Fluid Ontologies in the Search for MH370

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Abstract

This paper gives an account of the disappearance of Malaysian Airways Flight MH370 into the southern Indian Ocean in March 2014 and analyses the rare glimpses into remote ocean space this incident opened up. It follows the tenuous clues as to where the aeroplane might have come to rest after it disappeared from radar screens – seven satellite pings, hundreds of pieces of floating debris and six underwater sonic recordings – as ways of entering into and thinking about ocean space. The paper pays attention to and analyses this space on three registers – first, as a fluid, more-than-human materiality with particular properties and agencies; second, as a synthetic situation, a composite of informational bits and pieces scopically articulated and augmented; and third, as geopolitics, delineated by the protocols of international search and rescue. On all three registers – as matter, as data and as law – the ocean is shown to be ontologically fluid, a world defined by movement, flow and flux, posing intractable difficulties for human interactions with it.

Keywords

Malaysian Airways flight MH370, Southern Indian Ocean, fluid ontologies, scopic systems, maritime search and rescue

Introduction

It is very rare, if ever, that the Southern Indian Ocean has come into view with the intensity that it did than during the search for missing Malaysian Airways Flight MH370 in March and April 2014. During that period, major news channels throughout the world carried daily reports of the search underway in a remote part of the Indian Ocean. They showed a great deal of footage of the surface of the sea and people scanning it, simulations of ocean eddies and ships scurrying across it, data visualisations of possible flight paths and ocean depths, daily statistics of ships and aircraft searching for the plane, how far they went each day, where they searched and whose ships and aircraft they were. Little known terminology, communication companies and technologies used in the search became household words. Measurements, statistics and simulations served in lieu of evidence and as the basis of authoritative political pronouncements. Political alliances and fault lines began to show. At the same time, satellite systems, technologies and science were shown to be full of delays, glitches and error, confounded by the unassailable materiality and opacity of the ocean.

In this paper, I attempt to delineate the contours of this ocean and human combinations with it. I do so by examining the tenuous clues as to where the aeroplane might have gone after it disappeared from radar screens – seven satellite pings, hundreds of pieces of floating debris and six underwater sonic recordings – as apertures into ocean space. Despite failing in their forensic objectives vis-à-vis the aeroplane, these clues led into the ocean and gave it witness in powerful new ways. The first three sections of the paper follow the trail left by the three sets of clues. This corresponds, not only with the dimensions of the oceanic volume through which the aeroplane moved on its way to its final resting place – air, ocean surface, and sub-surface aquatic depth, but also with the temporal sequence of its journey. This provides a narrative scaffold on which I assemble a composite portrait of the ocean and its human amalgamations.

The clues took the search into a remote part of the ocean where land and land-based material, experiential and legal frames of reference receded altogether. The power and agency of a vast, little known, intensely mobile ocean come into play, stretching to the limit and ultimately confounding all attempts to call it to account for the aeroplane's disappearance. The aeroplane's ongoing invisibility provided a privileged, if tragic, moment to see beyond a world constructed by humans and to get a little closer to understanding the properties of the ocean itself:

a vast liquid space whose ambient thickness and intensity is in a permanent state of becoming: folding, shifting, arching, twisting; always in motion, always displacing its volume across vast distances, always indifferent to the life forms enveloped by its mobile flows. (Gordillo, 2014)

To be interrogated however, the ocean's surface, waves, currents and depths were translated into data – coordinates, measurements, simulations, and visualisations. This mobilised an extensive scopic system, comprising ‘screen-based technologies of observation and projection that render[ed] distant and invisible phenomena situationally present, unfold[ed] remote spaces and information worlds, and shift[ed] the boundaries between situation/system and the environment’ (Knorr Cetina, 2010–2012). This transformed the ocean into something resembling a ‘synthetic situation’, a concept borrowed from Karen Knorr Cetina's analysis of global financial markets (Knorr Cetina, 2009; Knorr Cetina & Breugger, 2002). These are fluid, constantly mobile composites of physical settings (trading floors, computer screens, traders’ bodies, and so on) and scoped components (informational composites of bits and pieces of data, assembled from many parts of the world through ‘an arrangement of hardware, software, and human feeds that together function like a scope’ (Knorr Cetina, 2009, p. 64). The aeroplane and ocean encountered by most people, myself included, during the search for MH370, were entirely synthetic, scoped situations, constantly being updated on television or computer screens by multiple agencies into a fluid, global, multi-scalar, multi-centred scopic system (cf. Knorr Cetina, 2003; Knorr Cetina & Breugger, 2002).

The search was conducted within the jurisdictions and protocols of the International Maritime Organisation's (IMO's) International Convention on Maritime Search and Rescue (1979). This mapped across other maritime jurisdictions such as those of the United Nations Convention on the Law of the Sea (UNCLOS, 1982), setting up what Heller and Pezzani (2014, p. 664) call forms of ‘mobile governance’, in which the rights and obligations that compose modern state sovereignty on land expand and contract depending on the specific issue in question at sea. It should come as no surprise (Steinberg, 2014b), given what we now know of the politics of humanitarian aid (Chandler, 2001; Duffield, Macrae, & Curtis, 2001; Middleton & O’Keefe, 1998; Weizman, 2011) and the role of emergency response in forging and projecting state power (Cooper Drury, Olsen, & Van Belle, 2005; Fassin & Pandolfi, 2010; Tironi, Rodriguez-Giralt, & Guggenheim, 2014), that that the search was used to further global and regional hegemony, promote nationalist interests, build alliances and espionage. These dynamics at times directed or thwarted the search itself.

The paper will examine the ocean that the search for MH370 made visible on these three registers: as more-than-human materiality, as synthetic situation and as law. As more-than-human materiality with particular properties arising from earth's energies and forces, as a synthetic composite of informational bits and pieces scopically articulated and augmented, and as legal and geopolitical space delineated by a mesh of international laws and conventions, the ocean is shown to be ontologically fluid; all three registers are constituted by mobility, flow and flux (Peters, 2014). The intractable difficulties for human engagement, comprehension and law that result are analysed and discussed.

Seven satellite pings

Knorr Cetina (2009) describes the aeroplane cockpit as a quintessential scoped, synthetic situation, where all transactions take place with a future goal in mind – safe landing at a projected destination. Pilots are continuously bombarded with and respond to streamed data towards this envisaged goal. She argues that this makes a synthetic situation ‘fateful’ (Knorr Cetina, 2009, p. 81) –charged with significance and directed at an anticipated, but uncertain future. A flight is an ‘engine of fatefulness’ (Knorr Cetina, 2009, p. 81) thrusting pilots and passengers into a temporally organised, synthetic engagement with a vast scopic system – air traffic control towers, satellites, data link systems, data feeds, radio, radar, etc., which articulates their developing fate. She suggests that this fatefulness is inherent to all scopic systems because of their enhanced informational content. ‘They make visible, project, and record things that cannot be seen in a physical situation, …casually implicating themselves in the progress of the situation and its outcomes’ (Knorr Cetina, 2009, p. 82). It is this scopic fatefulness that was scrolled through, replayed, modelled and mobilised as evidence in the search for MH370.

ACARS (short for Aircraft Communications Addressing and Reporting System) is a digital data link system for transmission of messages between aircraft and ground stations via radio or satellite that began replacing voice communication on commercial aircraft in 1978. The ACARS equipment on an aircraft is linked to that on the ground via a data-link service. Flight MH370 was fitted with an ACARS system called Classic Aero and its data-link service was provided by the UK based company Inmarsat (Pratley, 2014).[1] Classic Aero is turned on and off manually via a switch on the ceiling of the cockpit or behind the throttles between the pilot and co-pilot, but it has a second terminal that operates independently and cannot be switched off while the aircraft still has power. After MH370's ACARS data transmission link ceased operating (or was shut down), this second terminal continued to respond automatically to seven hourly pings[2] from Inmarsat-3 F1, a geo-stationary satellite hovering 35,800 km above the equator over the Indian Ocean with a footprint that covers Africa and much of Asia and Australia.[3] The last of seven pings from MH370 was received by Inmarsat's satellite ground station in Perth, Australia at 08:19 on 9 March 2014.[4]

The little batch of seven pings or handshakes between MH370 and Inmarsat-3 F1 is, as yet, the only confirmed evidence of the aeroplane's existence after it disappeared off radar screens. They were extracted from deep inside the architecture of the scopic system that fed the aeroplane (Schuster Bruce, 2014) and were enhanced and fatefully modelled, to use Knorr Cetina's terminology, to determine the aeroplane's likely destination. Pings do not specify a plane's location or the direction it's heading, but they provide two kinds of data that are useful for this purpose. The first is the time it takes for the ping to travel between satellite and aircraft, from which the distance between the two can be calculated; the second is the radio frequency at which the response is received by the satellite (the pitch of its voice), from which can be calculated whether it was moving towards or away from the satellite when it was transmitted, the so-called Doppler effect, which we commonly experience as the sound of a train approaching and leaving a platform (Schulman, 2014). Inmarsat engineers took the data provided by the seven pings and modelled possible flight paths to fit them. Malaysian authorities released this data on 15 March 2014, in the form of the now-famous two arcs map, one following a northbound trajectory, one a southbound. They later released data about ping frequencies in the form of graphs for flights paths along these arcs (Steel, 2014b). These show the frequency shifts or offsets, i.e. the differences between the normal pitch of the ping's frequency and the one actually received by the satellite. When a plane moves away from a satellite, the radio signal is stretched out and the frequency decreased, and vice versa. The graphs show the shifts that could be expected for hypothetical northbound and southbound flight paths, with the measured values closely matching the southbound path (Schulman, 2014). This is the basis on which engineers and officials have been so confident that the plane went south.[5]

If one examines the ping data and their ongoing interpretation by investigators, it becomes clear that the judgements made about them were intricate, inductive arguments, not verifiable truths (Edwards, 1999). They were mathematical models or simulations, on the basis of which decisions were made and actions followed. Models however, cannot be verified; they can only be validated i.e. be shown to have internal consistency. At best, they can be confirmed if their results agree with observation, but they can never be proven correct (Edwards, 1999). The ping data were subjected to mathematical and computational techniques for drawing information out of them to model likely flight paths and predict where the plane went down, against which the data was then matched. This involved a raft of assumptions, algorithms, judgements and approximations, theories about aeroplane speed and height, satellite position and movement, atmospheric conditions etc. all of which produced different results. For example, initial results released by Inmarsat showed that the faster it was assumed the plane was moving, the more sharply its path arced away from the satellite. Later, in June 2014, the Australian Transportation Safety Bureau (ATSB) announced that the next phase of the search for the missing aeroplane would focus on a ‘new hotspot’ hundreds of miles south of the first suspected crash site (Amos, 2014b). This was not based on new data, but on refined analysis of existing data. ‘There was a very complex analysis and there were several different ways of looking at it. Specialists have used several different methodologies and bringing all of that work together to get a consensus view is what we’re finalising at the moment’, Mark Dolan, Chief Commissioner of the ATSB said on 20 June 2014 (Associated Press, 2014). Modelling then, is always an ‘inexact science’ (Edwards, 1999; Rayner & Collins, 2014). Most data themselves depend on modelling and are inherently uncertain. Joseph Dumit (2006) reminds us that in all communication systems, every transponding event, such as a satellite ping, is cause for existential doubt. Each interface a ping passes through generates a new ping, it does not just pass the ping received along. Pings are like whispered messages in a game of broken telephone. Participants (interfaces) can never be certain about what they have heard; they compile data from fuzzy audio sensoria and make judgements about them before relaying them on. ‘Each interface, gap and infinitesimal delay’, Dumit tells us, ‘poses the question of truth' (Dumit, 2006, p. 439). How much more so in the case of remote sensing systems, where interfaces are required to aggregate uncertain signals transmitted across vast distances through a changing atmosphere distorted by Doppler and other effects, and sort them and rank them for truth before emitting them again. They are, says Dumit (2006, p. 185), 'structurally and logically paranoid', wired with uncertainty, anxiety and neurosis.

The Inmarsat data, once released, coursed through the media as maps, charts, diagrams and pronouncements, and was mobilised in the service of socio-political priorities and agendas. The official map shared by Malaysian authorities with families of victims and the public on 15 March and sent around the world on Reuter's twitter feed (Reuters, 2014) showed a series of concentric circles radiating out from the Inmarsat F3-1 satellite. On one of them, the two arcs are outlined in red, indicated the 'last known possible position' of MH370, based on 'satellite data' (Reuters, 2014). Stamped with the seal of authority, this map ascribed to data a regime of truth, anchoring its analyses with scientific and graphic certainty. On 24 March 2014 Malaysian Prime Minister, Najib Razak announced that the aeroplane had crashed in the southern Indian Ocean 'beyond reasonable doubt', and was lost with no survivors, attributing agency to the Inmarsat data: 'It is with deep sadness and regret that I must inform you that, according to this new data, flight MH370 ended in the southern Indian Ocean' (Malaysia Plane: Families Told Missing Flight Lost, 2014). Families of the victims received the announcement with anguish, anger and mistrust. Deep scepticism prevailed over the way that the Malaysian authorities had handled the investigation. The authorities were accused of delays and of failing to share information because they did want to admit weaknesses in their radar and satellite capabilities (Moss, 2014). The Malaysian Prime Minister denied this, saying that the country 'shared information in real time with authorities who have the necessary experience to interpret the data'. The Chinese government begged to differ, asking Malaysia to provide 'more detailed information in its possession, including third-party information, in a timely, accurate and comprehensive manner' (Pasztor, Ostrower, & Hookway, 2014).

While the arguments went on, British and US intelligence agencies were gathering military and civilian satellite images to analyse them for possible debris in the southern Indian Ocean. By 14 March, the USA had dispatched a Poseidon P8 submarine and USS Kid into the Southern Indian Ocean. On 18 March, rescue teams in the Southern Indian Ocean announced that they had narrowed the search for the aeroplane to a location 2400 km southwest of Perth in Western Australia, where sightings of debris had been made.

Hundreds of pieces of floating debris

The search for the missing aeroplane had been directed by the Inmarsat data to a vast, unbounded, deep, cold, turbulent ocean region subject to some of the most dynamic weather conditions on the planet. It is swept by unrelenting westerly winds driving cold fronts ahead of them; during the search, a typhoon swirled across the sea, cancelling search operations for two days. The waves in this part of the ocean are monstrous, dwarfing the ships sent out to search it; it is whipped up into storms by the bands of low-pressure sweeping eastwards across it. Powerful undercurrents run along its surface slopes – the Antarctic Circumpolar Current transporting 130 billion cubic metres of water per second eastwards around the southern part of the planet virtually unobstructed, and the Indian Ocean Gyre swirling anti-clockwise up the west coast of Australia. Moulded by little known trenches and mountains on the seafloor, these currents connect deep, cold, abyssal waters with the surface and, influenced by differences in speed, temperature, salinity and pressure they collide, swirling, eddying and transmitting energy in complicated, turbulent, non-linear ways. The crash site was located in the boundary between these two currents, in a 'sea of uncertainty' (Amos, 2014a), where eddies are about 60 miles wide and debris can travel up to 30 miles a day. Oceanographic and meteorological experts expressed doubts about finding any plane debris at all as, even if it was spotted, it could have drifted hundreds of miles before it could be verified (Farrell, 2014a).

Looking for plane debris in the ocean began in outer space. The search mobilised a vast scopic system of satellites, floats, drifting buoys, data collection systems on ships, computer screens, imaging techniques, UN agencies and protocols, national agencies, private companies etc.[6] On 11 March, China's Meteorological Administration requested activation of the Charter On Cooperation To Achieve The Coordinated Use Of Space Facilities In The Event Of Natural Or Technological Disasters (2000) to gain access to global satellite imagery. The 15 national and international organisations that were signatories to the charter were required to supply space-based remote-sensing data free of charge in support of the search effort. DigitalGlobe, the commercial US satellite operator, expanded Tomnod its digital crowdsourcing platform (http://www.tomnod.com/) to engage the public in the search for the missing plane (Missing Airplane: Malaysian Airlines MH370, 2014).[7] Satellite imagery of the ocean's surface was uploaded to the Tomnod site; alerted on Facebook when new imagery was available, amateur data analysts were able to view it and tag potential signs of wreckage by dropping a pin onto a satellite map. A crowd-rank algorithm then identified overlaps in tagged locations before they were investigated by DigitalGlobe analysts (D. Lee, 2014; Svitak, 2014). On 16 March, DigitalGlobe sent satellite images of two large objects captured floating in the Indian Ocean 2400 km southwest of Perth to the Australian Maritime Safety Authority.[8]

Australia was by now coordinating the search operation as it fell within its Search and Rescue Region (SARR), as defined by the IMO's International Convention on Maritime Search and Rescue (1979). Australia has the largest SARR in the world. It covers 12% of the earth's surface, stretching from approximately the central line of longitude of the Indian Ocean in the west, incorporating Tasmania in the east, more or less following Australia's Exclusive Economic Zone boundary in the north (although significantly excluding Christmas Island, but including the Cocos islands), and extending southwards to the South Pole.

The two DigitalGlobe images were assessed by the Australian Geospatial-Intelligence Organisation as credible and a Norwegian car carrier, the Hoegh St Petersburg was diverted to look for them. On 18 March, Chinese news agency *Xinhua* published images of two more large objects, spotted close to the DigitalGlobe sightings by one of its satellites. China sent nine vessels to verify the sightings, including its largest rescue ship, Haixun 01 and the icebreaker Xuelong (Hodal, 2014); a number of other commercial vessels in the vicinity were diverted to verify debris sightings. A third set of satellite data, released on 23 March by French satellite sources indicated a possible debris field of 122 objects of varying sizes 2600 km south-west of Perth. At this point, Malaysia's acting transport minister Hishammuddin Hussein confidently said the find was 'the most credible lead we have' and 'consistent with a plane having struck the sea nearby' (Withnall, 2014). A day later, Thailand's Earth Observation Satellite, Thaichote, spotted over 300 new objects about 2700 km from Perth, 170 km outside the international search area. According to a report from Tokyo, a Japanese satellite also spotted about ten objects possibly related to the missing aeroplane (Malaysian Plane Search, 2014).

With this mounting evidence of possible plane debris, Australian Prime Minister, Tony Abbott announced on 30 March that responsibility for coordinating and communicating the search operation would be transferred from the Australian Maritime Safety Authority to a specially created Joint Agency Co-ordination Centre (JACC) set up in terms of Section 2.2 of the International Convention on Maritime Search and Rescue, possibly – it is alleged – due to sensitivities about classified surveillance data on border protection activities in its northern waters being leaked (Bateman & Bergin, 2014).[9] The JACC set up base at Pearce Air Force Base 32 km north of Perth, and began coordinating daily search operations, initially for plane debris on the surface, followed by an underwater search, continuing throughout April 2014. Over this period, 19 military aircraft, ten civilian aircraft, 14 ships and two submarines representing eight countries (Australia, China, Japan, Malaysia, New Zealand, South Korea, the UK and the USA) are known to have participated in the operation (Gander & Marks, 2014).

Each morning the JACC issued a media release about the search to be conducted that day, including maps showing the current location of search vessels, grey patches indicating areas of the ocean already searched and the search area planned for the day, as measured from the land mass of Western Australia (http://www.jacc.gov.au/). While graphically appearing to represent the progress being made in the search, these maps failed to take into account the ocean's constitutive mobility. Static representations of ocean space are false representation of geophysical processes (Steinberg, 2014a). Put simply, an expanse of ocean water, designated as having been searched by a patch of grey on a map, would not be the same ocean from one day to the next. One simply cannot plot the ocean through stable coordinates. To do so, one would have to follow its vectors of movement. The maps were not maps of the ocean at all, but maps of human combinations with it.

Aircraft flew from Pearce Air Force Base on ten-hour missions each day searching for debris: three hours heading out to sea, three to four hours searching (depending on weather conditions) and three hours heading back to base. Searches were divided into legs, straight lines of flying lasting for 30 to 40 minutes, clearly visible strips on the maps of areas searched. At this point, the vast scopic system mobilised by the search came down to the human eye. Each plane carried five observers, one resting while two peered through its windows. Most of the people doing this were 200 Australian State Emergency Service volunteers from Western Australia, New South Wales and Victoria who signed up for it, indicating the extent to which Australians subscribed to the search and rescue narrative (Farrell, 2014b). Searching required saccading, a particular way of looking that involved moving the head up and down in a fixed position to scan foreground, middle ground, background with pin point accuracy, while talking to keep the concentration going. Once a piece of potential debris was spotted, ships in the vicinity were alerted and divers were sent to investigate it further (Farrell, 2014b).

On 6 April, the Australian Defence Force released a video of a group of divers investigating a piece of ocean debris (Australian Government, Department of Defence, 2014a). A diver surfaces from the water with a small item held between thumb and forefinger. He swims to the side of a dinghy where he hands it to a member of the Australian navy. This person takes it between thumb and forefinger of both hands, inspects it briefly, and then tosses it contemptuously into the bottom of the dinghy. There is something enormously incongruous, funny even, about a search for a missing aeroplane that began in outer space, mobilised a vast scopic system and been modelled and simulated by countless agencies and flowed across millions of computer screens, coming down to this minute, intimate conclusion – a second or two of a tiny piece of marine trash held between eye, thumb and forefinger, being casually inspected and then tossed aside. Sightings of objects become more sporadic and none were linked to the disappeared plane. They turned out to be abandoned fishing equipment, the carcass of a dead whale or other pieces of marine trash (MH370: Chinese and Australian Ships Draw Blank, 2014).

What MH370's ongoing invisibility had made visible however was the sheer volume of trash in the ocean and how geo-physical materialities, forces and rhythms have been appropriated and transformed by globalisation and consumerist culture. Until UNCLOS there was a general understanding that it was acceptable to dispose of anything into international waters unless it was chemical waste. UNCLOS however encouraged nations to take ‘all measures necessary to prevent, reduce, and control pollution of the marine environment from any source’ (United Nations, 1982, p. 100). In 2012, the IMO's Marine Environmental Protection Committee (2012) adopted measures to prohibit the disposal of plastics anywhere in the ocean. Despite this, the amount of ocean-trash has mounted, some of it deposited via rivers, some the result of natural disasters or accidents at sea, while other trash is simply dumped into the ocean by cruise liners and cargo ships. In turbulent weather, cargo is often swept overboard, and it is cheaper to allow a certain amount of loss from container ships than to make them absolutely storm-proof (Mayer, 2014). Because the ocean is constituted by vectors of movement responding to earth forces, most of this ends up in five gyres – the North Atlantic, South Atlantic, North Pacific, South Pacific and Indian Ocean gyre (which flows just west of the search area for MH370), although recent research in the Pacific Ocean has shown debris pulled by gravity to the ocean floor up to 4000 m deep (K. Schlining et al., 2013).

The swirling debris spotted on the surface of the southern Indian ocean during the search for MH370 gave some indication of the extent to which the ocean's fluid terrain and more-than-human materiality has been incorporated into human culture in this way. Michel Serres argues that the increasing volume of industrial waste produced by humans appropriates physical space in ways similar to bodily excretions (sweat, blood, urine, etc.) and is today ‘engulfing the planet’ (Serres, 2011, p. 35). ‘At the limits of growth’, he writes, ‘pollution is the sign of the world's appropriation by the species’ (Serres, 2011, p. 53). The millions of sightings of ocean trash that were made during the search for MH370 revealed that it is no longer possible to view the ocean as outside of culture; it has been urbanised through waste. It was Michael Hardt and Antonio Negri who first made the observation that ‘there is no more outside’ (Hardt & Negri, 2000, p. 186). ‘Certainly we continue to have forests and crickets and thunderstorms in our world’, they told us (and the ocean is still made up of winds and waves and currents), ‘but we have no nature in the sense that these forces and phenomena are no longer understood as outside, that is, they are not seen as original and independent of the artifice of the civil order. In a postmodern world all phenomena and forces are artificial, or as some might say, part of history’ (Hardt & Negri, 2000, p. 187). Human society has taken advantage of the ever-mobile becoming of the ocean to soil it, thus incorporating it into everyday life and spatially expanding human influence and territory without limits, although unevenly, throughout the planet.

Six underwater sonic recordings

As the surface water search for debris went on, the underwater search for the aeroplane's black boxes began. This brought into play the agency of the oceanic volume, with its multi-layered spatiality, unassailable opacity, unreadability and more-than-human cunning to thwart surveillance technology. The ocean volume is what Gordillo (2014) calls a ‘liquid vortex’, a ‘pure multiplicity of intensities in motion’. It owes its materiality to the anomalous physical properties of water, kept in permanent motion because its molecules are constantly making, breaking and reforming bonds with one another, and, in the ocean, adapting to the shape of the earth's surface and being mobilised by the forces of the planet and its atmosphere. The surface of the ocean is not level; it follows gravity, pushed up by underwater ridges and slumping down into underwater troughs. Its water mass is not homogeneous, but a multi-layered spatiality, defined by permanently changing differences in temperature, salinity and pressure. These differences divide the ocean into layers through which huge volumes of water circulate as currents and underwater rivers, mobilised by the rotation of the earth around its own axis and around the sun, by exposure to the atmosphere and the gravity of the moon. Sound waves move through water more than four times faster than they do through air, but in the ocean, their movement is affected by such differences in temperature, pressure and salinity. In the thermocline, the middle layer of the ocean, temperature and density change very quickly (Roach, 2004). This can have the effect of warping sound waves, sometimes through 90° (Brumfield, 2014). They take squiggly, unpredictable paths through this layer, bouncing back and forth and becoming caught up in sound channels that carry them sideways for long distances. Retired French naval officer, Paul-Henry Nargeolet, who led the searches for the Titanic and AF447 said that, because of this, he did not put much faith in acoustic findings and would not believe MH370's whereabouts had been found until wreckage was seen (Brumfield, 2014).

All commercial aeroplanes are required to carry underwater locator beacons, otherwise known as ‘pingers’ to locate their black boxes should they crash into water. These emit ultrasonic signals or pings at 37.5 kHz frequency (the human ear hears sounds up to about 2 kHz) about once a second for approximately 30 days after an aircraft goes missing, or until their batteries die (Yan & Ahlers, 2014). In the search for MH370's black box, three types of devices were deployed. Australian naval vessel, Ocean Shield towed a 1 m wide, 32 kg underwater ‘trailed pinger locator’ (TPL-25) on loan from the US Navy, built and operated by US company Phoenix International. We saw a great deal of TPL-25 in the media; it looked like a yellow stingray and was equipped with a sensor that could recognise flight recorder signals up to 6000 m below the ocean's surface while towed at speeds of up to 3 knots. At this speed and because turning around was a long process given the huge lengths of cable involved, it was only able to scan an area of 4.8 × 4.8 km a day in seven to eight hour stretches. The Chinese patrol ship Haixun 01 used hand held devices lowered over the side of small open boats and Royal Australian Aircraft dropped sonobuoy listening devices – small, portable sonar units into the ocean.[10]

On 5 April 2014, news that a pinger detector aboard the Chinese ship Haixun 01 had detected an ultrasonic pulse emerged via the Chinese state media agency, *Xinhua*. This caused considerable consternation at the JACC as the news was released before the coordination team had verified the signals. The pulse had a frequency of 37.5 kHz, the standard frequency emitted by black box pingers. It was detected for 90 seconds in an area of the search zone where the ocean was estimated to be about 4500 m deep. Haixun 01 had picked up a fleeting signal one nautical mile away 24 hours earlier. A day later the towed pinger locator dropped from Ocean Shield about 300 nautical miles away from the Chinese ship detected a signal, on the northern edge of a small oceanic plateau called Wallaby or the Zenith Plateau. Ocean Shield went back over the same area and picked up signals on four separate occasions, one holding for five minutes thirty-two seconds, another for seven minutes (Safi & Branigan, 2014).

The Australian Defence Force released two short videos of the pings picked up by TPL-25 on 6 April (Australian Government, Department of Defence, 2014b, 2014c). In the first video (2014b), the yellow towed pinger locator is lowered into the water from the deck of Ocean Shield. It then cuts to an operator in front of a computer screen, the bottom half of which is covered with flickering horizontal yellow lines on a dark background, the upper half with a corresponding vertical graph; the visual display is accompanied by an acoustic hum. The video then cuts to a full-screen image of the computer display, where we see that this is a screen shot of data visualised by Spectrumlab V2.79b11, which is freely downloadable spectrum analysis software. It displays the frequency of signals being picked up on the horizontal axis and amplitude on the vertical axis as a colour spectrum. The towed pinger locator appears as a red dot moving slowly across the lower part of the screen where a point is marked and labelled as 33.20271 kHz, –66.98 dB. Slowly a distinctive acoustic beat emerges from the low level humming noise at approximately one-second intervals, corresponding with a spike on the vertical axis of the graph at the top of the screen. The display then changes to a three-dimensional sweep across a topography of sound waves visualised as a colourful undulating surface, the distinctive signal puncturing upwards into the red colour spectrum at regular intervals. The second video repeats similar footage (Australian Government, Department of Defence, 2014c). This imaging of the acoustic signal was an enormously powerful one. The signal was made available so that it could be experienced through scopic media as rhythmic waveforms resembling those of heartbeats as displayed by electrocardiograph machines. The missing aeroplane was made situationally present through what looked and sounded like tenuous, fragile, yet still living heartbeats.

This anthropomorphic association made the revelation, on 30 May 2014, after weeks of fruitless underwater scanning for the missing aeroplane, that these signals were not from the aircraft's black boxes after all, doubly hard to bear. The pinger sounds, it was suggested, could have come from the search boat, the pinger-detector itself, or from other sources such as tagged sea creatures (Richards, 2014). MH370's pulses could also have been drowned out by many other sounds in an increasingly urbanising marine environment of shipping traffic, oil and gas exploration and production, recreational activity and so on, which scientists refer to as ‘ocean smog’ (Brumfield, 2014). The ocean, they say, is ‘full of pings’ (Richards, 2014).[11] Not only had the ocean been shown capable of lying and the instruments used to listen to it proved faulty and prone to error, but the screen-based media that filtered and translated their data had been shown to be cruelly deceptive. Its effect was not a reduction of uncertainty in the face of disaster, but its magnification, increasing the feelings of anger and helplessness in families of the crash victims and affirming, more generally, the ‘dangerous threshold of existence’ in a contemporary world where survival is increasingly dependent on such remote sensing technologies (Evans & Reid, 2014, p. 13). However, at the time, scientists and political authorities viewed the ping data as incontestable evidence of the aeroplane's whereabouts. ‘There is no other noise like this’, said oceanographer Chari Pattiaratchi, ‘I have absolute confidence that the airplane will be found’ (Malaysia Airlines Flight MH370 Will Be Found, Expert Says, 2014). On an official visit to China five days later, Australian Prime Minister Tony Abbott said he was confident that they knew the position of the black box flight recorder to within kilometres (Branigan, 2014).

On 14 April, Ocean Shield began scanning the ocean floor for the aeroplane within a 12 km radius of the strongest pings, while the surface hunt for debris continued. Another instrument on loan from the US Navy, Phoenix International's Autonomous Underwater Bluefin-21 Vehicle ‘Artemis’ was deployed for this task.[12] It was a yellow, 5.3 m long, 725 kg remotely operated vehicle (ROV). The depth it could operate at was upgraded from 1500 m to 4500 m in only July 2013, so this was likely one of its first deployments at this depth (Phoenix International, 2013). It worked by sweeping sonar pulses underneath its chassis in two arcs, producing acoustic reflections of objects on the seabed, while also collecting high-resolution black and white imagery at up to three frames per second. Hopes of finding the plane were pinned on this single piece of equipment diving to unprecedented depths. After some initial programming glitches, it was deployed on eighteen 24- hour missions, taking four hours to dive and resurface, 16 hours to scan and four hours to download the recorded data each time. Significantly, none of these data have ever been publicly released. In its absence, some extraordinary and somewhat comical depictions of the oceanic volume appeared in the media, in attempts to visualise the ocean's depth and make it more humanly comprehensible.

The *Washington Post Online* published a scroll-down visualisation of the ocean's depth entitled ‘The depth of the problem’ (Johnson & Chartoff, n.d.). At the top of the drawing are vector shapes of a Boeing 777–200 and the Australian naval vessel Ocean Shield, with their dimensions annotated (200 ft. wide for the aeroplane, 347 ft. long and a draught of 22 ft. for the vessel). Beneath this, a number of buildings are overlaid, floating upside down, with their heights annotated: the Washington Monument (–555 ft.), the Empire State Building (–1250 ft.) and the Burj Khalifa (–2717 ft.). As one scrolls down, one passes lines annotated with water depth and pressure and the colour of the ocean gets gradually darker. After the Burj Khalifa, sea creatures, underwater submersibles or previous disasters are used to give a sense of scale: the test depth of the America Sea wolf-class submarine (–1,690 ft.); the maximum known depth at which giant squid swim (–2600 ft.); the maximum depth sperm whales are known to dive (–3280 ft.); the depth at which the towed pinger locater detected ping signals (–4600 ft.); the depth the pinger locater would probably have to reach to hear a pinger on the ocean floor depending on oceanic conditions (–6000 ft.); the maximum known depth reached by Cuvier's beaked whale (–9816 ft.); the depth at which the wreck of the Titanic was found (–12,500 ft.); the depth at which flight data recorders from Air France Flight 447 were found (–13,100 ft.); the depth Alvin, the first deep-sea submersible able to carry passengers dived (–14,763 ft.); the depth the signal from MH370 was thought to have been detected (–15,000 ft.).

This graphic is a patchwork of data drawn from multiple sources – the Australian Maritime Authority, *Hydro International* magazine, NOAA Fisheries, BBC.co.uk and Plosone.org. It reveals its own institutional address, *The Washington Post*, through the selection of objects it uses to scale the ocean. These lay claim to the ocean as a cultural artefact by comparing it with objects whose dimensions are likely to be familiar to a US audience. A similar graphic on the UK's *The Guardian* website (Branigan, 2014) lays claim to the ocean through a different set of cultural coordinates, in this case more familiar to a British and European audience: the wreck of the Russian submarine Kursk (–354 ft.); an inverted London Shard (–1004 ft.) and 1 World Trade Centre (–1776 ft.); the depth light can penetrate the ocean (–

3280 ft.); the average depth of the Mediterranean (–4,9000 ft.) and the deepest living octopus (–13,000 ft.). Making the Ocean comprehensible in this way uses familiarity to appropriate and comprehend it – it is represented as a US ocean or a UK ocean by way of the things that inhabit it in media space.

These ‘depth of the problem’ diagrams reduce oceanic volume to a two-dimensional column of graded turquoise colour overlaid with a rhetorically selected collection of textual information and icons. These incorporate an eclectic mix of land and sea-based images – buildings, mountains, bits of technology, sea creatures, and times – past disasters at sea, current events, and straightforward empirical measurements – ocean depth and pressure. They get us no further in imaging the ocean than the medieval Catalan Atlas (1375) or Cantabrian sailor and cartographer Juan de la Cosa's Mappa Mundi (1500), which depicted the ocean as a two dimensional surface crossed by rhumb lines and illustrated with astronomical, astrological and religious references and images from travel literature. Sense is made of the ocean by constructing it as a mythical space, in which multiple places and times overlap and multiple representations co-join. These diagrams are not so much diagrams of the ocean as diagrams of ways of navigating the assemblage of technologies and institutions through which ocean space is made visible today. To quote from Stephan Helmreich, in his discussion of Google Ocean, they are diagrams of ‘the ways that many of us image now, layering icons, indexes, and symbols on top of a world of previous infrastructures, transparent and opaque, taken for granted and found as well as forgotten’ (Helmreich, 2011, p. 1236).

But this eclectic collection of icons and measurements only really make relative sense of one another; they render the entity they are supposed to give scale to even more vast and incomprehensible. Beyond a certain depth, there are no measures of ocean depth left and uncertainty prevails – the depth a pinger locater would probably have to reach, the depth the signal was thought to have been detected, and so on, are the only clues given. The ocean ultimately evades attempts to codify and scale it against things or events whose dimensions are terrestrial or part of human history.

The geopolitics of search and rescue

A third graphic on *MailOnline* (Thornhill & Evans, 2014) places a rudimentary and scale-less ‘depth of the problem’ diagram alongside a map of the eastern Indian Ocean and Western Australia. On the map one can faintly read the seventh ping arc and the outline of the areas of ocean being searched for MH370. The map is boldly overlaid with a graphic of the nations engaged in the search; countries are named and represented by their flags and their fleets of aircraft and vessels are numbered and represented by colour-coded icons. These are drawn without scale, and laid in tabular form over the ocean, miniaturising it and reducing it to an immaterial board in a strategy game called ‘Search and Rescue’. The graphic also reveals the relative size and strength of each country's stake in the game. China, represented with red icons, has eight ships and two aircraft; Australia, in blue, five ships and seven aircraft and New Zealand, also in blue, one aircraft; South Korea, in white, two aircraft; Japan, also in white, two aircraft; the UK, in pink, one ship and one submarine; the USA, in pale blue, one ship and two aircraft, and Malaysia, in bright pink, one ship and two aircraft. This is not only a diagram of ocean depth versus operational strength; it is also diagram of the competitive geopolitics of the search and rescue operation.

Disaster-related protocols[13] overlay other international legislative regimes such as the Chicago Convention on International Civil Aviation (1944), which governs sovereignty over airspace and the United Nations Convention on the Law of the Sea (1982), which codifies the legal jurisdictions and protocols of maritime space. This produces patchy legal spaces with different temporalities and overlapping and often conflicting sovereignties (Heller & Pezzani, 2014).

A map of Australian Regulatory Zones shows search and rescue zones, restricted air spaces, customs and port limits, excisions from migration zones, scheduled areas under the Offshore Petroleum and Greenhouse Gas Storage Act, exclusive economic zone limits, the extent of Australia's continental shelf and unresolved continental shelf areas. Each of these overlapping jurisdictions not only delimits a particular surface area, it also has different legal status and connotes different rights and obligations. This sets up what Heller and Pezzani (2014) call forms of ‘mobile sovereignty’, which, they argue, is not a malfunction, but expresses the structural condition of global law key to the policing of the ‘freedom of the seas’ (Heller & Pezzani, 2014, p. 664).

International search and rescue, while being important for humanitarian reasons, serves a number of geopolitical objectives. For Australia, the search for MH370 served as a way of boosting national pride, testing its military and scientific capabilities, building or testing strategic alliances and promoting itself as a regional power. ‘While search and rescue operations are important in themselves, they also serve an important political purpose; they build patterns of peaceful interaction between countries with limited experience of each other, and so help generate strategic trust’, states an Australian Strategic Policy Institute blog post (Bergin & Grant, 2014). However, while the search for MH370 produced unprecedented military cooperation between traditionally antagonistic countries, trust only went so far. Early in the search, when Thailand admitted it had surveillance information it did not initially share, it was clear that south-east Asian countries were not coordinating as well as they might (Bateman & Bergin, 2014). The IMO's SAR Convention requires that parties allow other countries to enter their territorial waters, meaning that among the Association of South East Asian Nations (ASEAN), only Indonesia, Singapore and Vietnam are signatories of the convention, as long-standing antagonisms overrule SAR (Thayer, 2014). However, these regional tensions were dominated during the search for MH370 by competition between the US, its allies and China. When the search shifted from the South China Sea to the Indian Ocean, China accused the US of withholding intelligence about the disappearance of the aeroplane (Thayer, 2014), and during the Indian Ocean search, China acted independently of its obligation to cooperate through the JACC on a number of occasions (Bateman & Bergin, 2014). For instance, its announcement in *Xinhua* that it had detected black box signals was made before the information was analysed by the JACC, and was followed a day later by the detection of signals by the US towed pinger locator on the Australian vessel, later shown to be false. Countries involved also took the opportunities the search offered to find out about each other's military assets and capabilities. A Reuters report suggests that the Chinese ‘no doubt’ used the opportunity to spy on the US Poseidon submarine and that the submarine's sophisticated remote sensing capabilities were a prime target for Chinese intelligence (Siegel & Wardell, 2014). The same applied in reverse, as was born out in a conversation I had with Ian Lyn, Deputy Director of the Royal Navy's National Maritime Information Centre on 27 June 2014, who stated that the opportunity offered by the MH370 search to ‘see the opposition's kit’ at close range in a non-adversarial situation was unprecedented.[14] The search was not only about finding the aeroplane; it was about minimising exposure to present and potential future adversaries (Rogan, 2014).

At the end of April 2014, President Obama became the first US president to visit Malaysia in 50 years. His Deputy National Security Advisor, Ben Rhodes, stated ‘Malaysia is a growing partner of the USA, which seeks to deepen that relationship’ (Liptak & Karimi, 2014). Obama made frequent reference to the US's contribution to the search operation during his visit. A month later, Malaysian Prime Minister, Najib Razak paid a six-day visit to China to celebrate 40 years of diplomatic ties (Yi, 2014). He acknowledged that the disappearance of the aeroplane had ‘tested the friendship between the two countries’ and that he was ‘grateful for the support of the Chinese government, which has spared no expense in the search effort’ (Agence France-Presse, 2014). The missing aeroplane had exposed not only vulnerabilities and fault-lines, but also the strategic importance of Malaysia in regional and global politics (Geopolitics of MH370, 2014).

At the end of April 2014, the search and rescue operation was called off. Malaysia named an international investigation team to review and re-evaluate the satellite data[15] and parties met in Canberra, Australia to plan the next phase of the search (Missing Flight MH370: Search ‘Could Take a Year’, 2014). On 2 May, Malaysian Airlines issued a press release and a preliminary report on the fight's disappearance, including a cargo manifest, seating plan and maps generated from the Inmarsat data (Media Statement & Information on Flight MH370, 2014). With this in the public domain, fresh rounds of conspiracy theories and speculation about the causes of the disappearance and what had happened circulated. In Canberra later that month, the Australian Transport Safety Board announced that 155,000 sq. km of seabed would be subject to a full bathymetric survey using multi-beam echo sounders to help refine the search area (Smith & Marks, 2014).[16] Chinese navy vessel Zhu Kezhen started on the project and was later joined by the Dutch-owned vessel, Fugro Equator. By mid-June 2014, consensus had been reached between the members of the international investigation team on new interpretations of the satellite data and on 26 June 2014, the Australian Transport Safety Bureau released a 64-page report on the future of the search operation (Australian Transport Safety Bureau, 2014). This summarised the search to date, explained the revised satellite data analysis and concluded: ‘Based on all the above, it seems reasonable to propose a search width of 50 NM (20 NM to the left of the arc and 30 NM to the right of the arc)’ (Australian Transport Safety Bureau, 2014, p. 35), the arc referring to the arc of the seventh and final satellite ping identified by Inmarsat. The next phase of the search will be a commercially contracted deep sea search that began in October 2014 after this mapping is complete and could take up to 12 months.

Conclusion

After it disappeared on 8 March 2014, the ongoing invisibility of Malaysian Airlines flight MH370 opened a window into the forceful, turbulent materiality of the southern Indian Ocean and brought it into contact with humans with an intensity and at a scale never before experienced. It made a remote oceanic region and hidden information worlds situationally present via the global media, the internet, on blogs, via social media, through reports and official statements, videos, diagrams and images. An extensive scopic system, transformed the ocean's surface, waves, currents and depths into what Heller and Pezzani call ‘a vast and extended sensorium, a sort of digital archive’ (Heller & Pezzani, 2014, p. 674) that could be interrogated and cross-examined as a witness to the aeroplane's disappearance. As we have seen however, the ocean was not a very reliable witness and the very instruments and techniques used to probe, calibrate and digitise it were easily outwitted by its materiality – its fluidity, turbulence, crushing water pressure, impenetrable depths and seawater's capacity to ‘suck up’ (Campbell, 2014) the electromagnetic radiation most modern communication technology relies upon. The ocean was shown to be an unassailably opaque, more-than-human vortex, demanding that its materiality and agency be taken into account when interacting with it (Peters, 2014). At the same time, the extent to which the ocean had become highly urbanised, and incorporated into global processes of production, consumption and distribution as workplace, laboratory, strategic asset and sea-fill (as opposed to land-fill) became evident. The ocean emerged as a form of global urban infrastructure, a vast, urbanising, sonic volume, recognised not only as the engine that drives the way the world works (Earle, 2005), but also being irreversibly altered by the detritus of globalisation (Gordillo, 2014; West, 2014).

The ocean, as more-than-human materiality, as synthetic situation and as law is not static, but constituted by mobility. The search and rescue operation made it clear that even the rights and obligations that compose modern state sovereignty on land are more fluid at sea – they expand and contract depending on the specific issue in question. On all registers, the ocean is ontologically fluid, ‘an infinite succession of non-identical matter projecting itself forward as a changing situation’ (Knorr Cetina, 2009, p. 72). This Langrangian perspective (Steinberg, 2011) is beautifully illustrated in an animation released by Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) during the search for MH370, which shows an area of the ocean off the west coast of Australia between latitudes 24° and 47° South, with the ocean's temperature as a colour gradient, from blue (6°C) in the south to red (27°C) in the north (Saab, 2014). Two strands of debris in the form of black particles are released into this swirling mass of colour from the bottom left hand corner. They are caught up in eddies and swirls and pushed in complex, non-linear ways northeastwards, dispersing laterally as they move. They are ultimately caught in a temperature gradient at around 30° South and spun around and around in swirling eddies while being dispersed into a vast debris field. Finding an aeroplane or its fragments in this dynamic, flowing, fluid terrain will continue to unground notions of place, unhinge the global panopticon and alert us to the shifting jurisdictions and mobile sovereignties of the oceanic world.

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Notes

1. Until MH370, Inmarsat was a relatively low profile UK satellite communications company. It was created in 1979 as the International Maritime Satellite Organisation, a not-for-profit venture created by the International Maritime Organisation to enable ships to stay in contact with the shore and call for help; emergency distress calls are still routed by Inmarsat as priority for free. The company was privatised in 1999, bought by private equity houses Apax and Permira in 2003, then floated in London two years later, trebling in value in the next half-decade. It was briefly a member of the FTSE 100 before a fall in the share price in 2010 and

2011. Now the share price has almost regained its old levels, rising by 9% as a result of Inmarsat's contribution to the MH370 search (Pratley, 2014).

2. ‘Ping’ is a common term in IT networking vocabulary. It refers to the utility used to test the reachability of a host on an IP network and to measure the round trip time of the signal. In an ACARS network, a satellite sends a signal about once an hour to a receiver on an aircraft, which sends back a response signal, or handshake, thus signalling that it is still on the network (Cenciotti, 2014).

3. A geo-stationary satellite is one that moves around the earth at the earth's own angular velocity and thus appears not to move. The location of Inmarsat-3 F1 can be seen in real time on Real Time Satellite Tracking and Predictions (http://www.n2yo.com/satellite/?s=23839). Because it was launched in 1996 and has deteriorated, it is no longer absolutely geostationary, but moves from a height of 35,793.3 to 35,806.2 km (22,370.8 to 22,378.9 miles) above the earth's surface and from 1.539N to 1.539S and 64.471E to 64.594 E. Taking into account these slight movements in relation to the earth adjusted the analysis of where the aeroplane had come down (Steel, 2014a).

4. On Saturday 8 March 2014 at 00.41 (Malaysian time, MYT), Malaysian Airlines Boeing 777–200 Flight MH370 departed from Kuala Lumpur International Airport bound for Beijing, where it was due to arrive at 06.30, 9 March 2014, with 227 passengers and 12 crew on board. At 00.42 it was cleared to climb to 18,000 ft. (and subsequently to 35,000 ft.) and issued a direct track by Kuala Lumpur Air Traffic Control (KLATT) to waypoint IGARI (N6°56.87′, E103°34.63′). At 01.07, the plane's ACARS data transmission link, which transmits signals about speed, altitude, position and fuel level every 30 minutes, sent its routine signal. At 01.19 KLATT instructed it to contact Ho Chi Minnh Air Traffic Control (HCMATT) as it was passing out of Malaysian airspace and into Vietnamese airspace. MH370 acknowledged with ‘Good Night Malaysian 370’. Two minutes later, at 01.21 it was observed on KLATT radar screens as it passed over waypoint IGARI. At 01.22 its ACARS transponder was turned off or ceased operating. At 01.35, though this was only revealed three days later, Thai military radar showed the jet climbing to 45,000 ft. and turning sharply west. It then fell to 23,000 ft. and climbed again to 35,000 ft. Its radar signal was infrequent and did not include a flight number. At 01.37 the flight's expected routine ACARS update was not sent. A minute later HCMATT asked KLATCC of its whereabouts. KLATCC made enquiries of Malaysian Air Services Operation Centre, Singapore Air Traffic Control, Hong Kong Air Traffic Control and Phnom Penh Air Traffic Control to establish its location. No contact had been established with any of these Air Traffic Control Centres. At 01.45 the aeroplane is thought to have dropped to 5000 ft. in what is known as terrain masking to avoid radar detection. This was on the basis of reports from Malaysian villagers of bright lights and loud aircraft noises. At 02.15 what was thought to be the aircraft showed up on Malaysian military radar, wildly off course over the Malacca Strait. At 05.30 the Kuala Lumpur Rescue Co-ordination Centre activated a search and rescue operation. At 08.11, an Inmarsat satellite 22,245 miles above the earth's surface recorded a faint signal from the plane. This is its last known contact. The search for the missing aircraft initially took place in the South China Sea, south of Vietnam's Ca Mau peninsula, the direction the aircraft would have been heading in if it had stuck to its course. When Thai military radar data was released on March 11, the search moved to the Straits of Malacca and then, on March 14, after Inmarsat satellite data and calculations were released, to the Southern Indian Ocean. On March 24, the Malaysian Prime Minister Najib Razak announced that ‘beyond reasonable

doubt' (Flight MH370 'Crashed in South Indian Ocean, 2014), the plane had crashed in Southern Indian Ocean with no survivors. To date, no shred of evidence to this effect has been found.

5. This has since been challenged as other investigators have subjected the data to different analytical techniques (Marszal, 2014; Schulman, 2014) and even the southern arc trajectory has been contested (Steel, 2014b). Inmarsat engineers themselves adjusted their initial calculations after changing their assumptions about how fast the plane was moving, and further refinement of the data shifted the long-term search site further south again (Associated Press, 2014).

6. Ocean data are coordinated by the Global Ocean Observing System, GOOS (http://www.ioc-goos.org/), established in 1991 by the United Nations. Three satellites are particularly important to this mission: Jason-2, Cryosat-2 and SARAL (K. Lee, 2014). Jason-2 is a collaboration between the French National Centre for Space Studies (CNES), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and the USA's NASA and NOAA and was launched in 2008 (OSTM/Jason-2 Fact Sheet, n.d.); Cryosat-2 is an EU Space Agency research satellite launched in April 2010 (ESA's Ice Mission. n.d.) and is used largely to monitoring changes in the thickness of ice in polar-regions. SARAL is part of a technological collaboration between the Indian Space Station and CNES and was launched in 2013 (SARAL/Altika, 2013). These satellites have high-precision Poseidon-2 altimeters able to map ocean-surface topography within an accuracy of 5 cm (K. Lee, 2014). Complementing these satellite missions is a collaborative partnership between more than 30 countries to produce real-time data about the world's oceans, underpinned by a protocol of global data sharing, the Argo Program. The programme was named after the mythical Greek ship Argo, to emphasise its complementary relationship with Jason satellites and Poseidon altimeters. It has deployed a fleet of approximately 3600 drifting floats in the ocean worldwide since 2000. Argo floats are extraordinary sensing instruments stationed at a depth of 1000 m beneath the ocean surface (the so-called parking depth), from where they transmit regular data regarding their drift. Every ten days, they are programmed to change their buoyancy by changing their density (How Argo floats work, n.d.) and dive to a depth of 2000 m, then ascending to the sea-surface, measuring conductivity, temperature profiles and pressure as they do so. These data are transmitted to shore via satellites and distributed by the World Meteorological Organisation, adding to the data about sea level, speed, direction, ocean currents and heat stored in the oceans provided by Jason satellite missions. Chapter Three of the Fifth IPCC Assessment report of September 2013 was written on the basis of Argo data (Argo (oceanography), 2014). In the search for MH370, Australia's national science agency, the Commonwealth Scientific and Industrial Research Organization (CSIRO) used GOOS data as well as data from Australia's Integrated Marine Observation System, IMOS, (http://imos.aodn.org.au/imos123/), a national array of observing equipment (satellites, floats, moorings, radars, robotic gliders, etc., that monitor the ocean around Australia), as well as self-locating data marker buoys dropped into the ocean in support of the search, to run drift models to produce a possible debris field (K. Lee, 2014). This involved backtracking items spotted on the ocean's surface by satellite to their possible origin and forward tracking items from where they were spotted to where they could have drifted, to direct planes and boats to search areas (K. Lee, 2014).

7. Germany's commercial remote-sensing service provider, BlackBridge offering a similar crowdsourcing capability, with images from its satellites loaded onto a MapBox platform (Search for Flight MH 370, n.d.).

8. It was not revealed whether Tomnod played a role in identifying the data sent by Digital Globe to the Australian authorities. What was released though was that before its use in the MH370 search, Tomnod had 10,000 users. After the flight went missing, 3.6 million participants visited the platform, generating more than 385 million map views and tagging 4.7 million objects.

9. Section 4.1.1 of the Annex to the Convention requires that coordinating parties be given access to any information that may provide assistance in a search and rescue operation; in the MH370 search, this included classified surveillance data (Bateman & Bergin, 2014).

10. In addition to this, British naval vessel HMS Echo and Trafalgar-class nuclear powered attack submarine HMS Tireless, were deployed to the southern Indian Ocean two weeks after the first release of suspected wreckage images. This was significant, because HMS Tireless possesses advanced sensor platforms, possibly even the 2076 sonar system, one of the UK's most advanced and classified programmes, that complements ‘integrated active-passive detection capabilities’ with sophisticated imaging processes, enabling naval scientists to ‘see what they hear’ (Rogan, 2014).

11. For some time, pingers with frequencies of 30 to 50 kHz have been used to track deep ocean animals or as fishing net protectors (Richards, 2014).

12. Designed and manufactured by Bluefin Robotics, the Bluefin 21 is typically used by the oil and gas industry to conduct deep-water oilfield surveys.

13. Of these, the most significant during the search for MH370 were the Charter On Cooperation To Achieve The Coordinated Use Of Space Facilities In The Event Of Natural Or Technological Disasters (2000), which required that satellite data be released free of charge in support of the search effort, the International Convention on Maritime Search and Rescue (1979), which determined that Australia co-ordinate the search effort in the Southern Indian Ocean as it fell within its Search and Rescue Region and the Montreal Convention for the Unification of Certain Rules for International Carriage by Air (1999), which governed compensation for the victims of the aeroplane's disappearance.

14. This conversation took place at the ESRC-sponsored Ideaslab on Maritime Security at Cardiff University, 26–27 June 2014 (http://piracy-studies.org/).

15. This team included representatives from the US National Transport Safety Board, the UK's Air Accidents Investigation Branch, China's Aircraft Accident Investigation Department, France's Land transport Accident Investigation Bureau, Australia Transport Safety Bureau, Boeing, Inmarsat and representatives from Singapore and Indonesia.

16. The only available surveys of this part of the ocean had been made by two Russian vessels during the International Indian Ocean Oceanographic Expedition (1959–1965), using dead reckoning (Smith & Marks, 2014).

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