than the 27,809 LBS M-ATV[40].

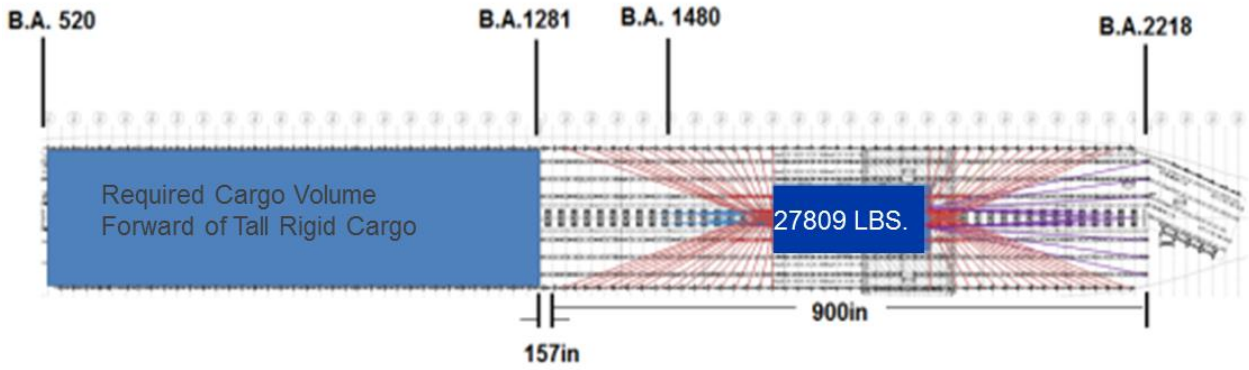

Figure 91 - Boeing M-ATV Tie Down

For their study Boeing used the following G load factors: 1.5G forward, 0.75G aft, 1.45G side and 2.20G up. Boeing determined that it would require 900 inches of linear space and sixty 5,000 LB rated straps to tie down one M-ATV weighing about 27,809 LBS (12,614 KG) (Figure 91). For their study Boeing utilized all available tie down points including the available seat tracks and also allowed for the movement of the pallet locks as necessary to gain additional tie down points forward and aft of the MRAP's (Tables 5 & 6).

[39] For this loading, the required frangible cargo is loaded in Positions A1, A2, B1 and CL/CR, refer to reference 2 section 1-69-121 page 2.

[40] Refer to Reference 10.

Restraint Direction	M-ATV Tie Down Point	Number of Aircraft Tie Down Points	Aircraft Tie Down Type
Aft	Left Front Bumper	5**	Seat Track
		1**	Center Guide
	Right Front Bumper	5**	Seat Track
		1**	Center Guide
Left Side	Left Front Bumper	17*	Side Guide
	Left Rear Bumper	15*	Side Guide
Right Side	Right Front Bumper	17*	Side Guide
	Right Rear Bumper	15*	Side Guide
Forward	Left Rear Bumper	3**	End Stop
	Left Rear Bumper	2**	Center Guide
	Left Rear Bumper	5**	Seat Track
	Right Rear Bumper	3**	End Stop
	Right Rear Bumper	2**	Center Guide
	Right Rear Bumper	5**	Seat Track
Up	Over the Top	12	Seat Track
	Over the Top	8	Pallet Lock

Table 5 – Boeing M-ATV Tie Down Details, * Two fittings per strap with the remaining fitting attached to a single strap. ** Two fittings per strap. Each strap runs thru both bumper fittings and similar attach fittings on opposite sides of the airplane.

Restraint Direction	# of Straps	G Load
Aft	6	0.75
Left	17	1.45
Right	17	1.45
Forward	10	1.50
Up	10	2.20

Table 6 - Boeing Strap Summary

Boeing concluded that, at most, one M-ATV could be transported safely per the Boeing weight and balance manual provided enough airplane tie down points existed.

Boeing also studied the loading of the heavier 18 ton Cougar aft of B.A. 1220[41]. Boeing determined that a Cougar could not be properly loaded and secured without exceeding the structural strength limitations of the main deck cargo floor.

In order to satisfy the cargo volume requirements forward of the TRC the Cougar would have to be loaded aft of B.A. 1281, same as the M-ATV. A minimum of 900 inches of linear space would be required to secure a M-ATV aft of B.A. 1281, requiring the heavier

[41] The most forward position for tall rigid cargo that is 118 inches tall is B.A. 1220. The Cougar and double pallet combination measure 121 inches tall refer to reference 2 section 1-69-121 page 2 and.

Cougar to be secured at least as far aft as the M-ATV, resulting in the Cougar being located in a position aft of B.A. 1480 (Figure 91). Due to the running load per foot limitations aft of B.A. 1480 it was not possible to carry a Cougar. The linear load limit for centerline loaded cargo based on a 96" pallet width is approximately 155 LBS per inch (Figure 89). The running loads per inch for each Cougar are 172[42], 170 and 167 LBS per inch. To utilize the 170 LBS per inch running load on a centerline load aft of STA 1480, the cargo needs to be shored to a width of 117 inches (Figure 92).

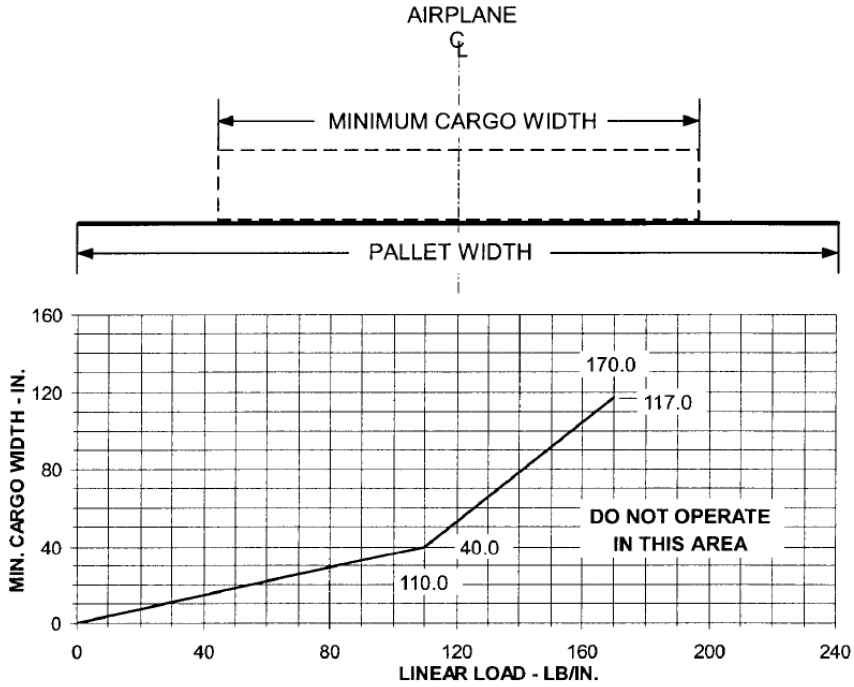

Figure 92 – Cargo Width versus Linear Load LB/IN

D.13.2. Telair

Telair also performed a tie down study[43]. Per their Weight and Balance manual guidelines[44], Telair determined that no MRAP's could be transported per Telair guidelines[45]. When Telair drafted its Weight and Balance manual in 2005, it used Boeing's B747-400F Weight

[42] Position #2 Cougar 41,107 LBS (18,646 KG), position #3 Cougar 40,640 LBS (18,434 KG) and position #4 Cougar 39,749 LBS (18,030 KG).

[43] It is important to note that the NTSB requested Telair to disregard the tall rigid cargo requirements set forth in the Telair WBM and Boeing WBM. These portions of the Telair studies, which are included in references 11 and 12, were conducted for theoretical and informational purposes only. Operators are not allowed to disregard the tall rigid cargo requirements of the Telair WBM or the Boeing WBM. Refer to references 11 and 12 and Figures 93 thru 97. For illustrative purposes only. All TRC requirements were ignored for the example tie down schemes.

[44] Refer to reference 1.

[45] Refer to references 11 and 12.

and Balance manual[46] available at the time. Boeing's manual at that time stated: "There must be a minimum of the equivalent of seven 125 inch long loaded ULDs positioned directly forward of the TRC greater than 96 inches in height." Boeing has, since 2005, revised its manuals such that the phrase "directly forward" no longer appears and allows for a space between the TRC and the ULD's directly forward of the TRC. [47] The manual contained a footnote which stated that "[t]his restriction does not apply if the ULD with rigid cargo over 96 IN. in height, and all ULD positions aft of it, are restrained to a 9G forward load factor." These statements appear verbatim in the Telair Weight and Balance Manual in section 11.1.2. Telair did not revise its Weight and Balance Manual to reflect this change. Telair has explained that they do not believe the new language in the Boeing Weight and Balance Manual has altered the requirement that, when following the frangible cargo requirements for TRC, ULDs must be loaded directly in front of the TRC. Thus, under the Telair Weight and Balance Manual, seven 125 inch long ULDs must be placed directly forward of the TRC in order to meet the frangible cargo requirements. Alternatively, the TRC and all cargo aft thereof, must be restrained to 9G forward[48]. Telair determined that it was not possible to restrain even one MRAP on the accident airplane to the 9G[49] forward requirement using straps, given the available number of tie down points and the strapping allowables (Figure 98)[50]. Thus, under the Telair Weight and Balance Manual, the requirement to have seven 125 inch long loaded unit load devices positioned directly forward of the TRC greater than 96 inches in height would have to remain in effect. Due to the weight of the vehicles at issue, the number of straps required to secure them, and the foregoing frangible cargo requirements, Telair concluded that it was not possible to load any MRAP's on the accident airplane due to the inability to access the required tie down points forward of the TRC to properly secure it.

[46] Refer to reference 3 section 1-64-123 Revision July 31, 2003.

[47] As of September 22, 2005, Boeing now allowed for a volumetric calculation of frangible cargo specific to the load being carried per flight, which will allow for space between the TRC and the ULD's forward of that TRC, refer to reference 2 section 1-69-121 and reference 3 1-69-120.

[48] Note the MRAP tie down points are certified to only 3G's forward. Refer to references 6, 7 and 8.

[49] Refer to reference 13.

[50] It was not possible to safely and properly secure a M-ATV vehicle in any location to the 9G forward requirement using straps. Refer to reference 13.

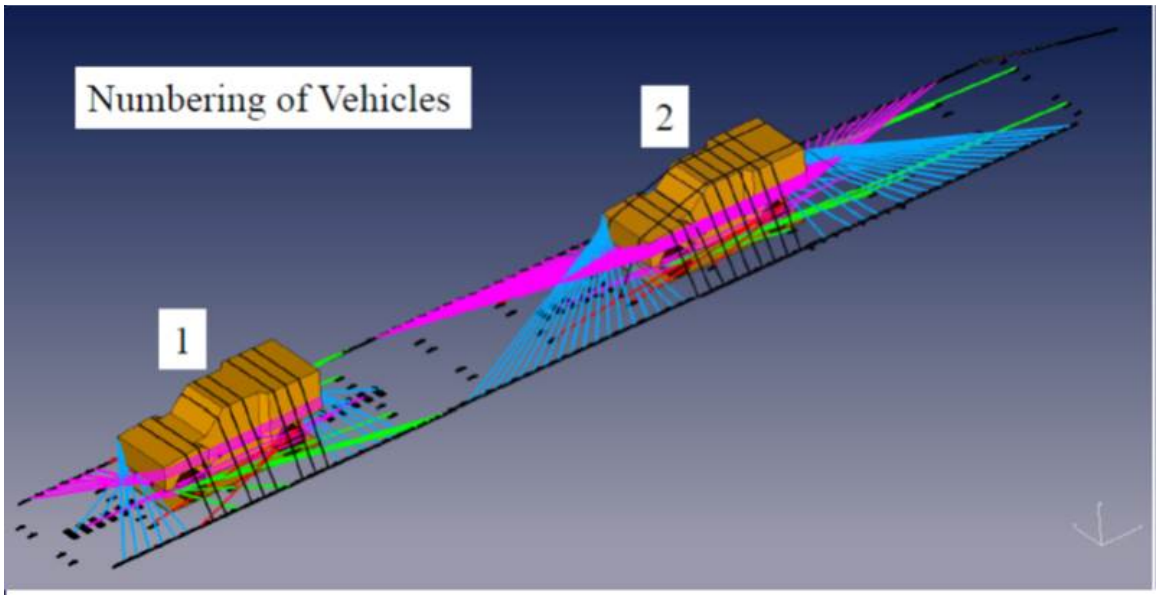

Figure 93 - Example of tie down requirements and spacing for two 12 ton M-ATV's (72 & 122 straps). For illustrative purposes only.[51]

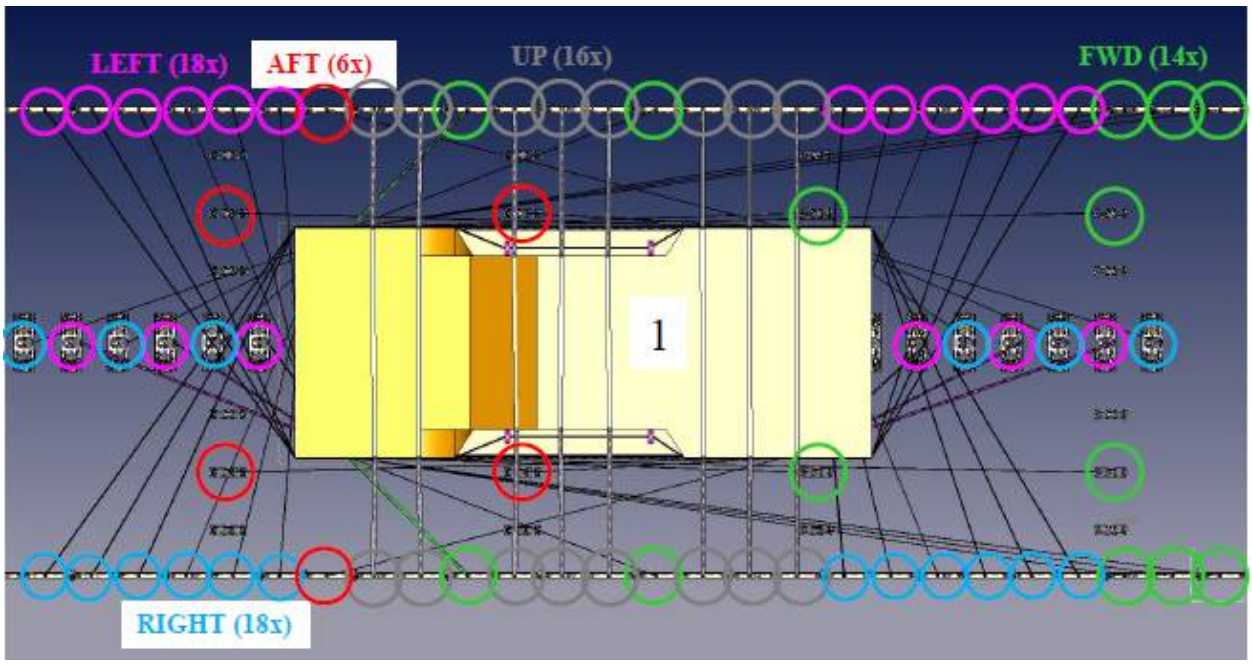

Figure 94 - Example of tie down requirements for M-ATV #1 (36 straps). For illustrative purposes only.

[51] This example is for illustrative purposes only to show the required number of straps and amount of linear space required to secure two M-ATV's while ignoring all TRC requirements. Refer to reference 11.

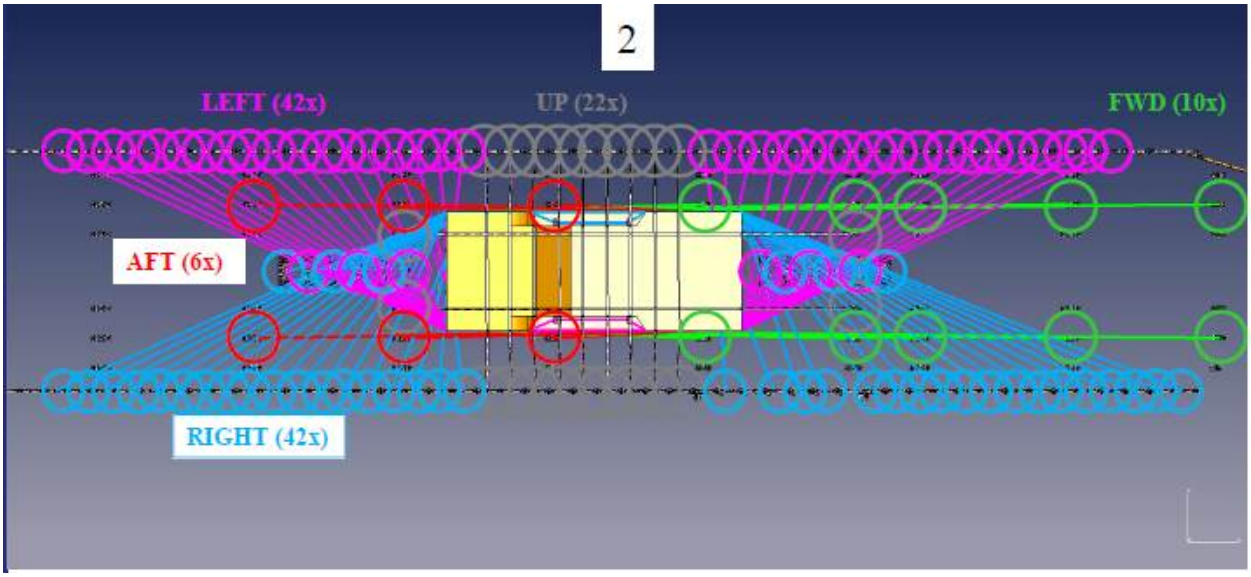

Figure 95 - Example of tie down requirements for M-ATV #2 (61 straps). For illustrative purposes only.

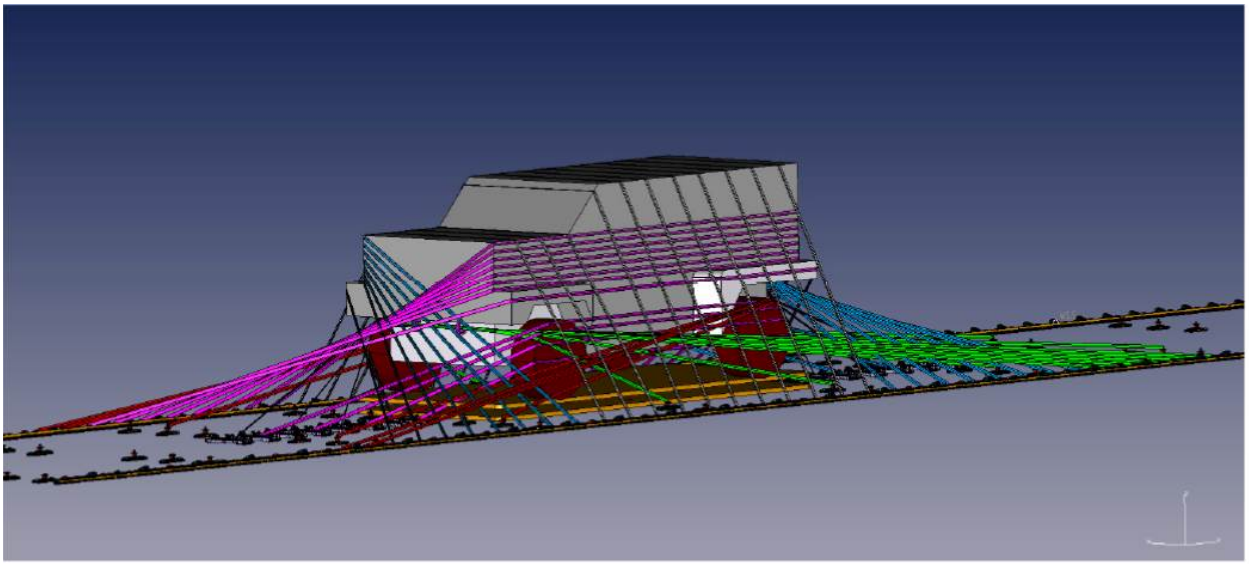

Figure 96 - Example of tie down requirements for one 18 ton Cougar (48 straps). For illustrative purposes only.[52]

[52] This example is for illustrative purposes only to show the required number of straps and amount of linear space required to secure two M-ATV's while ignoring all TRC requirements. Refer to reference 12.

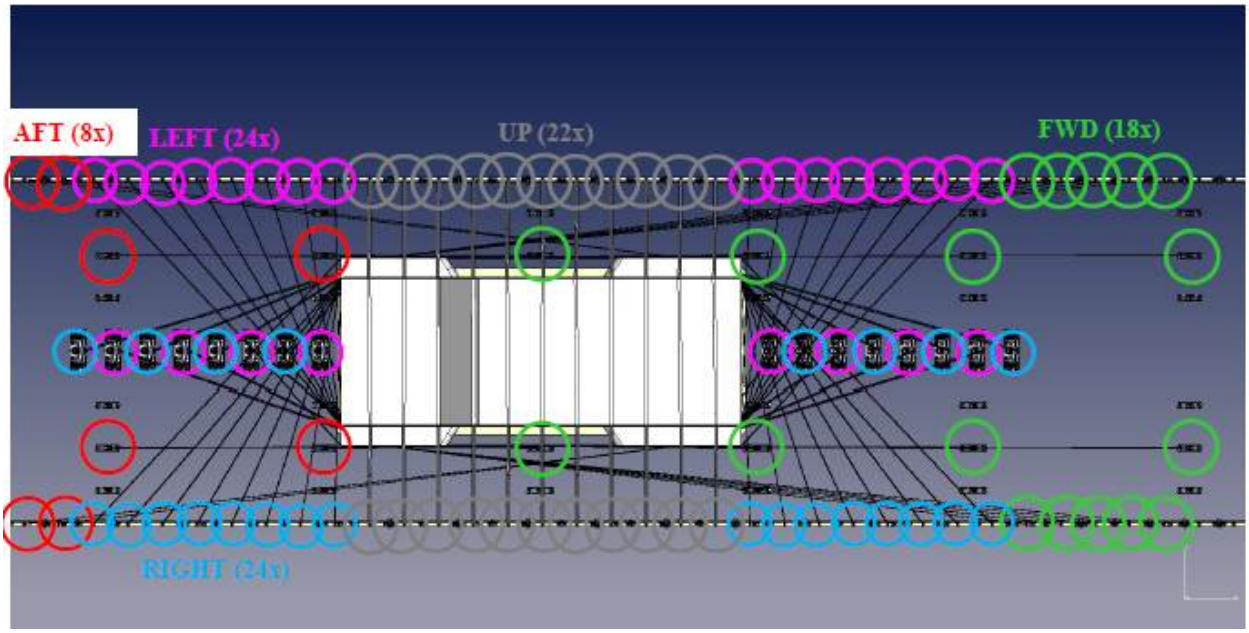

Figure 97 - Example of tie down requirements for a Cougar (96 straps). For illustrative purposes only.

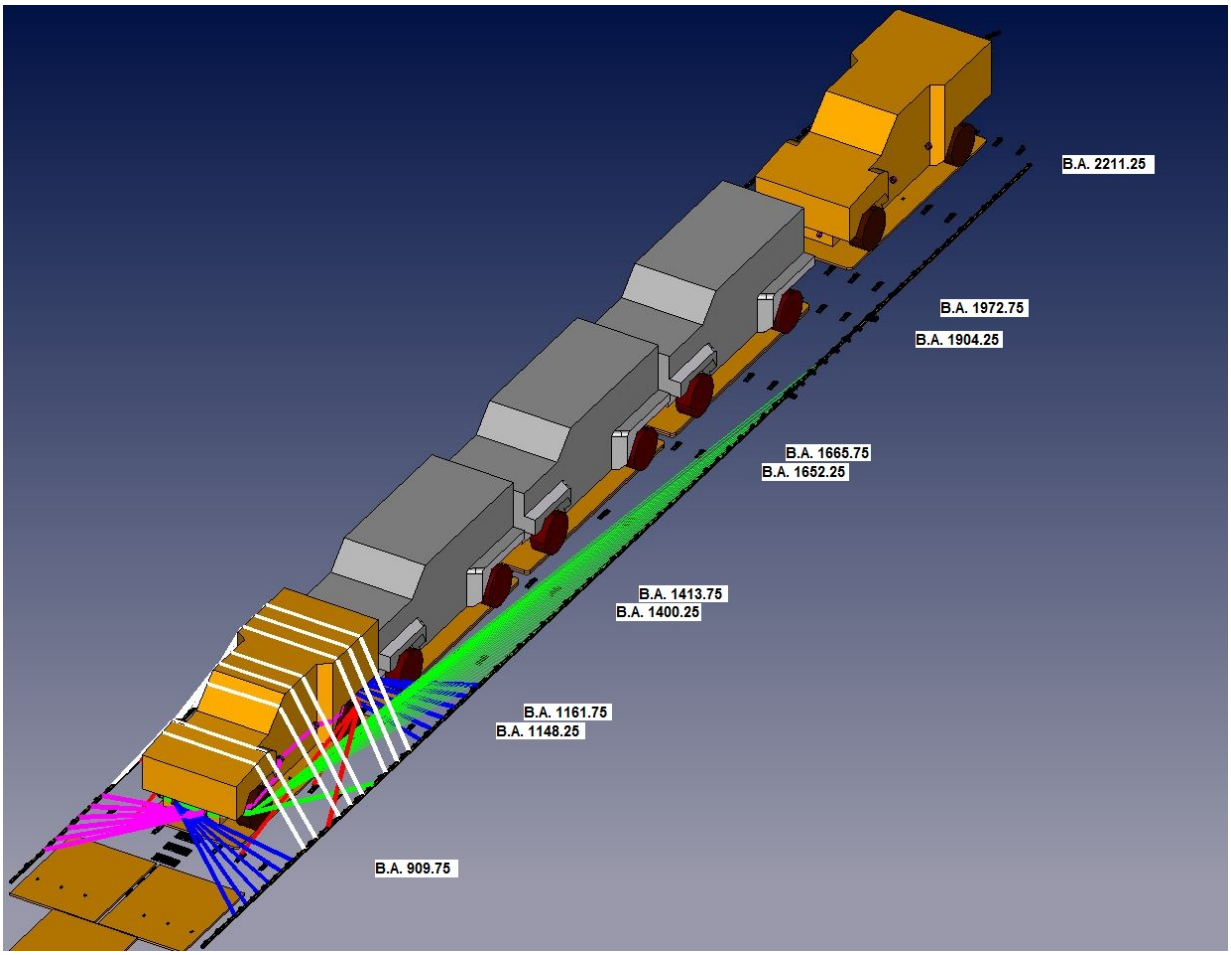

Figure 98 - Example of M-ATV restrained to 9G's forward. For Illustrative purposes only.

Submitted by;

Brian K Murphy