

The History of Australian Weather and Cyclone Reconnaissance Aircraft:

Australia's Cyclone Hunters

By David Reade

On 21 February 1979, an American hurricane research aircraft took off from Royal Australian Air Force (RAAF) Base Garbutt (*Townsville, Queensland*) and headed out over the Coral Sea to rendezvous with Tropical Cyclone Kerry, which was situated some 435 miles (*700 kms*) east, southeast of Townsville.

This National Oceanic and Atmospheric Administration (NOAA) WP-3D Orion conducted what has been dubbed the first scientific reconnaissance of an Australian Basin (*western South Pacific*) tropical cyclone. The instrumented WP-3D would go on to fly three more flights into Kerry over as many days, as well as conducted a reconnaissance flight into Tropical Cyclone Rosa, transmitting storm data directly to the Australian Bureau of Meteorology's Tropical Cyclone Warning Center, to be incorporated into cyclone forecasts and warnings for these two storms.

Although this event was presented as the first (*ever*) reconnaissance flight of an Australian cyclone, at the time by the local Australian press, this is not actually the case. Australian aviation history is peppered with weather and cyclone reconnaissance flights as well as repeated efforts to establish a routine airborne reconnaissance capability to provide specific synoptic weather observations and to locate, track and report cyclones towards national weather forecasts and warnings.

Little known outside Australia, and somewhat within it, airborne weather and tropical cyclone reconnaissance flights have been flown by Australian aircraft throughout the 1950s, 1960s, 1970s and during different periods of the 1980s and 1990s. In these instances, airborne weather and tropical cyclone reconnaissance flights were conducted in Australia for a variety of specific and specialized circumstances, occasions and operations, where the weather data collected ultimately filtered down to figure into national weather forecasts (*to varying degrees*) that directly benefited the general public.

Australia and Cyclones

Australia has had a very long history of tropical cyclone activity. From pre-historic times on through to the present day, destructive cyclones have devastated coastal areas of Australia and have greatly affected communities and various industries in recent years.

Unlike in the North America, Australia has three coastlines susceptible to the impacts of tropical cyclones, including the country's long northern coastline as well as the eastern and western coasts. Some of the strongest winds, highest storm surges and severest flood's ever produced by tropical cyclones have occurred in Australia. There have been more than 200 known impacts of tropical cyclones along the east coast of Australia since 1858 alone. Tropical cyclones continue to pose a serious threat to Australia and the general public at-large today.

The principle meteorological tools available to the Australian Bureau of Meteorology (BOM) for tracking and forecasting tropical cyclones, consists of access to various international weather Satellites. This satellite capability is further supported by an extensive network of 15 "Automatic Weather Stations" located off shore of the Queensland coast and positioned within the Great Barrier Reef.

But even at this late date, no aerial cyclone reconnaissance capability exists. However, this hasn't always been the case.

The Early Days

The earliest known connection between weather data gathering and aircraft in Australia began in 1919, during WWI, where early Australian Flying Corps (AFC) Bristol F.2 Fighter (*Type 14 F.2B Mk II*) biplanes made rudimentary meteorological flights gathering temperature and air pressure measurements as well as visual observations in the upper atmosphere.

In 1926, a RAAF de Havilland DH-50 floatplane flew from Sydney to Adelaide taking weather measurements along the way. The DH-50 was equipped with a clockwork meteograph that measured air pressure, temperature and humidity, as well as an early model of psychrometer collecting similar data.

Later in the 1936-37 additional meteorological flights were flown by the RAAF in the upper atmosphere. Much like similar aerial observation flights flown in the United States at the time by US Military aircraft, the so-called Australian meteorological flights were little more than aerial soundings – an extension of upper air observations that were (*later*) routinely performed by weather balloons. These Met flights were flown from Point Cook / Laverton airfields (*near Melbourne*) and comprised climbing up between 2000 and 16,000 feet (*610 – 4,877 meters*) to make vertical weather observations that included temperature, pressure and wind measurements as well as cloud formation and type observations. During the flights, the pilots would record all observations on knee-boards (*notebooks*) and later phoned in the observations to the weather bureau upon landing.

These Met Flights were flown by RAAF No.1 (*fighter*) Squadron, out of RAAF base Point Cook (*just southwest of Melbourne*) in bi-wing, open-cockpit (*single seat*) Bristol Bulldog fighters that had been purchased from the United Kingdom in 1929. The acquisition of the Bulldogs actually prompted the establishment of No.1 and No.2 RAAF Squadrons at Point Cook, which is considered the birthplace of the RAAF as the first AFC airfield established in Australia in 1913. RAAF base Laverton and the Point Cook base were amalgamated into RAAF Base Williams in 1999.

The US Weather Bureau discontinued similar aerial Met observation flights in 1940 with the development of the weather balloon mounted radiosonde that provided a lower cost method of obtaining upper air observations.

WWII Flights

The first actual weather reconnaissance flights flown in Australia occurred during WWII. Beginning in early 1943, RAAF Meteorological Service weathermen participated in dedicated weather reconnaissance flights flown on US Army Air Force (*US AAF*) 5th Bomber Command aircraft, as part of a Joint (*allied*) Meteorological Service. Flown from RAAF Base Garbutt and elsewhere around the South Western Pacific Area (*or SWPA*), the joint weather flights comprised over-target, en route and area synoptic weather reconnaissance missions - supporting forecasts towards allied operations.

On Australia's far west coast, US Navy Catalina Flying-boats flew long-range patrol missions out into the southern Indian Ocean. On these patrol flights, out of Geraldton (Western Australia), the crews often collected and reported weather conditions along their search areas. The Navy Catalina would patrol out some 500 miles (805 kms) due west, then turn south for 500 miles (805 kms), before turning back to the Northeast for Geraldton. It was on these flights that RAAF Met observers would often accompany the US Navy crews to collect weather data.

Although Australian and allied forces were engaged in combat operations against the Japanese, it became recognised early that the weather itself had become "*another enemy*" and a hazard to those operations.

Especially concerning were localized areas of convective thunderstorms, fast moving cold fronts made up of towering cumulonimbus and cumulus clouds, that raised up from bases near 2000 - 3000 feet (619 – 914 meters) to heights upwards of 50,000 feet (15, 240 meters). Known as “Guba” storms in Papua, these monsoonal-spawn, low–pressure frontal storms or squalls were characteristically of a severe nature with hurricane-force wind gusts, rough turbulence, torrential rains and severe lighting. The Guba storms were also known to be associated with sleet, hail and water-spouts or other tornado-like occurrences.

A hazard to aircraft operations, the Guba storms often contained strong turbulence and violent up and down drafts that forced planes down into the ocean or ripped off their wings in sudden up drafts. Other particularly hazardous flying conditions from these storms included (*blinding*) torrential rains, lightning, severe icing and or large hailstones.

Other weather hazards to Allied operations comprised the seasonal cyclonic (*tropical*) storms and cyclones that materialized. Between 1941-45, BOM records show that a number of cyclones occurred along the Queensland coast and the Northwestern Australian coast, that affected numerous military facilities and wreaked havoc with allied force’s efforts to push the Japanese back across the Pacific.

RAAF Squadron records are filled with encounters with adverse weather, tropical storms and cyclones during the war. In one particular incident, on 16 April 1944, a combined (*allied*) bomb strike was mounted against Japanese forces at Hollandia, (*Papua*) New Guinea, by General Douglas MacArthur’s command.

The planned bomber strike comprised more than 300 different aircraft, mostly from the US 43rd Bomber Group (*5th Air Force*) and numerous allied fighter units, tasked to bomb and strafe Japanese airfields and installations as part of a softening up campaign prior to planned amphibious landings in May 1944. After the raid, the 300 planes were caught by surprise in severe weather that had moved into the area with no warning, blocking their courses back to their base at Nadzab Aerodome.

More than 37 aircraft (*54 aircrew-men*) were lost into the raging seas, torrential rains and severe turbulence reported with this storm, never to be seen again. Some of the aircraft were forced into the sea from severe down drafts, while others blinded by torrential rain, sleet and or snow (*reported at 18,000 feet or 5,486 meters*), flew around in circles until they ran out of fuel - crashing in to the sea or into mountains and the thick jungles of New Guinea.

Although most of the 300 planes and aircrews survived, landing at alternative airfields all around the region, nearly all these remaining aircraft made crash landings and were damaged beyond repair. In one case, a squadron within the 43rd Bomb Group only had one serviceable airplane after the bomb strike.

Known as “*Black Sunday*” this incident became the largest weather-related loss of aircraft in military history.

Earlier in March 1944, a B-24 Liberator from the US AAF’s 403rd Bomb Squadron (*43rd Bomb Wing*) was lost in bad weather associated with a Cyclone that tracked across the bomber’s course, during a flight from Dobodura, New Guinea to Garbutt Field, near Townsville on 28 March 1944. The cyclone made landfall later that day just south of Townsville and the B-24 never arrived at its destination.

The Liberator was found later in April 1944 on a small hill near Leichardt Creek (north of Bluewater Creek) or about 23 miles (37 kms) northwest of Townsville, with all 7 on-board listed as killed.

In January 1945, two RAAF No.100 Squadron Bristol Beaufort fighters were lost in bad weather upon returning to their base at Milne Bay - from a strike mission in New Guinea. The aircraft were later found to have crashed in the Owen Stanley Mountains from severe turbulence and zero visibility associated with a cyclonic tropical storm in the vicinity.

During a tropical cyclone that struck along the Queensland coast later in March 1945, a RAAF twin-engine Lockheed Hudson Bomber got caught in the severe storm conditions and was forced into the sea near Cairns - with no survivors. Having taken off from Townsville, despite cyclone warnings, the Hudson bomber became lost in the storm and was later found to have crashed into the sea, some 400 yards (366 meters) out from Machan's Beach, just north of the mouth of the Barron River, or less than 2 miles (3 kms) north of the Cairns airfield.

Eleven military personnel on board were killed, including two important Australian Army generals of some renown.

Later in May 1945, a number of RAAF No.100 Squadron attack aircraft were lost in foul weather associated with a cyclonic storm off the village of Gasmata on the south coast of New Britain (*Papua, New Guinea*) after conducting bombing raids on area Japanese forces installations.

It was because of these losses, and other ones like it, that dedicated weather reconnaissance flights were first begun in the SWPA. Both Australian and US weathermen, flying on US AAF aircraft, participated in the weather flights.

It was during long-range synoptic weather reconnaissance flights, flown out over the open ocean, that the very first Australian tropical cyclones reconnaissance flights were made by Australian and US weathermen.

Post War Flights

By the end of the war in late 1945, with the withdraw of US Forces from the region, RAAF aircraft units began their own weather reconnaissance flights. RAAF No.31 and No.93 Squadrons, both equipped with fighter-attack Bristol Beau-fighters, flew weather reconnaissance flights that included severe tropical storms.

Beginning in 1946, RAAF No.6 Bomber Squadron, headquartered at RAAF Base Amberley and equipped with Avro Mk-30 Lincoln Bombers, began flying a series of long-range weather reconnaissance flights over the southern oceans. These weather flights were the first to have ever been made so far south and supported the establishment of manned weather stations in remote areas around Australia. The following year, these weather flights were expanded to Antarctica, as Australia began establishing Antarctic research stations under the Australian National Antarctic Research Expedition to the austral continent. Through this period, No.6 Squadron flew two 13-hour long Antarctic weather reconnaissance flights per week.

For the next 49 years, weather reconnaissance flights would be flown intermittently by RAAF aircraft for various reasons and would include tropical cyclone reconnaissance.

Atomic Bomb Tests

Another situation that saw RAAF aircraft flying weather reconnaissance flights occurred between 1951 and 1958 - during British Atomic Bomb tests in Australia. By the early 1950s, the United Kingdom's development of the Atomic Bomb reached a point where above ground tests were required. Lacking its own available real-estate to conduct such tests, the British looked towards the vastness of Australia's outback and remote islands as potential areas to conduct atomic bomb tests.

The first test of a British atomic bomb occurred in October 1952, off the Northwest coast of Australia. Known as "Operation Hurricane", this first British atomic device tested in Australia was based upon a

modified version of the American 25 kiloton (Nagasaki) Fat Man bomb. It was detonated in a lagoon off Trimouille Island, in the Monte Bello Islands, on 3 October 1952.

In support of these bomb test operations, RAAF Mk.30 Lincoln bombers were tasked to conduct weather reconnaissance flights and more. RAAF No. 2 and No. 6 Bomber Squadrons flew weather reconnaissance missions for the bomb tests as well as another interesting mission later called "*Cloud Chasing*", where No.2 Squadron aircraft actually chased and penetrated atomic bomb clouds to take air (*particle*) samples.

Later between 1954-56, Australian aircraft were unavailable to support the bomb tests. The British imported their own weather reconnaissance capabilities to Australia, that encompassed Royal Air Force (RAF) Avro MR.1 Shackleton maritime patrol bombers. These British Shackleton weather reconnaissance flights, comprised the participation of British RAF No. 202 Meteorological Squadron weather observers assigned to various RAF Shackleton equipped maritime patrol squadrons (*including aircrew elements from RAF No.269 and No.206 Maritime Patrol Squadrons*) deployed to Australia. The British weather reconnaissance flights consisted of daily (*9-hour*) long-range weather reconnaissance missions often as low as 10 feet (3 meters) above the sea surface.

In 1956, a British RAF Canberra Jet, flown by a RAAF Weapons Research Establishment (WRE) aircrew, was utilized for weather reconnaissance missions as well as air sampling / radiological survey flights out of the Monte Bello, Islands, towards the north and west, out into the Indian Ocean.

By the latter part of 1956, RAAF aircraft began supporting the British bomb tests again with a detachment of No.11 Maritime Reconnaissance Squadron P-2 Neptune's flying over-seas weather survey flights, and ocean security patrols - far out into the Indian ocean from Onslow. The aircraft flew over designated areas of the ocean at approximately 1800 feet (*549 meters*) with observations taken at 58 mile (*93 km*) intervals. Every 200 miles (*322 kms*) the aircraft would descend to 200 feet (*61 meters*) to take sea-level observations, including temperature, pressure, wind speeds and direction measurements.

During bomb test operation in 1957, the remaining RAAF Mk.30 Lincoln bombers still in service (*flown by RAAF No.2 and No.6 Squadron aircrews*) were reported to have flown 26 weather reconnaissance missions off the Western Australian Coast.

It was during these bomb test weather reconnaissance flights, that the reconnaissance aircraft would be in a position to detect, track and report any and all tropical cyclones encountered - and often did.

Cyclone Reconnaissance 1954

Most of the tropical cyclones that affect the Australian East coast normally manifest themselves along the northern and central coastal areas of the Queensland.

In February 1954, one of three storms that struck along the Queensland coast that year, materialized out of the Coral Sea as a powerful tropical cyclone and struck near Coolangatta. This storm uncharacteristically tracked south into the Northern Rivers district of northern New South Wales. This destructive cyclone pack winds in excess of 115 mph (*185 km/h*), that pushed a high surf and storm surge (*45 feet / 15 meters*) over the high tide line with very heavy rainfall that dumped more than 10 inches (*250 mm*) of rain over a wide region. The town of Lismore (*NSW*) was inundated with so much rainfall, that the whole town was actually and completely underwater for more than two-days.

Later in April 1954, because of this and the other storms that season, the BOM announced a series of new facilities establishments and existing facilities improvements, that comprised the installation of meteorological equipment specifically designed to enable improved tropical cyclone forecasts and

warnings along the Queensland coast. The primary focus of the existing facilities improvements consisted of the further development of the BOM's evolving weather radar network. The program included the installation of additional radar systems at RAAF bases in Townsville, Brisbane and Rockhampton - that comprised WWII surplus radars units providing a cyclone detection radar coverage out 186 miles (300 kms) from the coast.

On 6 March 1956, the first Australian cyclone to have ever been captured and tracked on a radar was photographed at the Townsville radar station. Cyclone Agnes passed inland along the Queensland coast, very near Townsville and the Radar unit there observed the storm's rainbands as she came on shore.

More importantly under this announced BOM facilities program, was a proposal to be considered towards the establishment of a routine cyclone reconnaissance capability including the utilization of RAAF aircraft for cyclone reconnaissance out over the Coral Sea. With some government proponents of this effort, the BOM pursued the establishment of a cyclone reconnaissance capability for Australia.

In the meantime however, and somewhat unrelated to this effort, the RAAF had initiated its own tropical cyclone flights supporting local BOM forecasts and warnings centers. Back in March 1956, when Cyclone Agnes struck along the Queensland coast, it actually caused significant damage to numerous buildings and structures at the RAAF base in Townsville. This prompted area commands to begin a base policy of supporting the local BOM cyclone forecasts, which ultimately led to directing RAAF aircraft out into tropical cyclones.

Canberra Jet Tropical Cyclone flights (1960-64)

In February 1960, a tropical cyclone developed out in the Coral Sea and subsequently tracked along the east coast of Australia, just east of Brisbane.

On 27 February 1960, an Australian GAF Mk.20 Canberra Jet Bomber, assigned to RAAF No.6 Bomber Squadron at RAAF Base Amberley, was dispatched to make a reconnaissance of the storm. The jet, a high-altitude, photo-reconnaissance equipped version of the Canberra Bomber, was tasked to locate the storm's center, fly-over it and photograph specific regions of the cyclone's eye, under the guise of a maritime navigational training mission - to accurately navigate to the storm's center and back to fix the storm's location for the BOM's tropical cyclone warning center in Brisbane.

The RAAF jet subsequently flew out over the Coral Sea and located the storm more than 100 miles further south of the BOM's estimated position given to the flight crew before the flight. Locating the eye, the aircraft flew through the cyclone at 22,000 feet (6,706 meters) with no discernible difficulties. Ascending to 30,000 feet (9,144 meters), the crew photographed the storm's central region (eye) cloud structures and reported that the eye was some 35 miles (56 kms) across. The crew recorded other visual observations that were consistent with the characteristics of a mature tropical cyclone, including cloud observations, rough wind speed estimates and radar observations - mapping the precipitation patterns of the cyclone all along the aircraft's track in the vicinity of the storm.

With the success of this RAAF jet flight over the storm, other Canberra Jet cyclone reconnaissance flights were flown, including a storm on 2 March 1960 and another cyclone on 6 January 1961. On this last flight in January 1961, the RAAF jet's crew was able to confirm that the previously detected cyclone off the coast from Amberley was weakening and had changed course away towards the north - no longer presenting a threat to the coast of Queensland.

However, during another cyclone reconnaissance flight in March 1961, the Jet's crew was unable to locate the center of a storm off the Queensland coast within 100 miles (161 kms) of the estimated position, and failed to complete the reconnaissance mission. Due to the inability of the military flight crew to interpret the cloud structures within the March 1961 cyclone and locate the storm's center, it was suggested that BOM personnel from the Brisbane Tropical Cyclone Warning Center be permitted to fly in

the jet's bombardier seat as meteorological observers supporting the proposed tropical cyclone reconnaissance mission.

After much debate, several hand-picked BOM personnel received aircrew ejection seat and survival safety training to qualify for flights on the RAAF jets. The BOM observers flew their first cyclone reconnaissance flights on 3-4 April 1964, when two Canberra jets flew over Cyclone Henrietta, as it tracked south in the Coral Sea between Brisbane and New Caledonia. Although no clear eye was visible, on either flight, the BOM flight observers were able to locate the storm's center and photographed the storm's cloud features.

Like with the other Canberra Jet cyclone reconnaissance flights, important storm information was passed to the BOM's cyclone warning center and incorporated into public storm forecasts and warnings.

Through these flights, Australia had successfully demonstrated (*to itself*) that operational military reconnaissance aircraft could, at high-altitude, safely reconnoitre a fully-developed mature tropical cyclone and provide vital storm information towards cyclone warnings. However, despite having been successful and seemingly a practicable tool in support of national tropical cyclone forecasts and warnings towards the benefit of the public, none of these Canberra Jet flights had any official RAAF authorization beyond the local base command at Amberley. No further flights were flown beyond 1964.

The BOM on the other hand, recognised the benefits of these aerial tropical cyclone reconnaissance flights, and drove a priority within the Bureau to establish cyclone reconnaissance capability. The BOM published a number of technical papers on the Canberra Jet flights, as a means to present this concept to the government at large and garner support towards the establishment of an official routine aircraft cyclone reconnaissance capability.

Other RAAF Cyclone Reconnaissance Flights

During this same timeframe of the 1960s, and running independent to the Canberra flights, other RAAF aircraft had been conducting weather reconnaissance and tropical cyclone reconnaissance flights in unofficial support to regional BOM forecast offices. RAAF aircraft, particularly those serving with maritime patrol squadrons, began providing weather observations during routine long-range maritime patrol flights in around Australia.

Although RAAF maritime patrol squadrons never had tropical cyclone reconnaissance or weather reconnaissance missions assigned to them in any official capacity, RAAF patrol aircraft were directed to, on occasion, report special weather conditions and or storms encountered during long-range maritime reconnaissance patrols for specific purposes.

RAAF maritime patrol units involved in cyclone reconnaissance consisted mostly of No.10 Maritime Reconnaissance Squadron, based at the time at Garbutt Field (*Townsville*), Queensland and No.11 Maritime Reconnaissance Squadron headquartered at the time at RAAF Base Richmond, (*Richmond*) New South Wales.

On 17 January 1961, a No.10 squadron Mk.31 Lincoln maritime patrol aircraft was sent out to reconnoitre a developing cyclone as it tracked towards Darwin, to support BOM public forecasts and warnings. Later in February 1962, a No.11 squadron P2V-5(F) Neptune detected a nascent cyclone off the northwest coast of Western Australia. On 20 February 1962, the RAAF P-2 located the cyclone's center and the crew's observations predicted the storm's subsequent intensification. Vital information that was transmitted directly to area tropical cyclone forecasters.

Another No.11 Squadron patrol flight in March 1962, discovered a decaying cyclone in the Indian Ocean near the Cocos Islands. Two flights were flown into this storm, including one on 3 March, near the center where strong winds, broken cumuliform clouds and intermittent rain were observed and reported. A

second flight was flown on 7 March, near the center of the remnants of the decaying storm, with the aircraft reporting only intermittent rain.

Another situation where RAAF aircraft specifically carried out weather reconnaissance, including specific “cyclone hunting” flights, was during Royal visits to Australia.

Australian Royal Visits

During Royal visits to Australia by Queen Elizabeth II and the Duke of Edinburgh in 1954 and 1963, RAAF aircraft were often tasked with weather reconnaissance flights to support these tours.

In March 1963, RAAF P-2 Neptune maritime patrol aircraft, from No.10 Squadron, flew 10-hour long tropical cyclone hunting missions to specifically locate any potential cyclones far at sea, to safe-guard the Queen during her Northern Australian tour – which occurred during the peak of the Australian cyclone season. The flights were conducted throughout the Arafura and Timor Seas and along the Northern Australian coast. The Neptune flights reported weather conditions and meteorological measurements with much effort taken to guard against the appearance of cyclones with little or no advanced warning.

RAAF No.11 Squadron P-2 Neptunes also supported this Royal Tour, with one aircraft having intercepted the Queens’ flight 600 miles out at sea and escorted the aircraft to Canberra.

As it was, no tropical cyclones occurred in the area to have affected this year’s royal Australian visit. However, the preceding Royal Visit between in February and April 1954, occurred during an active cyclone period with more than 6 storms materializing over a 4 month period. During Her Majesty’s tour, the Queen travelled approximately 10,000 miles (16,093 kms) in and around Australia by air (some 33 flights) visiting more than 70 Australian towns and cities. During this period, the RAAF flew more than 363 sorties, totaling approximately 600 flight hours. Most of these support operations comprised weather reconnaissance missions and specific cyclone hunting / reconnaissance flights, that helped forecasters assess the weather for planned royal events and to allow for alterations to the royal schedule. No.11 Squadron aircraft were known to have support this royal tour and would have flown long-range weather patrol and cyclone hunting flights.

RAAF patrol aircraft tropical cyclone flights continued through 1963 with a cyclone reconnaissance flight made on 9 May 1963. Flying out of Townsville, a No. 10 Squadron P-2 Neptune located a decaying cyclone tracking through the southeastern and eastern Coral Sea, some 140 miles (225 kms) west, northwest of Lord Howe Island, adjacent to New South Wales.

RAAF cyclone flights continued periodically out of Townsville throughout the 1970s, which saw the introduction of the new RAAF P-3B Orion patrol aircraft into cyclone reconnaissance in 1968.

In February 1975, two RAAF P-3 Orion radar storm fixes were reported on Tropical Cyclone Trixie as it tracked along the Western Australian coast for more than 1367 miles (2200 kms). Trixie was the first tropical cyclone to develop and track within range of an Australian coast since Cyclone Tracy, just less than eight week before.

..... side bar Cyclone Tracy (20-25 December 1974)

Considered to be the most destructive cyclone to have ever struck Australia (at the time) Cyclone Tracy crept out of the darkness of the Arafura Sea on Christmas Eve 1974 and nearly completely destroyed the city of Darwin.

Tracy was a small, slow-moving, intense tropical cyclone with sustain winds in excess of 135 mph (217 km/h), registered at Darwin Airport before the wind anemometer itself was blown away. Point-of-fact, higher gusts estimated at 186 mph (300 km/h) were unofficially measured and or estimated. Wide spread devastation prevailed in the wake of Tracy, with more than 75 percent of the city destroyed - including 90 percent of all housing and most of the city's infrastructure, prompting officials to evacuate more than half the population of 48,000 after the storm.

Fatalities from Tracy comprised approximately 71 people; 49 killed in Darwin and another 22 lost at sea in the storm.

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In the weeks and months after Tropical Cyclone Tracy, as means to placate a nervous public within the region and potentially those elsewhere, the Government directed RAAF patrol aircraft to fly low-level cyclone reconnaissance missions into any storm that materialized in and around Australia. These flights included BOM meteorologists on-board as observers that made "*aircraft reports*" directly to the BOM regional cyclone warning centers to support forecasts. On 18 February 1975, a No.11 Squadron P-3B Orion made two radar storm fixes of Cyclone Trixie within an hour span, one near Port Hedland and the other 111 miles (178 kms) from the eye near Dampier.

The RAAF Orion reports were just two of six aerial reports filed on Cyclone Trixie. The others having been made by commercial transport and passenger aircraft transiting through the area in the outer fringes of the storm.

Piper Navajo Cyclone Flights

Little known within Australia itself, another situation occurred where-by a small commercial aircraft was tasked with flying around tropical cyclones in support of the off-shore petroleum industry.

Unrelated to the direct support of BOM cyclone forecasts, a test case was conducted between 1973 and 1974, whereby a small Piper Navajo commercial passenger plane was used to fly into the outer fringes of tropical cyclones, to make meteorological measurements of these storms.

Given that the principle government tropical cyclone warning and forecast capabilities were land-based, the petroleum industry, represented by Western Australian PETroleum Pty Ltd. or WAPET, looked towards developing a cyclone reconnaissance capability of its own to minimise the damage to their production operations posed by these storms. During the 1973-74 Australian tropical cyclone season, the trial aerial reconnaissance of tropical cyclones was undertaken over offshore areas of the northwestern regions of Western Australia.

The project was established and financed by WAPET, in partnership with the Burmah Oil Company of Australia Ltd. (BOCAL) and Port Hedland Port Authority as well as with meteorological support from the regional BOM office.

The flights comprised the peripheral reconnaissance around detected cyclones by a contracted Piper PA-31 (310) Navajo airplane. The Piper PA-31 Navajo is a six to eight passenger, twin-engine airplane marketed for general aviation passenger and light-cargo operations. This cyclone reconnaissance Navajo was further specially-equipped for the cyclone mission, modified with long-range fuel tanks, dual-Doppler navigation, and weather avoidance radar.

The modifications to the aircraft were made by Altair Pty. Ltd., who was also contracted to operate the aircraft on the cyclone reconnaissance flights. Altair was already providing air charter services to WAPET, flying a scheduled air passenger service back and forth to Barrow Island and conducting occasional geologic surveys.

During this first season, the Navajo flew a number of reconnaissance flights during three different cyclone events, included Tropical Cyclones Erica (30 December 1973 – 3 January 1974), Fiona (7-14 January 1974) and Helen (28 February - 8 March 1974). On Cyclone Helen, two flights were flown into the storm over as many days. The Navajo flew a triangular route around the periphery of the storm out of Barrow island, towards the northeast, then west and finally back to the Southeast and back to Barrow island. Cyclone Helen had paralleled the coast for over 2113 miles (3400 kms), some 81 miles (130 kms) off shore. The storm's center passed within a few kilometers of the oil rig Glomar Tasman and directly over the oil rig Ocean Digger.

The Navajo cyclone missions, included two-pilots and one passenger observer, were flown at altitudes between 2000 and 5000 feet (610 -1,524 meters). On Helen, the observer was a BOM forecaster that flew along on the flight.

Although the original WAPET contract included plans to fly the cyclone reconnaissance flights for an initial three years, with more immediate plans to fly the Navajo during the following 1974-75 cyclone season, no additional flight were ever made after October 1974. Unfortunately, the air charter company unexpectedly went broke in the fall of 1974 and the WAPET Navajo was never able to resume continued cyclone flights

In retrospect, the WEPET Navajo aircraft could never get close enough to the core within the storm to gather or provide any useful reconnaissance data on the cyclones to benefit WAPET.

NOAA Cyclone flights

During this same timeframe in the mid-1970s, the Australian BOM and NOAA began discussing the potential of moving NOAA's on-going hurricane research (*cloud seeding*) modification program, ``Project Stormfury`` to the Pacific and partnering with Australia.

Up until this point, NOAA's Stormfury project had been an experimental hurricane modification program which sought to weaken hurricanes in the Atlantic to diminish the storms' destructive power before making landfall in heavily populated areas of the US's southern and east coasts. Unfortunately after nearly 15 years, the program had only seeded 4 storms with mixed results. NOAA was interested in moving its experimental seeding project to the Pacific, where the frequency of potential storms to seed was greater than in the Atlantic and partner with another agency to help progress the success of the program.

Under the new proposed joint concept, the BOM, along with other Australian agencies and services (*such as the RAAF*), would team-up with NOAA to conduct *Stormfury-like* tropical cyclone seeding experiments in Australian waters. The benefits to Australia were to have comprised a generic aerial cyclone reconnaissance capability, to improve BOM cyclone forecasts and warnings, and an additional opportunity to participate in the American cyclone seeding operations to help find a definitive method to reduce the destructive forces of these storms in Australia – in the wake of Tracy.

US research aircraft were to have deployed to Australia each year and provided airborne tropical cyclone reconnaissance capability, associated with seeding operations, that could integrate storm reconnaissance data into BOM cyclone forecasts and warnings.

As previously discussed, NOAA had conducted scientific reconnaissance flights into Cyclones Kerry and Rosa during a visit in February - March 1979. Dubbed the "*Cyclone Tracker*" by the Australian press, the NOAA WP-3D operating out of RAAF Base Garbutt in Townsville (*also from Brisbane*) and flew reconnaissance flights into Cyclone Kerry while it tracked off the Queensland coast. Later the American P-3 flew Cyclone Rosa in the Gulf of Carpentaria near landfall.

But in the end, elements in the Australian Government opposed the joint Australian – American project and the liabilities associated with the experimental modification of tropical cyclones. Although the BOM further tried to gain support towards budgetary requests for tropical cyclone reconnaissance (*capability*) funding, it never materialized.

Continued Cyclone Flights

In the meantime, during periods in the 1980s and into the 1990s, RAAF maritime patrol squadrons continued to make occasional weather and cyclone reconnaissance flights while participating in government-sponsored meteorological research projects.

Later on 21 February 1995, a RAAF P-3 made a reconnaissance flight on a cyclone that had developed out over the Timor Sea and moved westward along the western Australian coast, eventually making landfall just east of Onslow. Detected by a No.10 Squadron P-3C, while conducting maritime surveillance flights out over the Indian Ocean, from the Cocos Islands, Tropical Cyclone Bobby was found to have peak winds in excess of 175 mph (282 km/h) and torrential rainfall (*more than 16 inches or 400 mm*) that caused severe flooding in the Onslow area

Between the 23rd and 24th, another RAAF P-3C flight detected an alarming drop in the storm's central pressure (*down to 964 mb or 28.47 inches*). A severe drop in pressure over a 24-hour period is indicative of a severe intense cyclone. The P-3 also reported on the storm's cloud structure and that its hurricane force winds extended out 250 miles (402 kms) from the center.

It is clear from Australian BOM storm reports and RAAF operations records, that P-3 maritime patrol units continued to report on tropical cyclones as they come across them, during their long-range patrols around Australia for years during this period of the 1980s-90s.

COASTWATCH Cyclone Flights

Another government agency that regularly provides occasional weather observations and air reports on cyclones is the Border Protection Division of Australian Customs, or more traditionally known as the *Australian Coastwatch*.

Currently, the Border Protection Command conducts long-range surveillance patrols throughout the Australian Exclusive Economic Zone (EEZ) with a small fleet of fix-wing patrol aircraft and in-shore helicopters (*operated under government contract by Surveillance Australia Pty Ltd.*) searching for illegal fishing vessels, refugee smugglers, drug traffickers and immigration and quarantine breaches.

The agency also provides an auxiliary search and rescue (SAR) capability and by virtue of their long-range patrols, offers weather observations in data sparse areas in and around Australia.

It's during these patrols that the so-called Coastwatch aircraft would occasionally encountered tropical cyclones. Mostly involving Coastwatch Bombardier DHC-8 (*Dash 8*) Maritime Patrol Aircraft, equipped with military search radar, weather avoidance radar and a sophisticated navigation and (*satellite*) communications suite, the Coastwatch aircraft can provide a higher level of storm fixes than those reports by commercial aircraft. The Dash 8 can often encounter tropical cyclones during low-level flights, generally below 10,000 feet (3,048 meters), however well away from storm's center.

Since the Coastwatch's earliest air operations, beginning in the 1980s, assigned aircraft have provided regular weather reports during long-range patrols. In 1987, a Coastwatch patrol plane detected a severe cyclone (*Tropical Cyclone Jason*) and provided the first critical information on the storm to BOM Forecasters.

CSIRO F-27 Fokker (EMEX)

It was also during 1987, that another Australian aircraft, participating in meteorological research project, became involved in a flight into tropical cyclone.

In January 1987, during an international field research study conducted in Australia, several research flights were made into a tropical cyclone that developed during the project. The Equatorial Mesoscale Experiment (*EMEX*) group of international research aircraft, investigated the outer rainbands in the leading edge of the developing Tropical Cyclone Irma. Tropical Cyclone Irma (*19-21 January 1987*) unexpectedly formed out of an area of deep convection within the seasonal monsoon flow over the Gulf of Carpentaria.

Reminiscent of the Cyclone Kerry reconnaissance flights in 1979, some of the EMEX participating research aircraft were subsequently tasked to conduct (*research*) reconnaissance flights into the storm to collect vital data into this unusual occurrence. Again, a NOAA WP-3D Orion took the lead and conducted a research survey pattern through the storm, bringing the aircraft close to the storm's center.

Of particular interest on this occasion, was the participation of an Australian research aircraft that flew in the outer rainbands of the cyclone. A Fokker F-27 Atmospheric Research Aircraft, assigned to the Australian "Commonwealth Science and Industrial Research Organization" (*CSIRO*), criss-crossed the rainbands in the adjacent stratiformed region of the cyclone, collecting data. Configured as a cloud physics research aircraft, the CSIRO F-27 flew in the outer fringes of the Irma, in the cyclone's rainbands at low altitude.

The CSIRO F-27 was accompanied by another American atmospheric research aircraft, an L-188 Electra, from the US National Center for Atmospheric Research or NCAR. The Electra, participating in the EMEX project, additionally flew into Irma collecting data in the outer rainbands of the storm. A NASA high-altitude, earth resources U-2 research aircraft or ER-2, also participating in the EMEX project and flew photo surveillance and remote sensing missions over Irma during this event

Although this was an exciting event for the CSIRO aircraft, and an opportunity to expand the plane's mission capabilities and promote a domestic Australian cyclone reconnaissance capability, this flight was the first and last time that the CSIRO F-27 would fly into a tropical cyclone.

Aerosondes

It was later in the 1990s, that the Australian BOM considered another means by which to collect weather and cyclone reconnaissance data towards improved cyclone forecasts and warnings. This new form of tropical cyclone reconnaissance data-collection opportunity arose with the introduction of (*pilotless*) unmanned aerial vehicles called "Aerosondes".

The Aerosonde, is a small robotic meteorological probe with a 9 foot (2.74 meters) -wide wing-spanned and 20 cc (gasoline) driven-engine, that was designed to collect and transmitting continuous in-situ meteorological data – including wind speed and direction, pressure, temperature and humidity as well as vehicle flight information (course, speed, altitude and navigational / position) during reconnaissance missions.

Under an operational development field trial in January-February 1998, sponsored by the BOM, eleven early model Aerosonde UAVs flew multiple meteorological mission profiles, including the first UAV to have ever flown into a tropical cyclone. The 6-week field trial, conducted out of the Cargill Salt Flats (*Works*) near Port Hedland (*Western Australia*), comprised a series of operational test flights, including those that focus on sea-breeze, off-shore (*synoptic*) monitoring flights flown in and around thunderstorm, and subsequently a flight into the outer circulation of Severe Tropical Cyclone Tiffany. On 27 January 1998, a test Aerosonde flew into Cyclone Tiffany to sample the storm's environment, in and around convective cells within the outer bands of the storm as it tracked along the Pilbara coast of Western Australia.

Although successful in this operational evaluation, the BOM subsequently passed on the acquisition of a fleet of Aerosondes for weather and cyclone reconnaissance.

RAAF C-130 Hercules

Other RAAF aircraft that occasionally have provided weather data during long-range flights, included C-130 Hercules.

More noted for coming to the rescue after national disasters (*earthquakes, tsunamis and tropical cyclones*) with medical supplies, emergency equipment as well as food and water, and providing emergency evacuation of the sick and injured, RAAF strategic C-130 Hercules transport aircraft have additionally been tasked to gather meteorological data during long-range transport flights over adjacent oceans at the request of BOM forecasters.

RAAF No.36 and No.37 Transport Squadrons, conducting regular transport flights between Australia and South Vietnam (*between 1962-72 during the Southeast Asian conflict*), between Australia and the Malayan Peninsula, over the Southern oceans between Australia, New Zealand and Antarctica, as well as in and around the Australian Continent, often reported the weather and any special weather phenomenon encountered.

It was a No.37 Squadron C-130E Hercules that was the first military emergency aircraft to land in Darwin after the devastation wrought by Cyclone Tracy on Christmas Day 1974. A squadron Herk landed at the Darwin airport amid destruction and debris, from the destroyed airfield, scattered across the runway. This first transport aircraft was later the first aircraft to fly out of the destroyed city, after the storm, with 28 critically injured victims. This was the first plane of an armada of rescue aircraft that eventually evacuated more than half the city of 48,000.

But occasionally the RAAF Hercules did more than just respond in the aftermath of cyclones, sometimes they found themselves flying in and around tropical cyclones for specific missions. Such was the case in March 2009, when two No.37 Squadron C-130J Hercules participated in a search and rescue operations that had them fly into the eye of Cyclone Hamish, in a desperate bid to locate a missing trawler with three crewmen, off the Queensland coast.

Hamish, a particularly severe tropical cyclone, tracked back and forth along the Queensland Coast from Maryborough (*Gold Coast*) north to Cooktown (*Far North region*), but fortunately stay well off shore presenting a danger only to ocean going vessels in the area. In fact, a bulk carrier off Stradbroke Island lost most of its deck-mounted cargo of shipping containers during the storm in mountainous waves, that further ruptured the ship's fuel tanks - causing an oil slick that came ashore along Queensland area beaches.

Between 10-11 March 2009, night vision-equipped RAAF C-130Js flew into Cyclone Hamish more than 161 miles (*259 kms*) east of Rockhampton, when the storm was at peak intensity with winds of 155 mph (*250 km/h*), looking for the missing fishermen. The RAAF Herks were also accompanied by a search and rescue Dornier 471, from Australian Maritime Safety Authority, that additionally braved the severe weather conditions to locate the missing trawler and crew. Both aircraft had been directed to the general location of the search by an emergency locator beacon, that ultimately resulted in locating one crew member from the missing vessel in the water. The SAR Dornier actually dropped the survivor a life raft, who was later picked up by a rescue helicopter.

Although never credited, this search and rescue mission again demonstrated that Australian military aircraft were capable of flying in the adverse conditions associated with tropical cyclones and could provide a means by which to secure vital tropical cyclone reconnaissance information to support improved cyclone forecast models.

Australian Cyclone Reconnaissance: Today

Since the time of the Canberra Jet cyclone reconnaissance flights in the early 1960s, the BOM has repeatedly sought to establish a routine cyclone reconnaissance capability and conducted a number of studies and cost estimates to acquire and maintain cyclone reconnaissance aircraft.

As late as 2007, an Australian government study of tropical cyclones in an era of climate change, establishing proposed research priorities, once again made recommendations for the establishment of weather reconnaissance and research aircraft capabilities (*manned or unmanned*) to support numerical computer-based cyclone track, intensity and landfall forecasts models similar to those used in the United States.

Weather satellites are currently the principle meteorological tool for the BOM, providing visible, infrared, radar as well as water concentration imagery that support these numerical weather computer models towards national forecasts and cyclone warnings. However, they are not able to provide the precise information derived from in-situ aircraft data collected during reconnaissance operations.

Despite a long history of unofficial cyclone reconnaissance flights, supporting cyclone forecasts and warnings, Australia today still does not possess a viable airborne weather and cyclone reconnaissance capability to support improved forecasts geared towards protecting it's populace against the ravages of tropical cyclones.

The End