## Loss of overwing slide, Boeing 747SP-100, N204 AE

**Micro-summary:** **This Boeing 747SP lost its overwing escape slide on approach.**

**Event Date:** **1996-08-24 at 1120 UTC**

**Investigative Body:** **Aircraft Accident Investigation Board (AAIB), United Kingdom**

**Investigative Body's Web Site:** **http://www.aaib.dft.gov/uk/**

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# Boeing 747SP-100, N204 AE

## AAIB Bulletin No: 6/98 Ref: EW/C96/8/10Category: 1.1

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|---|---|
| **Aircraft Type and Registration:** | Boeing 747SP-100, N204 AE |
| **No & Type of Engines:** | 4 Pratt and Whitney JT9D turbofan engines |
| **Year of Manufacture:** | 1989 |
| **Date & Time (UTC):** | 24 August 1996 at 1120 hrs |
| **Location:** | Near London Heathrow Airport |
| **Type of Flight:** | Public Transport (Passenger) |
| **Persons on Board:** | Crew - N/A - Passengers - N/A |
| **Injuries:** | Crew - N/A - Passengers - N/A |
| **Nature of Damage:** | Right off-wing escape slide torn away; minor damage to wing-to-fuselage fairing |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | N/A |
| **Commander's Flying Experience:** | N/A |
| **Information Source:** | AAIB Field Investigation |

### History of flight

During final approach to Runway 28R at London Heathrow Airport, the right 'off-wing' emergency escape slide deployed into the slipstream and was ripped from its fixings. The flight crew was unaware of the occurrence and the remainder of the approach and landing was accomplished without incident. After landing, a member of the cabin crew informed the commander that an unusual noise had been heard on the right side of the cabin during the approach. The flight engineer then checked his panel and found that the right off-wing escape slide compartment door warning light was illuminated. An external inspection revealed that the slide was missing and minor damage was found on the wing root fairing immediately aft of the slide compartment. The detached slide was later found, deflated, lying on the canopy of a petrol station forecourt some 3 miles from the runway threshold.

### Previous maintenance

In May 1996, the aircraft had undergone routine maintenance during which the off-wing slide compartments had been opened for inspection and adjustments made to the slide door latch rigging. The slide system was not disturbed subsequently.

**Off-wing slide system**

The aircraft was equipped with off-wing escape slides on each side of the fuselage. These provided for passenger emergency egress, via the overwing exit doors (doors 3L and 3R), and descent from the wings to ground level. The following description and explanatory diagrams apply to the right hand slide; however, the slide system on the left side was identical.

The slide pack was fixed to the inside face of the slide stowage compartment door, which was located in the aft section of the wing-to-fuselage fairing (see Figure 1). The pack comprised a conventional rubberised fabric triple-channel escape slide housed within an integral cover, which also provided the attachment of the slide to the inside face of the compartment door. The cover also housed a pair of injector pumps to inflate the slide after deployment. These pumps were driven by compressed 'cool gas' from a storage cylinder located in the body landing gear wheel well, immediately beneath the slide compartment.

The slide system is normally deployed automatically via the overwing exit door actuating system, which triggers a pyrotechnic thruster mechanism in the lower fuselage. This, in turn, is linked via a connecting cable to the deployment mechanism within the slide compartment. Alternatively, the slide can be deployed manually from within the cabin by means of an operating handle positioned alongside the overwing exit door, which acts on the slide deployment cable directly.

The principal components of the slide system are shown in Figure 1. The slide pack (shown in simplified form in the diagram) was fixed to the inside face of the compartment door, which was hinged along its lower edge. A series of four claw-type latches, spaced at intervals along the upper edge of the door aperture, engaged specially shaped button-head fittings on the top edge of the compartment door. The claw mechanism within each latch was operated by a cam plate which slides fore and aft inside the latch housing. The cam plates of each of the latches were linked together by a series of connecting rods, which were connected at their forward end to an integrator unit located just forward of the slide compartment door. Rearward movement of the cam plates, via the interconnecting rods, draws the latch claws into their tapered housings and causes them firstly to close over the button-heads of the door fittings, and then to pull these fittings back inside the latch housing, thus pulling the compartment door tightly closed. The rear latch mechanism incorporates a mechanical indicator comprising a spring-loaded pin, the inner end of which bears against the tapered end of the cam plate, and the outer end progressively moves outward, proud of the skin line, as the latch mechanism disengages. The latch train incorporates a microswitch which brings up the appropriate escape slide warning caption on the flight engineer's panel. A detent spring in the linkage adjoining the rearmost latch helps resist uncommanded movement of the latch operating mechanism.

The integrator unit forms the mechanical interface between the latching and deployment mechanisms within the slide compartment itself, and the slide deployment cable. Deployment of the slide, from either the cabin overwing exit door or the manual deployment handle, pulls the slide deployment cable forward; this movement is transferred to the door latches via the integrator unit, unlatching all four door latches. The unlatched compartment door is then opened by a pair of pyrotechnic thruster units, one at the forward end of the compartment triggered by a linkage from the integrator unit, and the other at the rear end of the compartment triggered by a short linkage

connected to the rearmost door latch. The thruster pistons are connected via pulleys to extensions of the adjoining compartment door hinges. Extension of the thrusters causes outward rotation of the door, assisted by gravity, exposing the slide which is packed on the inside face of the door (the situation shown in Figure 1).

The slide inflation process is triggered by an independent linkage attached to the inner face of the compartment door. As the door approaches the fully open position, movement of this linkage operates a bellcrank lever mounted just inside the slide compartment. The hooked output end of this bellcrank engages a 'T' bar attached to the upper end of an operating cable connected to the cool gas discharge valve on the stored gas bottle. High pressure gas then discharges via tubes to the two-stage gas injector pumps, which induce atmospheric air into the slide. The nominal inflation time is 8 seconds.

**System integrator**

Opening of the slide compartment for routine maintenance is achieved via the system integrator, which is accessed via a small hinged access door located immediately forward of the main compartment door (see Figure 1). The integrator unit comprises a series of lost-motion interlinks which allow the main door latches to be unlatched manually, without disturbing the deployment cable system forward of the compartment. When the compartment door is unlatched manually via the integrator, a separate cable system operates a disconnect mechanism in the inflation linkage attached to the door, allowing the compartment door to be opened fully without the slide inflating. Upon completion of maintenance, the main door is closed and locked via the integrator, and the integrator access door is closed. The integrator incorporates a simple mechanical interlock mechanism which is intended to prevent closure of the access door with the integrator in the unlatched (unsafe) condition. Figure 2 shows the integrator unit with each of the parts colour coded for ease of identification. The unit comprises:

a housing fixed to the fuselage structure.

a lost-motion mechanism connecting the deployment cable system to the door latch mechanisms.

a spring-loaded positive lock, to prevent the latch mechanism from 'back-driving' the integrator mechanism.

various subsidiary levers and cranks, the purpose of which will be described separately.

The actuating cables on the input side of the integrator unit are connected to the forward end of the piston (coloured green in the diagrams), which slides horizontally inside the housing. The aft end of this piston comprises a parallel blade section,in which there is a longitudinal slotted hole as shown in the exploded view at Figure 2. Sharing the same bore within the housing is an output shaft (coloured blue) connected to the door latch operating rods. Rearward sliding motion of the output shaft within the housing thus causes the door latches to lock, and forward motion disengages the latches. The forward section of the output shaft, ie the part which slides inside the housing, has a central slot which accommodates the projecting blade part of the piston. A horizontal cross pin (coloured orange) passes through a hole in the forward end of the output shaft, and also through the slotted hole in the blade part of the piston, providing a lost-motion connection between the two. The cross pin projects from both sides of the housing via longitudinal slots, to allow the crosspin to move fore and aft as the output shaft slides back and forth inside the housing (see lower diagram in Figure 2). Within the limits imposed by the slotted hole in the piston blade, the output shaft can slide

inside the housing without this movement being transferred to the piston, ie the output linkage (and latching mechanisms) may be moved independently of the input mechanism (and deployment cable system).

A spring-loaded lock pin (coloured red in the exploded view at Figure 2) descends behind the forward end of the output shaft when the latter moves to the fully aft (latches locked) position, preventing subsequent unlatching movement of the output shaft. A small cut-out in the top edge of the piston blade (see exploded view) provides the necessary clearance for the lock pin to descend behind the shoulder of the output shaft.

Forward movement of the deployment cable, via the cabin door thruster or the manual deployment lever in the cabin, pulls on the integrator piston; this motion is then transferred via the output shaft to the door latch mechanisms, and the slide inflates as the door opens. The integrator manual latching and unlatching pawls (coloured gold and purple respectively) comprise simple hand operated lever mechanisms, into which can be inserted a square-head socket-drive. These provide a means of access to the slide compartment for maintenance purposes. A secondary lever, formed integrally with the unlatch pawl (see lower diagram in Figure 2) is linked to the disconnect mechanism in the slide inflation linkage. The detailed operation of the integrator in both modes is complex, and is fully described in the accompanying explanatory diagrams. Figures 3a to 3d show the normal unlatch sequence, ie when deployment is initiated from the cabin door mechanism or the manual inflation handle in the cabin. Figures 4a to 4c illustrate the operating sequence when the compartment door is opened manually for servicing via the integrator unit.

Instructions for re-latching the compartment door and checking the integrator for proper engagement of the positive lock pin are provided in the form of an instruction placard fixed to the inside of the integrator access door. On the aircraft in question, the instructions comprised an explanatory diagram accompanied by the following text:-

"OPERATING INSTRUCTIONS - INTEGRATOR

To latch or unlatch: Insert a 1/4 drive wrench in the proper lever and rotate approximately 90° to end of stroke.

Before closing access panel, check latch system as follows:

1 Cross pin full aft in housing slot

2 Locking pin in detent (see detail)

3 Black marks aligned

4 Unlatch lever rotated aft to stop

5 "Door open" light on engineers panel extinguished

6 Latch position indicator if installed not protruding from fairing"

**AAIB examination of the aircraft**

**Right hand slide**

The right hand slide compartment door was fully open, with the remnants of the slide hanging from it. The inflation cable mechanism (not the slide deployment cable) had been pulled by the door actuated crank, and the cool gas cylinder had discharged. A small region of the wing-to-body fairing immediately aft of the compartment door was damaged by flailing of metal parts attached to the slide remnants. The integrator access door was fully closed.

The mechanical latch indicator pin was protruding by approximately 6 mm from the face of the fairing, indicating an unsafe condition of the latches, and the latch operating rods were displaced forward by approximately 15 mm from their most rearward position, evidenced by a witness line in the grease. When manually pulled outward, the claws of the latches could be opened by an amount sufficient to release the door button fittings. Neither door opening thruster had fired, and the slide deployment cable running forward from the integrator to the cabin door and the manual deployment handle were in their normal safe positions.

The integrator access door was opened and inspection of the integrator revealed that the manual unlatch pawl was incorrectly positioned; this being found rotated partially clockwise, toward the unlatch position, where it held the lock pin lifter in a raised position(see Figure 8). As a consequence, the positive lock pin had disengaged. This had evidently allowed the door latch mechanism to back-drive the output shaft slowly over time, eventually reaching a point where the latches released the door. The door had then fallen open under gravity, and had actuated the slide inflation mechanism. Figure 6 shows the state of the mechanism as found.

The operator later reported that whilst undertaking post-incident repairs and rigging checks in preparation for the installation of a new right hand off-wing slide, it was found that the detent spring at the rearmost latch (see Figure 1) had been inserted upside down. This would have rendered the system even more prone to unlatching in the absence of an effective positive lock in the integrator itself.

**Left hand slide**

The left hand slide compartment door was found closed and latched. However, upon opening the service access panel it was found that the unlatch pawl on the left side integrator was incorrectly positioned in precisely the same way as that found on the right integrator,with the lock pin lifter raised and the lock pin disengaged. Although the latches on this side had remained engaged, it was possible with relatively little effort to pull the latch rods manually rearward and unlatch the door, confirming that the integrator positive lock pin was not engaged.

**Examination of other Boeing 747 off-wing slides**

A Boeing 747 operated by a UK operator was examined for comparative purposes. Overall, no significant differences were found in the condition of the mechanism, or the integrator. However, it was noted that both the explanatory diagram and the instructions on the inside of the service access door differed significantly, the text reading:

"TO UNLATCH FAIRING DOOR, INSERT 1/4 IN. SOCKET DRIVE WRENCH IN UNLATCH LEVER & TURN CLOCKWISE 90° TO STOP PIN.

TO CLOSE: INSERT SOCKET DRIVE IN LATCHING LEVER, LIFT UP LIFTER & ROTATE UNTIL SPRING PIN SEATS IN AFT END OF INTEGRATOR HOUSING SLOT. CHECK THAT

THE BLACK MARK ON THE PISTON IS IN LINE WITH BLACK MARK ON HOUSING & THAT NO RED ON PISTON IS OUTSIDE OF HOUSING."

It was noted that there was no specific instruction to check 'Unlatch lever rotated aft to stop', and that the check 'no red on piston is outside of housing' was not included on the instructions placard on N204 AE.

**Probable cause of the unsafe condition of the integrator**

Rotation of the manual latch pawl drives the cross pin rearward, moving the output shaft rearward and engaging the door latches. Unless the operative ensures that the unlatch pawl is rotated back to its original position manually, this rearward movement of the cross pin will also rotate the unlatch pawl back towards its original position; however, it can do this only until the cross pin reaches the end of its slot in the housing. This sequence is detailed in Figure 5. It can be seen from Figure 5 that on completion of the latching motion of the latch pawl, the door will be fully latched. However, the unlatch pawl will not have been returned fully to its original position, preventing the positive lock pin from engaging. If, having rotated the latch pawl fully and confirmed that the output shaft is full back and the latch indicator pin is not showing, the operative rotates the latch pawl back to its original position without manually completing the movement of the unlatch pawl, the integrator will be left in an unsafe condition and the latch mechanisms could subsequently migrate forward and unlatch the door during flight. The latter condition is illustrated in Figure 6, and is identical to the 'as found' condition of both integrators on N204 AE. It should be noted that with the integrator in the unsafe condition illustrated in Figure 5, the cross pin is fully aft in its slot in the housing and consequently the access door interlock lever will have been lifted back down to its safe position, allowing the access door to be closed even though the mechanism is actually unsafe.

It was noted that the placard item in the operating instructions on the incident aircraft, 'Unlatch lever rotated aft to stop', was not given any special prominence, despite this being one of the most important actions in the latching sequence. This would appear to be of some significance, given that this action had not been carried out in this case. Much prominence was given to the need to ensure proper engagement of the positive lock pin by visually checking its position through the slot in the housing, but in practice this inspection would have been difficult to carry out effectively because:

The area in question is visually very restricted.

The slots in the housing and the relevant parts of the mechanism are invariably clogged with grease, making it extremely difficult to perform a meaningful inspection without first clearing all the recesses of grease and dirt.

Assessment of position is made difficult by the very small travel of the lock pin; ie approximately 2 mm.

Figure 9 shows a close up view of a typical in-service unit which has been set up to replicate the condition found on the subject aircraft. The difficulty of judging accurately the state of the lock pin is clearly apparent.

**Additional safety implications arising from incorrect positioning of the unlatch pawl**

With the integrator in the as found condition shown in Figures 6 and 8, the misplaced unlatch pawl creates restrictions in the integrator mechanism which limit the available travel at several points within the mechanism. This could potentially inhibit or prevent deployment of the slide in an emergency. Figure 7 shows the mechanism at the limit of travel when the system is actuated in an emergency via the deployment cable. The incorrectly positioned lock pin lifter creates a foul between the underside of the thruster actuating lever and the top of the lifter at 'G' in Figure 7. This foul has the following effects:

a) The thruster lever is unable to achieve full travel, potentially preventing the forward door thruster from firing.

b) Forward movement of the cross pin beyond the position shown in Figure 7 is restricted by the bottom end of the thruster actuating lever, restricting movement of the output shaft and door latch mechanisms.

c) The restricted motion of the latch mechanism limits movement of the connecting link to the aft door thruster, potentially preventing it from firing.

d) The piston is prevented from reaching full travel, due to the restriction on cross pin movement.

**Additional safety issues arising from the design of the integrator**

Further safety issues were apparent in relation to possible mispositioning of the input piston, the correct setting of which relies heavily upon the alignment of painted reference lines on the piston body and the integrator housing (see lower diagram at Figure 2). For example, if the piston is displaced rearward by an amount equivalent to 1/4 of the black reference line's thickness, then the lockpin will sit on the shoulder of the piston blade cut-out, rather than dropping down into the cut-out as intended. The output shaft will then be free to slide forward into the unlatched position. In these circumstances, the requirement for the red part of the piston to be inside the housing would be met fully and there would be no obvious misalignment of the black reference lines, yet there would be no positive lock to prevent the door from unlatching. Similarly, if the output shaft were to be displaced forward by more than about 1 mm from its fully aft position, then the lockpin would sit on the shoulder of the output shaft, with exactly the same result. This condition could arise in practice if theoutput shaft failed to be driven fully rearward during manual rotation of the latch pawl. It could even occur without any explicit interference to the integrator itself, eg if the deployment cable was disturbed in such a way as to move the piston forward by about 5 mm. This would be sufficient to lift the locking pin (via the ramped cut-out in the piston blade) and pull the output shaft forward by about 1 millimetre, sufficient for the lock pin to sit on the shoulder of the output shaft. In these circumstances, even if the movement of the deployment cable system was reversed and the piston returned to its original position, the lost motion mode of operation would prevent the output shaft from being returned to a safe position, and the lock pin would continue to sit on the shoulder of the output shaft.

**Previous occurrences**

A previous instance of slide deployment occurred near London Heathrow on 28 April 1996. This incident was investigated by the AAIB and reported in Bulletin 9/96 with associated Safety Recommendations. On that occasion, it was found that the latch mechanism had migrated open sufficiently to release the door. It was found that stiffness in the indicator pin mechanism at the rearmost latch gave the impression of a false detent when the door was closed and latched manually

via the integrator, and as a result the mechanism had not been driven back into the fully latched position. The microswitch on the forward latch mechanism was also found to be out of adjustment, resulting in a failure to illuminate the warning caption on the flight engineer's panel. The report noted that some 30 instances of in-flight loss of the off-wing slide were believed to have occurred on Boeing 747 aircraft over a period of 20 years, generally following maintenance. These were mainly attributed to improper closing of the slide compartment, incorrect indications of latching and improper rigging.

**Discussion**

The design of the integrator mechanism is such that it is extremely sensitive to the smallest misalignment of the various operating parts affecting the positive lock pin, and clear and unambiguous instructions on correct use are vital. At least two versions of the instructions on the access door placards appear to exist, neither of which provides consistent, clear and unambiguous information for users.

The sensitivity of the integrator to slight misalignments which could result in failure of the lock pin to engage, in combination with numerous potential rigging errors in the complex set of serial of linkages and lost-motion mechanisms within the slide deployment system overall, makes the system extremely vulnerable to rigging and maintenance errors which could lead to deployment of the slide in the air. Whilst such an event will probably cause no greater damage than occurred in this case, other potentially critical possibilities do exist. In particular, the possibility must be considered that an inflated, or partially inflated, slide could adopt an attitude at separation which could cause it to lift up into the path of the horizontal stabiliser, and become wrapped around the leading edge. A large bulky object of this kind, even if deflated, could seriously degrade tailplane aerodynamic efficiency, possibly to the extent of causing a loss of pitch control.

**Safety recommendation**

As a result of these findings, the following Safety Recommendation is made:

**Recommendation 98-23**

The FAA and the manufacturer should review the maintenance practices and instructions pertaining to servicing of the off-wing slide systems on Boeing 747 series aircraft so equipped, with a view to:

1 Introducing a more reliable and consistent means of checking for secure latching of the off-wing slide compartment door.

2 Introducing a more reliable and consistent means of confirming that the integrator positive lock pin is fully engaged.

3 Ensuring that in the event of any inadvertent (even very small) movement of the slide actuating cable, the system integrator is subject to a full check for integrity of the lock mechanism.

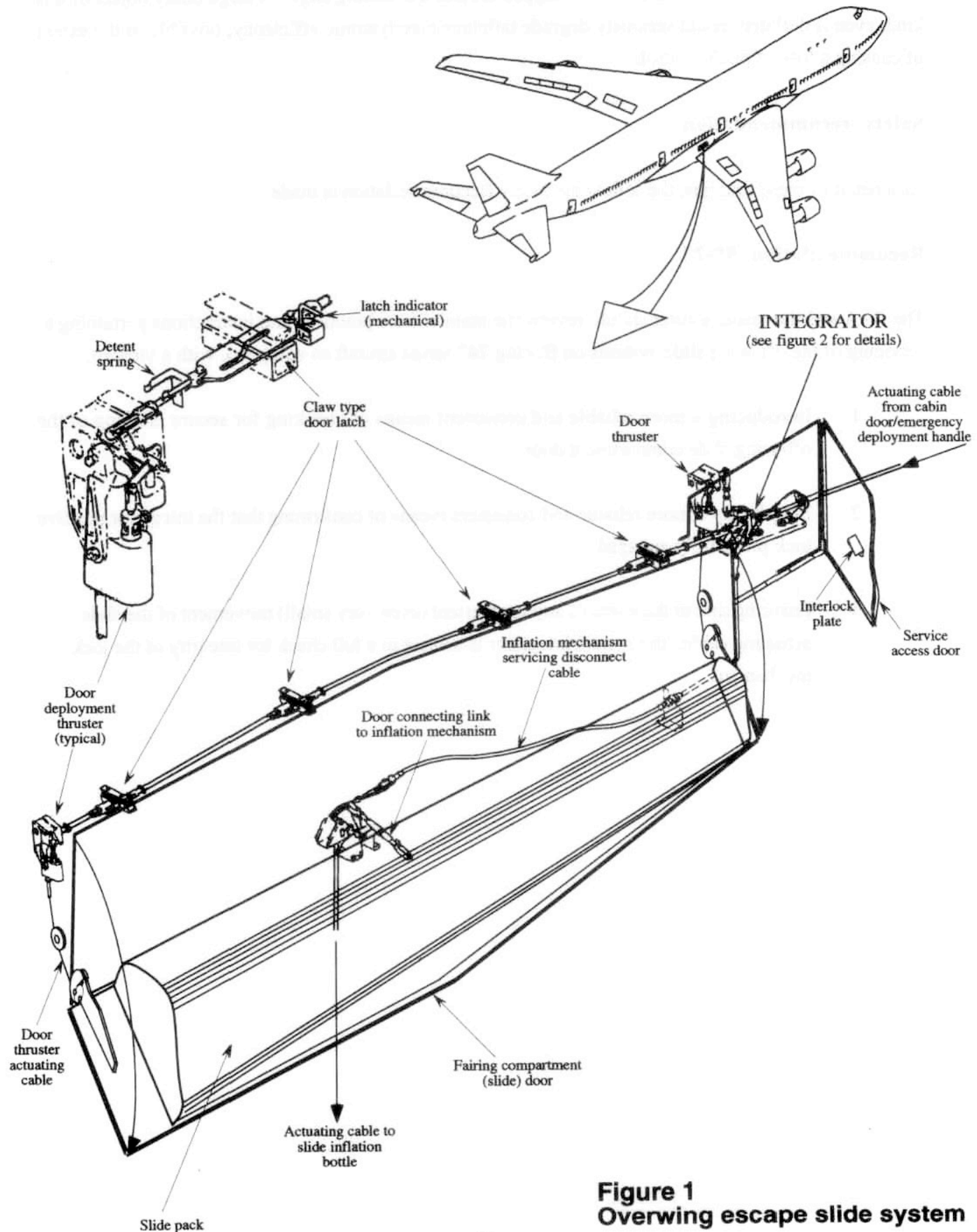


**Figure 1**
**Overwing escape slide system**

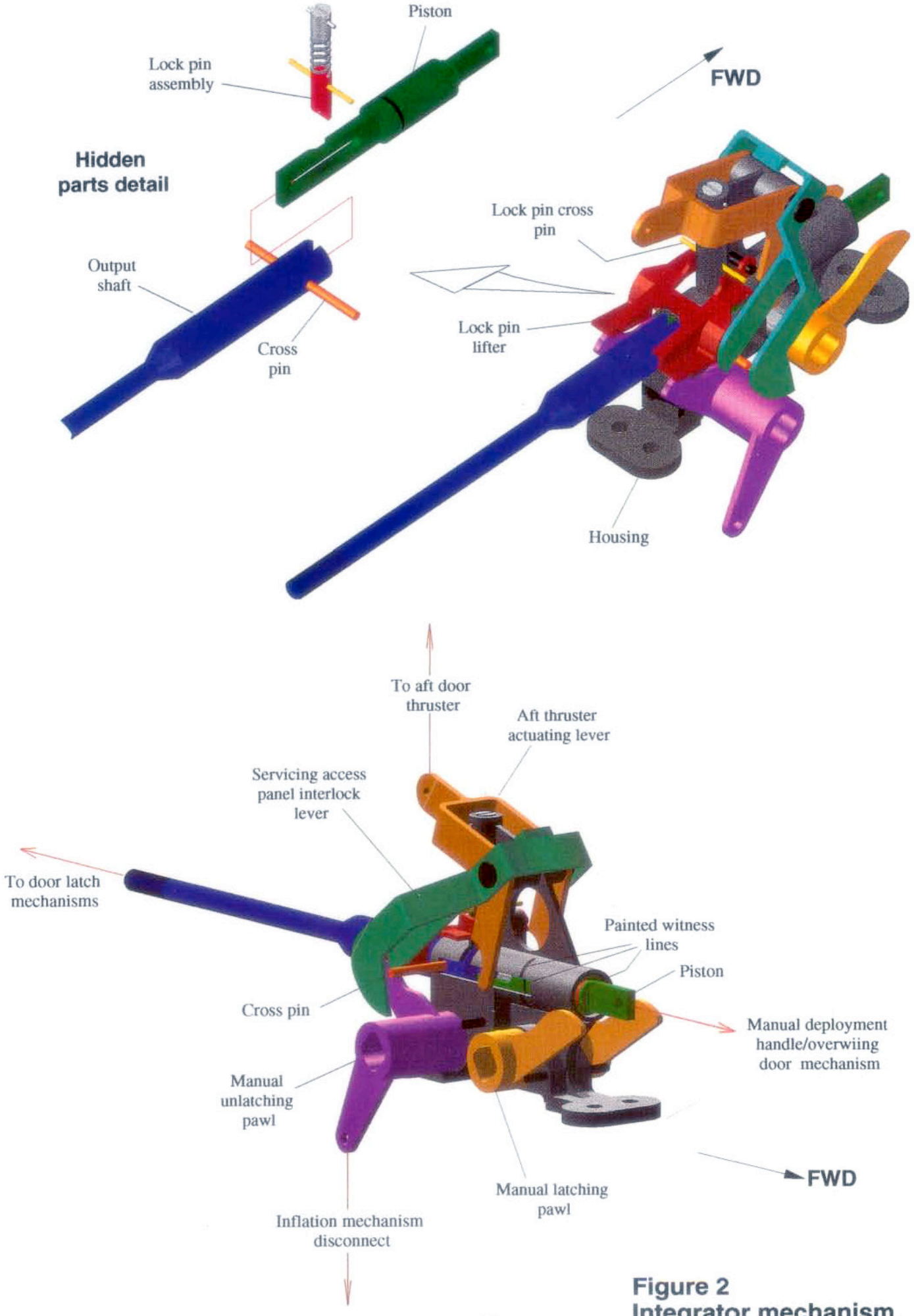


**Figure 2**
**Integrator mechanism**

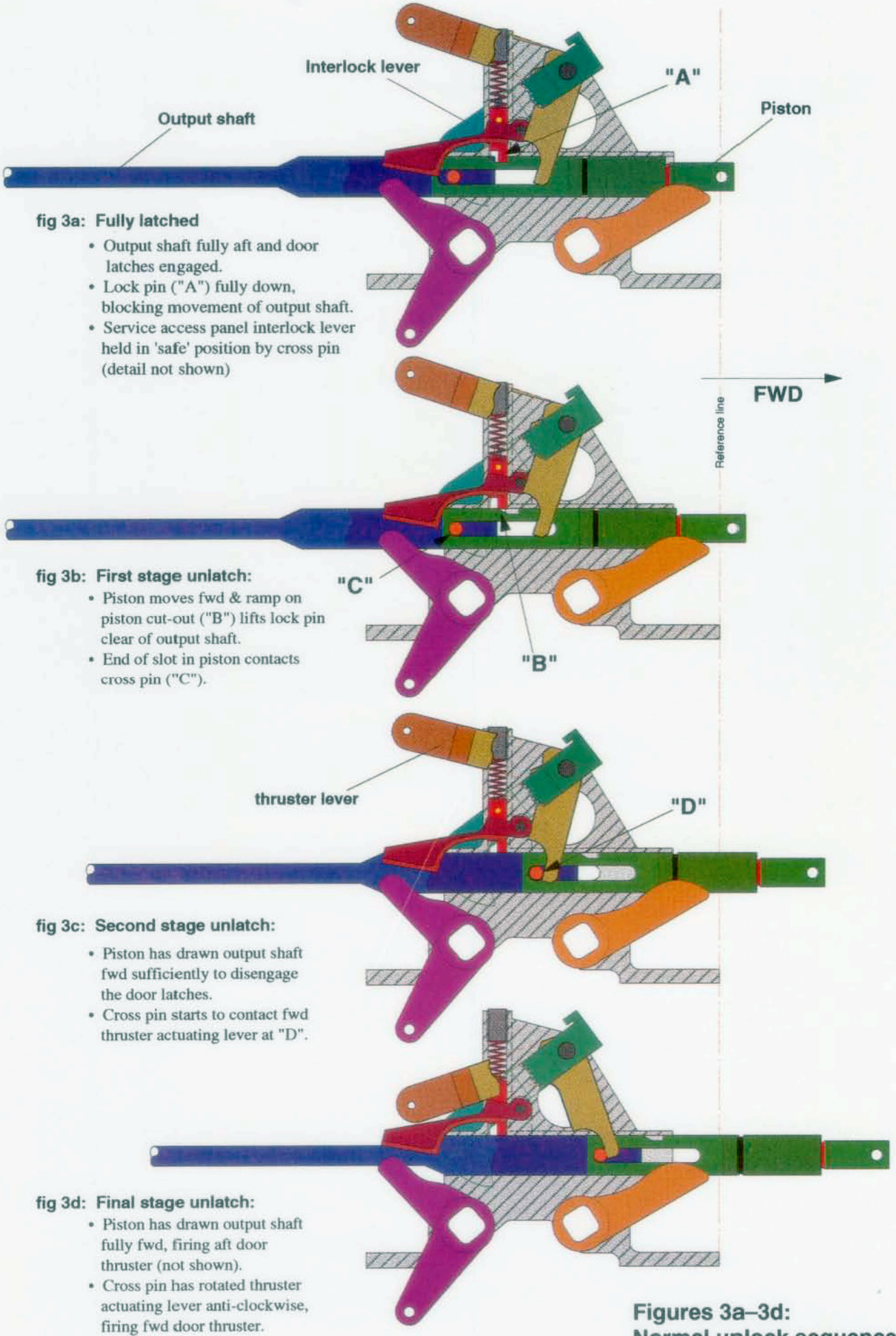


**fig 3a: Fully latched**

- Output shaft fully aft and door latches engaged.
- Lock pin ("A") fully down, blocking movement of output shaft.
- Service access panel interlock lever held in 'safe' position by cross pin (detail not shown)

**fig 3b: First stage unlatch:**

- Piston moves fwd & ramp on piston cut-out ("B") lifts lock pin clear of output shaft.
- End of slot in piston contacts cross pin ("C").

**fig 3c: Second stage unlatch:**

- Piston has drawn output shaft fwd sufficiently to disengage the door latches.
- Cross pin starts to contact fwd thruster actuating lever at "D".

**fig 3d: Final stage unlatch:**

- Piston has drawn output shaft fully fwd, firing aft door thruster (not shown).
- Cross pin has rotated thruster actuating lever anti-clockwise, firing fwd door thruster.

**Figures 3a–3d: Normal unlock sequence**

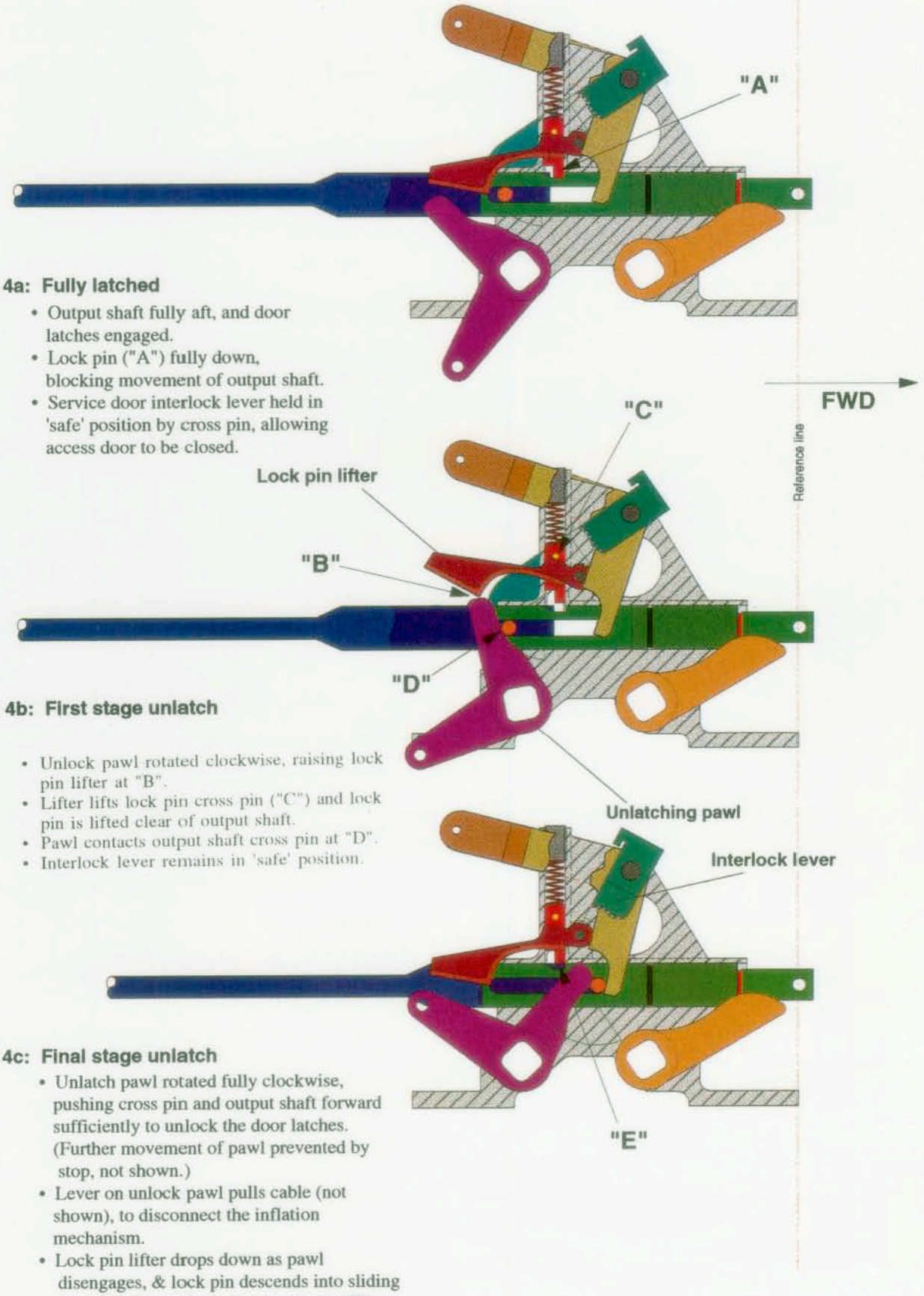


**fig 4a: Fully latched**

- Output shaft fully aft, and door latches engaged.
- Lock pin ("A") fully down, blocking movement of output shaft.
- Service door interlock lever held in 'safe' position by cross pin, allowing access door to be closed.

**fig 4b: First stage unlatch**

- Unlock pawl rotated clockwise, raising lock pin lifter at "B".
- Lifter lifts lock pin cross pin ("C") and lock pin is lifted clear of output shaft.
- Pawl contacts output shaft cross pin at "D".
- Interlock lever remains in 'safe' position.

**fig 4c: Final stage unlatch**

- Unlatch pawl rotated fully clockwise, pushing cross pin and output shaft forward sufficiently to unlock the door latches. (Further movement of pawl prevented by stop, not shown.)
- Lever on unlock pawl pulls cable (not shown), to disconnect the inflation mechanism.
- Lock pin lifter drops down as pawl disengages, & lock pin descends into sliding contact with top face of output shaft ("E")
- All movement of output shaft occurs within limits of slot in piston, ie. piston position, and linkage to cabin door etc., remains unchanged.
- Interlock lever drops down as cross pin moves forward, blocking interlock plate on inside face of access panel (see figure 1), preventing panel from being closed.

**Figures 4a–4c:**
**Maintenance unlock sequence**

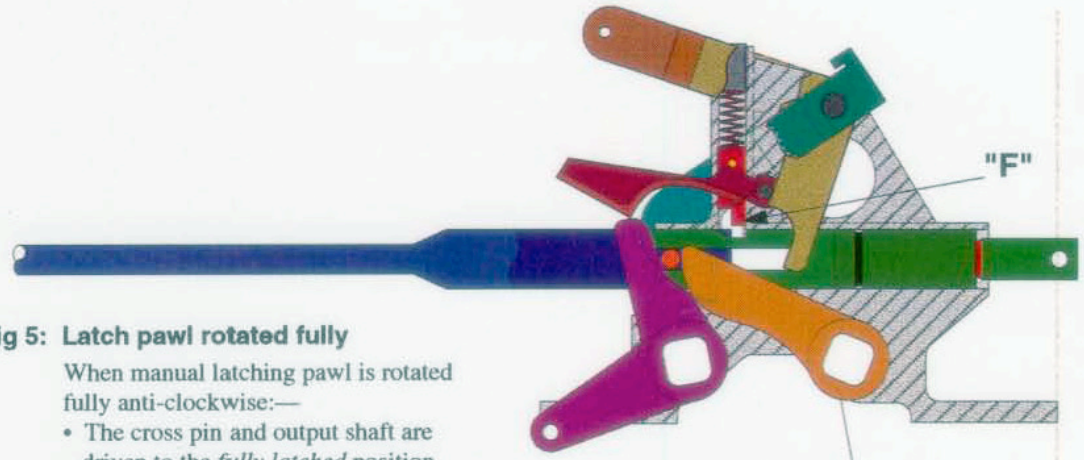


**fig 5: Latch pawl rotated fully**

When manual latching pawl is rotated fully anti-clockwise:—

- The cross pin and output shaft are driven to the *fully latched* position.
- The cross pin abuts the end of the slot in the housing, preventing further aft movement of the output shaft and obstructing further movement of the latching pawl.
- The unlatching pawl, which is driven anti-clockwise by the cross pin, stops moving at this point, leaving the pawl in the incorrect position as shown, with the lock pin lifter held in the raised position and the lock pin clear of the output shaft "F".

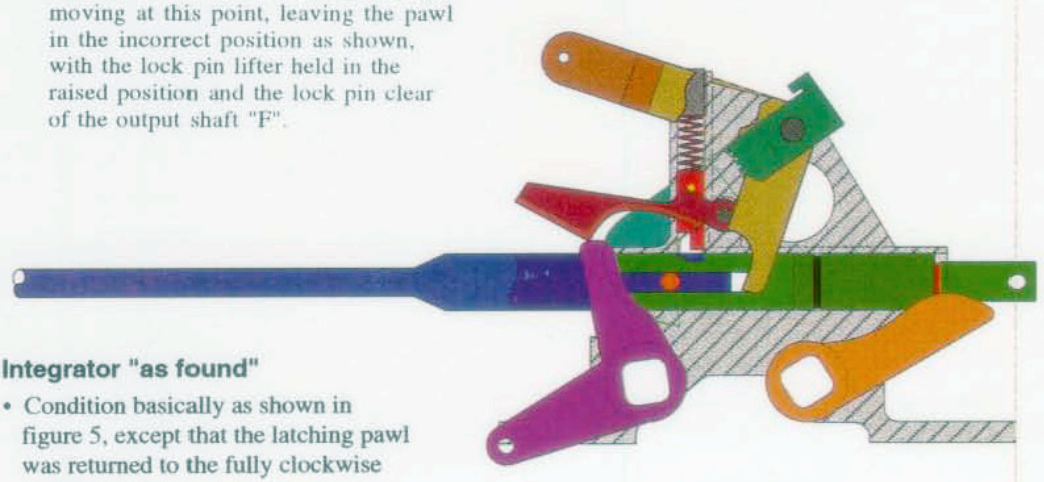

**fig 6: Integrator "as found"**

- Condition basically as shown in figure 5, except that the latching pawl was returned to the fully clockwise position.
- Lock pin was held clear of output shaft.
- System was left with no positive lock to prevent back-driving from the *latch end* of the system.
- Output shaft had migrated partially forward.

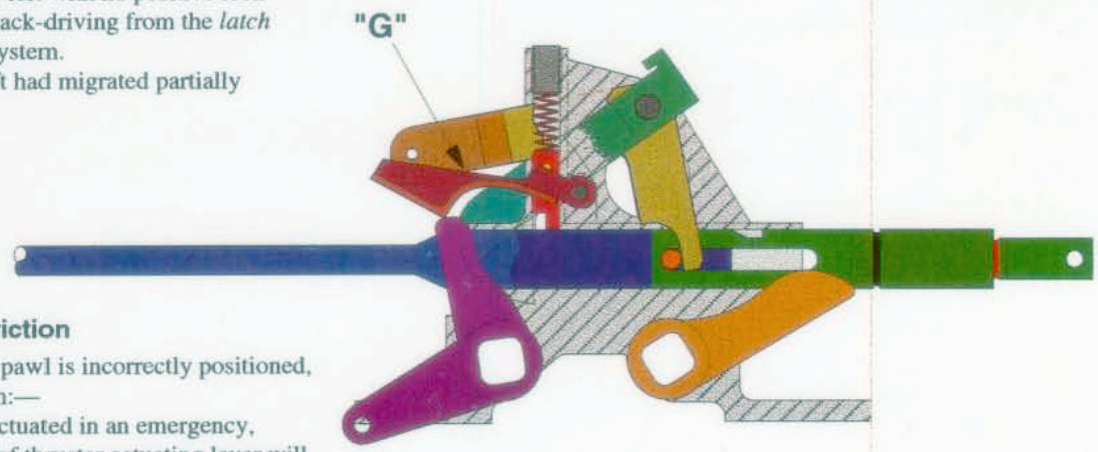


**fig 7: Travel restriction**

If unlatching pawl is incorrectly positioned, as found, then:—

- If slide is actuated in an emergency, movement of thruster actuating lever will be restricted due to jamming of the output end of this lever against the raised (out of position) lock pin lifter at "G".
- Jamming of thruster actuating lever stops further movement of the cross pin, which restricts travel of the piston and output shaft.








**Figures 5-7**
**Problems arising from incorrect positioning of the unlatching pawl**

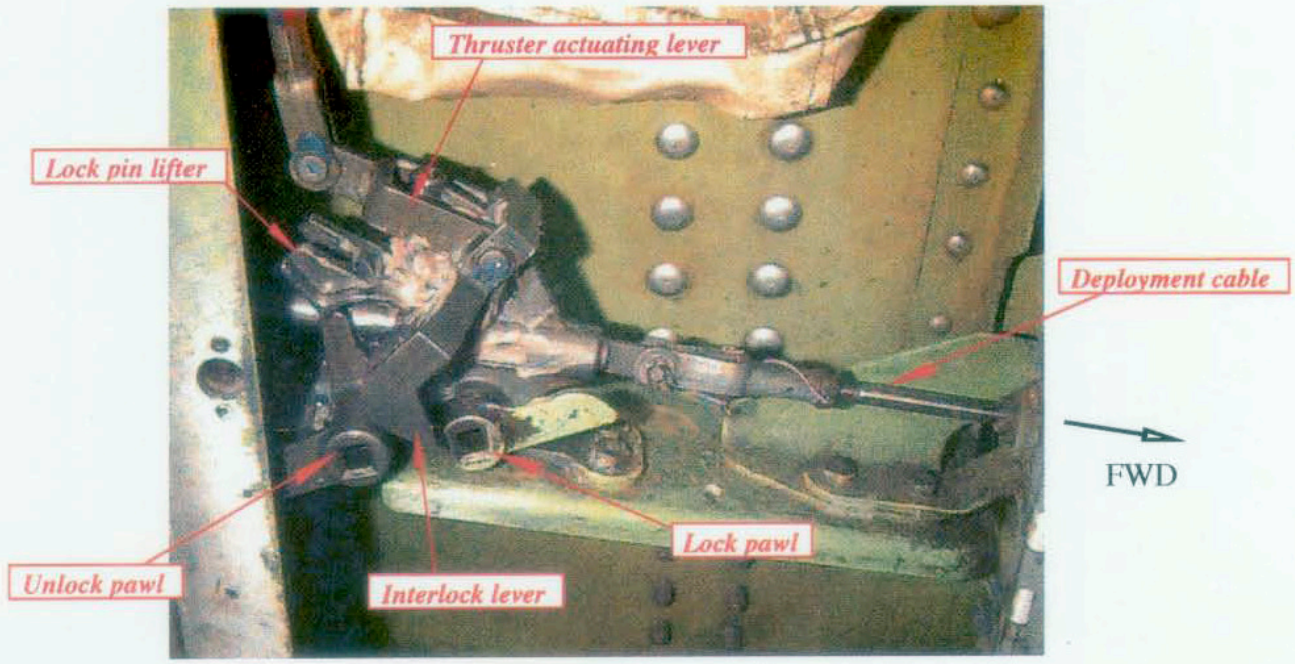


**Figure 8: Integrator "as found"**

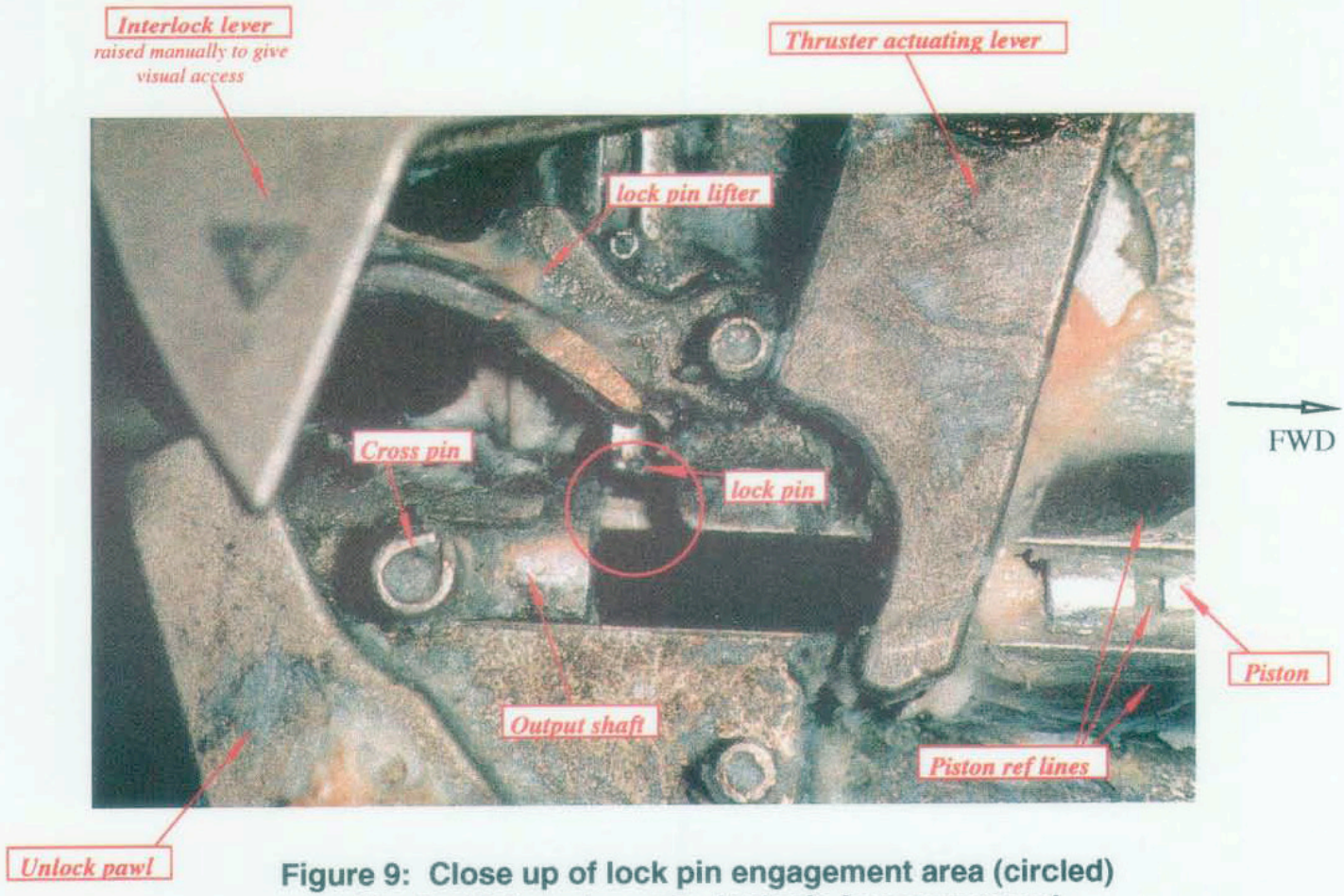


**Figure 9: Close up of lock pin engagement area (circled) of typical integrator unit: lock pin is not engaged**