



# Safe Anyway:

## *RAF Nimrod XV230 Crash over Afghanistan*

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# THE MISHAP

*On September 2, 2006, Nimrod MR2 XV230, a reconnaissance aircraft in the Royal Air Force, flew over southern Afghanistan in support of a NATO-led offensive against the Taliban. Several hours after takeoff, the 14-member crew paused operations for in-flight refueling, then prepared to resume its mission. Not long after Nimrod disengaged from the Tristar airborne tanker, two nearly simultaneous warnings alerted the crew to fire and smoke in the aircraft's bomb and elevator bays. The pilots declared a Mayday and initiated an emergency landing, but the fire that raged below the cabin gave them no chance to survive. Minutes later, the aircraft depressurized, and a Harrier G7 pilot nearby saw the aircraft explode in mid-descent. All 14 servicemen lost their lives in the disaster.*

## Engine and Fuel Tank Configuration

- Nimrod XV230 was the first of 43 Nimrod airframes to enter service with the Royal Air Force (RAF). Engineers based its design on the de Havilland Comet, which was the first commercial jetliner to enter production.
- Unlike the Comet, Nimrod had four engines that were paired and embedded in the aircraft's wing roots. Four additional fuel tanks were added, and these occupied the fuselage between the wings.
- A cross-feed duct connected the engines on either side of the aircraft. It occupied the No. 7 tank dry bay along with many fuel and hydraulic lines.
- Since the cross-feed duct could direct hot air from one set of engines to the other, pilots could shut down a pair of engines and restart them again while airborne. This practice could add several hours to Nimrod's flight endurance.

## Design Modifications

- After 1975, 35 Nimrods had supplementary conditioning packs (SCP) installed to provide extra cooling. The SCP operated using hot bleed air from the engines.
- To feed the SCP, designers added a special conduit, the SCP duct, as a branch off of the original cross-feed duct. The temperature of the cross-feed/SCP duct could exceed 400 °C.
- In 1982, the Nimrods received an air-to-air refueling (AAR) modification that placed refueling pipes in the aircraft's bomb bay. Additionally, fuel tanks received blow-off valves that relieved tank pressure during AAR by ejecting excess fuel into the atmosphere.

## Nimrod Safety Case

- Military regulations required the completion of a safety case for the Nimrod fleet in 2001. The Ministry of Defense (MOD) contracted BAE Systems to formulate the case along with an internally assembled Nimrod Integrated Project Team (Nimrod IPT) and defense analyst QinetiQ. The task spanned 4 years and cost more than £400,000.

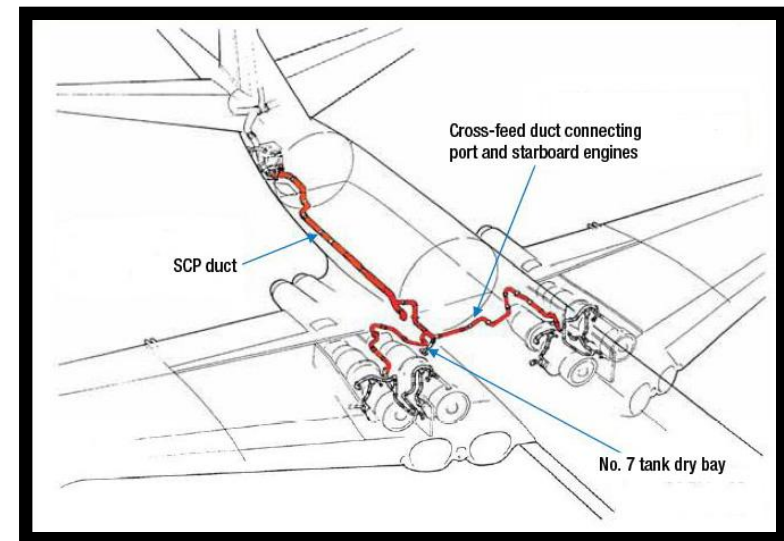


Figure 1: Nimrod schematic

# WHAT HAPPENED?

## Fire, Decompression, and Explosion

- On September 2, 2006, coalition forces mounted an offensive to clear the Taliban from the city of Panjwayi, Afghanistan.
- Manned by a 14-member crew, Nimrod XV230 flew over hostile territory in support of the operation, pausing for a 10-minute rendezvous with a Tristar in-flight refueling aircraft.
- Minutes after Nimrod disengaged from the tanker, alarms alerted the crew to fire in the bomb bay, located beneath the cabin floor. Less than a minute later, the aircraft depressurized, forcing the crew to don oxygen masks. The pilot declared a Mayday and initiated an emergency landing.
- Nimrod crew members reported flames emanating from the starboard engines and the aileron bay. This was their last transmission.
- Moments later, the aircraft exploded at an altitude of approximately 3000 feet, and debris plummeted onto the terrain below. No one on board survived.

## Retrieval

- The hostile area in which the wreckage landed made it difficult for combat and rescue teams to recover the victims and flight recorders, but they did so within 21 hours of the crash.
- Hostile forces then converged upon the area and removed most of the debris.



Figure 2: Nimrod XV230 crashed near Kandahar, Afghanistan.  
Photo Credit: whdh.com



Figure 3: Fourteen servicemen perished in the crash.  
Photo Credit: heraldscotland.com



# PROXIMATE CAUSE

Although enemy forces prevented the RAF from recovering most of XV230's wreckage, the Board of Inquiry (BOI) obtained enough material to determine that the explosion was the final event in a chain that began when jet fuel accumulated in the No. 7 dry bay. Fuel could have arrived in the dry bay in one of two ways: A) It ejected from the No.1 tank's blow-off valve during AAR, tracked back along the fuselage, and entered the dry bay through ports or intakes; or B) Fuel couplings in the dry bay failed, allowing fuel to escape from conduits in the dry bay and accumulate at the base of the compartment. Somehow this fuel contacted the extremely hot SCP duct and self-ignited. Without fire detection or suppression systems in the dry bay, the fire spread to the bomb and aileron bays before alarms alerted the crew to its existence. Eventually, heat from the fire caused fuel in tanks to boil, raising the tanks' internal pressure, causing them to explode and tear the aircraft apart.



## UNDERLYING ISSUES



### Design Flaws

- The cross-feed duct's placement among fuel and hydraulic lines contradicted good engineering practice because it placed a potential ignition source (the hot duct surface) in the vicinity of a potential fuel source (possible fuel leaks) without designating the area as a fire zone.
- Although Refrasil, a fluid-impermeable substance, covered the cross-feed duct, it deteriorated over time and was discontinuous in certain places.
- The addition of the SCP duct posed the same risks as the original cross-feed duct, and since it spanned the entire length of the No. 7 dry bay, it increased the area where an accident could occur.
- Not long after Nimrod's AAR capabilities were installed, engineers discovered the location of the No. 5 tank was such that during flight, fuel exiting the No. 5 blow-off valve could enter a port engine intake. The valve was disabled, but though a similar risk existed for blow-off valves on the starboard side of the aircraft, recommendations to probe the risks further were shelved, and further analysis was never conducted.



### Improperly Constructed Safety Case

- Those who worked on Nimrod's safety case suffered from a widespread assumption that Nimrod was "safe anyway."
- Constructing the case became a formality - completing the necessary steps became a "checkbox" exercise and, as a result, project planning suffered and standards slipped. Unsafe conditions were overlooked or miscategorized, and the best opportunity to prevent the disaster was lost.



### Organizational Disarray

- Between 1998 and 2006, the MOD experienced multiple significant changes in management structure and composition.
- Over 5 years, the Ministry increased outsourcing to industry and reduced its budget by 20 percent. This upheaval diluted the airworthiness regime and shifted RAF focus from system safety to cost savings.
- In 1998, a Nimrod Airworthiness Review Team warned that increased demands and reduced resources would threaten safety standards.
- As aging aircraft, the Nimrod fleet required more attention as time marched forward; instead, it received fewer resources and decreased vigilance.

# FOR FUTURE NASA MISSIONS

“The non-occurrence of system accidents or incidents is no guarantee of a safe system.”

-The Nimrod Review

“An organization’s culture is a powerful force that persists through reorganizations and the departure of key personnel.”

-CAIB

“Leaders create culture. It is their responsibility to change it...Leaders are responsible for establishing the conditions that lead to their subordinates’ success or failure.”

-The Nimrod Review

- Nimrod served the RAF for three decades, participated in every major conflict that occurred during those years, and experienced only two accidents prior to the loss of XV230.

- The apparent safety of the Nimrod lulled many, including BAE Systems, the Nimrod IPT, and QinetiQ, into a false sense of security.

- One parallel between the loss of XV230 and the loss of Space Shuttle Columbia was the “torrent of changes” and “organizational turmoil” that the MOD and NASA both faced just prior to the XV230 and Columbia disasters.

- Since Columbia, NASA has seen Constellation cancelled, space flight privatized, and the SLS project announced. Past experience has shown how major changes such as these can adversely impact organizational cultures.

- We must ensure that we continue to demand proof, be it inherent system design features, analysis, testing, or independent verification to ensure systems are safe. Systems are unsafe until proven otherwise.

- We must uphold the values and norms that foster healthy organizational practices.