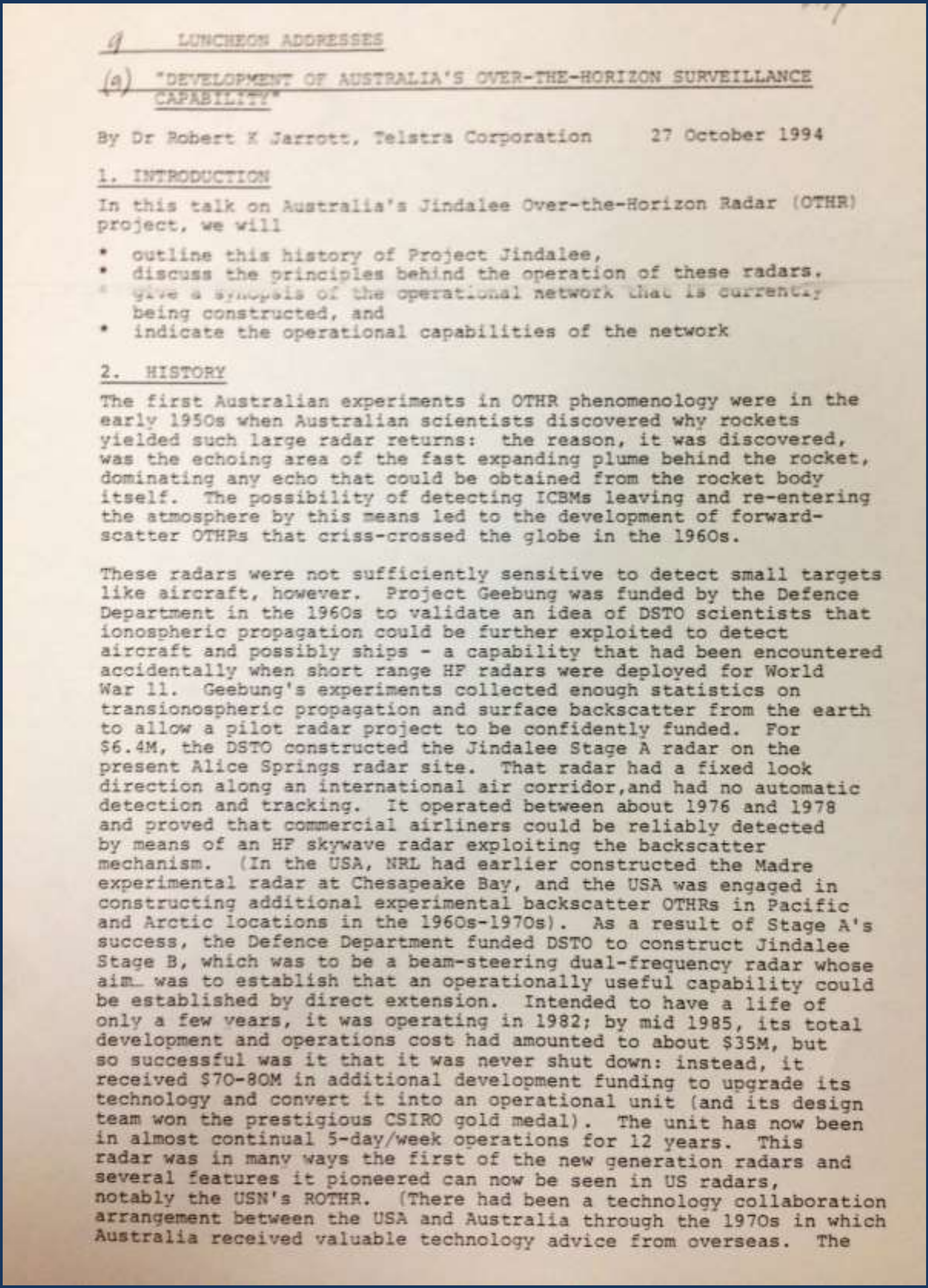


9 LUNCHEON ADDRESSES

(a) "DEVELOPMENT OF AUSTRALIA'S OVER-THE-HORIZON SURVEILLANCE CAPABILITY"

By Dr Robert K Jarrott, Telstra Corporation 27 October 1994

1. INTRODUCTION

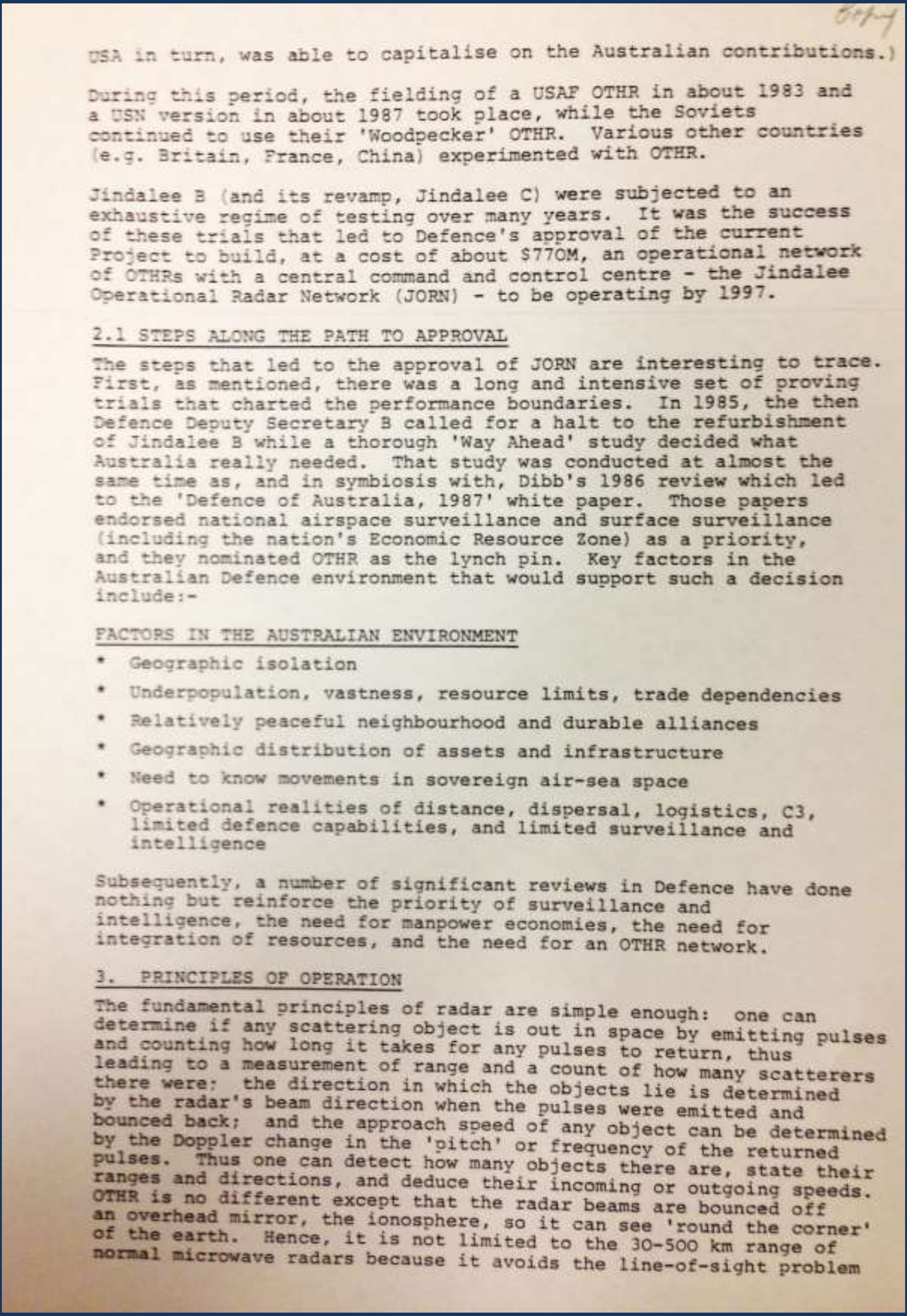
In this talk on Australia's Jindalee Over-the-Horizon Radar (OTHR) project, we will

- outline this history of Project Jindalee,
- discuss the principles behind the operation of these radars.
- give a synopsis of the operational network that is currently being constructed, and
- indicate the operational capabilities of the network

2. HISTORY

The first Australian experiments in OTHR phenomenology were in the early 1950s when Australian scientists discovered why rockets yielded such large radar returns: the reason, it was discovered, was the echoing area of the fast expanding plume behind the rocket, dominating any echo that could be obtained from the rocket body itself. The possibility of detecting ICBMs leaving and re-entering the atmosphere by this means led to the development of forward-scatter OTHRs that criss-crossed the globe in the 1960s.

These radars were not sufficiently sensitive to detect small targets like aircraft, however. Project Geebung was funded by the Defence Department in the 1960s to validate an idea of DSTO scientists that ionospheric propagation could be further exploited to detect aircraft and possibly ships - a capability that had been encountered accidentally when short range HF radars were deployed for World War 11. Geebung's experiments collected enough statistics on transionospheric propagation and surface backscatter from the earth to allow a pilot radar project to be confidently funded. For $6.4M, the DSTO constructed the Jindalee Stage A radar on the present Alice Springs radar site. That radar had a fixed look direction along an international air corridor,and had no automatic detection and tracking. It operated between about 1976 and 1978 and proved that commercial airliners could be reliably detected by means of an HF skywave radar exploiting the backscatter mechanism. (In the USA, NRL had earlier constructed the Madre experimental radar at Chesapeake Bay, and the USA was engaged in constructing additional experimental backscatter OTHRs in Pacific and Arctic locations in the 1960s-1970s). As a result of Stage A's success, the Defence Department funded DSTO to construct Jindalee Stage B, which was to be a beam-steering dual-frequency radar whose aim was to establish that an operationally useful capability could be established by direct extension. Intended to have a life of only a few years, it was operating in 1982; by mid 1985, its total development and operations cost had amounted to about $35M, but so successful was it that it was never shut down: instead, it received $70-80M in additional development funding to upgrade its technology and convert it into an operational unit (and its design team won the prestigious CSIRO gold medal). The unit has now been in almost continual 5-day/week operations for 12 years. This radar was in many ways the first of the new generation radars and several features it pioneered can now be seen in US radars, notably the USN's ROTHR. (There had been a technology collaboration arrangement between the USA and Australia through the 1970s in which Australia received valuable technology advice from overseas. The



USA in turn, was able to capitalise on the Australian contributions.)

During this period, the fielding of a USAF OTHR in about 1983 and a USN version in about 1987 took place, while the Soviets continued to use their 'Woodpecker' OTHR. Various other countries (e.g. Britain, France, China) experimented with OTHR.

Jindalee B (and its revamp, Jindalee C) were subjected to an exhaustive regime of testing over many years. It was the success of these trials that led to Defence's approval of the current Project to build, at a cost of about $770M, an operational network of OTHRs with a central command and control centre - the Jindalee Operational Radar Network (JORN) - to be operating by 1997.

2.1 STEPS ALONG THE PATH TO APPROVAL

The steps that led to the approval of JORN are interesting to trace. First, as mentioned, there was a long and intensive set of proving trials that charted the performance boundaries. In 1985, the then Defence Deputy Secretary B called for a halt to the refurbishment of Jindalee B while a thorough 'Way Ahead' study decided what Australia really needed. That study was conducted at almost the same time as, and in symbiosis with, Dibb's 1986 review which led to the 'Defence of Australia, 1987' white paper. Those papers endorsed national airspace surveillance and surface surveillance (including the nation's Economic Resource Zone) as a priority, and they nominated OTHR as the lynch pin. Key factors in the Australian Defence environment that would support such a decision include:-

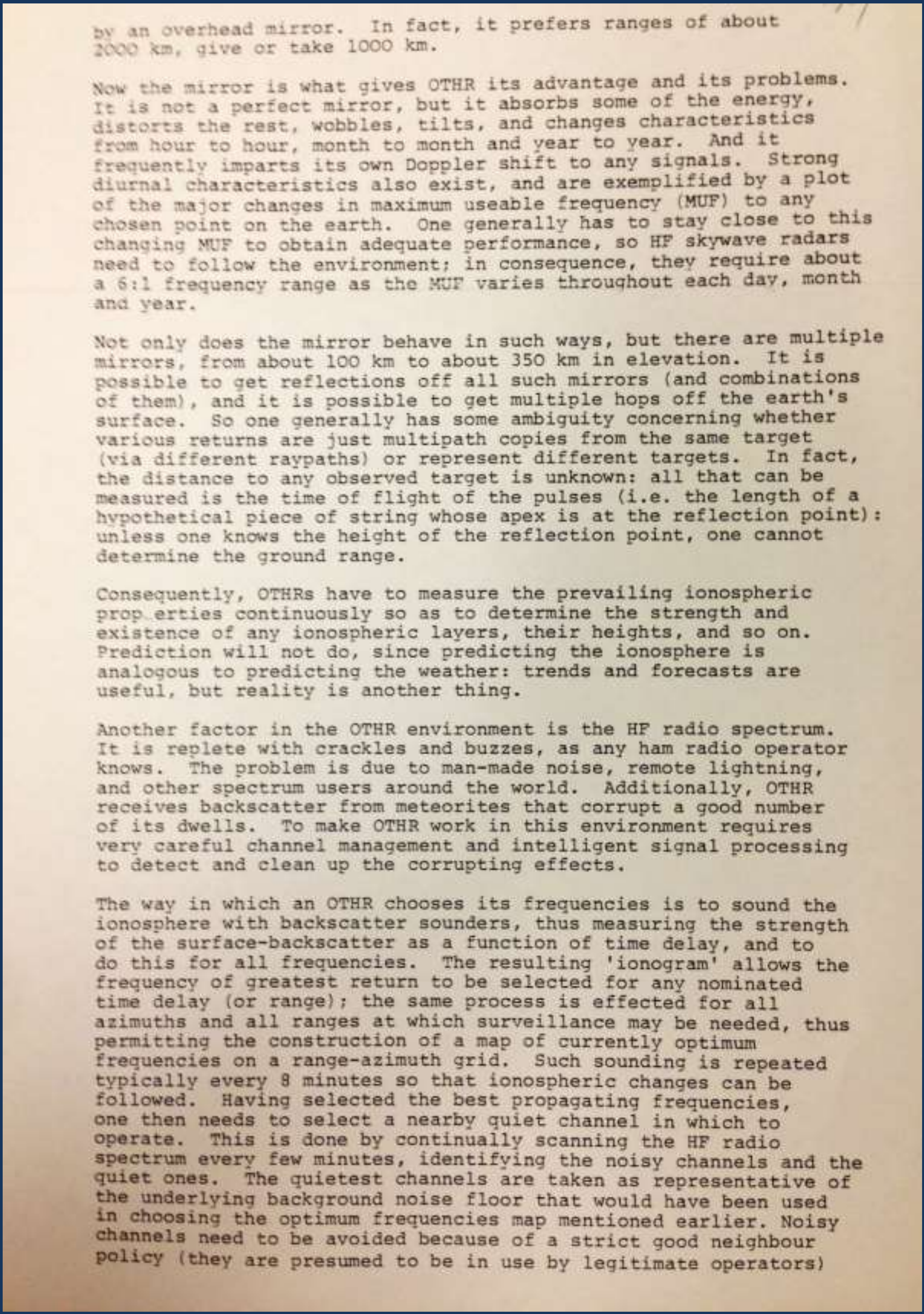
FACTORS IN THE AUSTRALIAN ENVIRONMENT

- Geographic isolation
- Underpopulation, vastness, resource limits, trade dependencies
- Relatively peaceful neighbourhood and durable alliances
- Geographic distribution of assets and infrastructure
- Need to know movements in sovereign air-sea space
- Operational realities of distance, dispersal, logistics, C3, limited defence capabilities, and limited surveillance and intelligence

Subsequently, a number of significant reviews in Defence have done nothing but reinforce the priority of surveillance and intelligence, the need for manpower economies, the need for integration of resources, and the need for an OTHR network.

3. PRINCIPLES OF OPERATION

The fundamental principles of radar are simple enough: one can determine if any scattering object is out in space by emitting pulses and counting how long it takes for any pulses to return, thus leading to a measurement of range and a count of how many scatterers there were; the direction in which the objects lie is determined by the radar's beam direction when the pulses were emitted and bounced back; and the approach speed of any object can be determined by the Doppler change in the 'pitch' or frequency of the returned pulses. Thus one can detect how many objects there are, state their ranges and directions, and deduce their incoming or outgoing speeds. OTHR is no different except that the radar beams are bounced off an overhead mirror, the ionosphere, so it can see 'round the corner' of the earth. Hence, it is not limited to the 30-500 km range of normal microwave radars because it avoids the line-of-sight problem



by an overhead mirror. In fact, it prefers ranges of about 2000 km, give or take 1000 km.

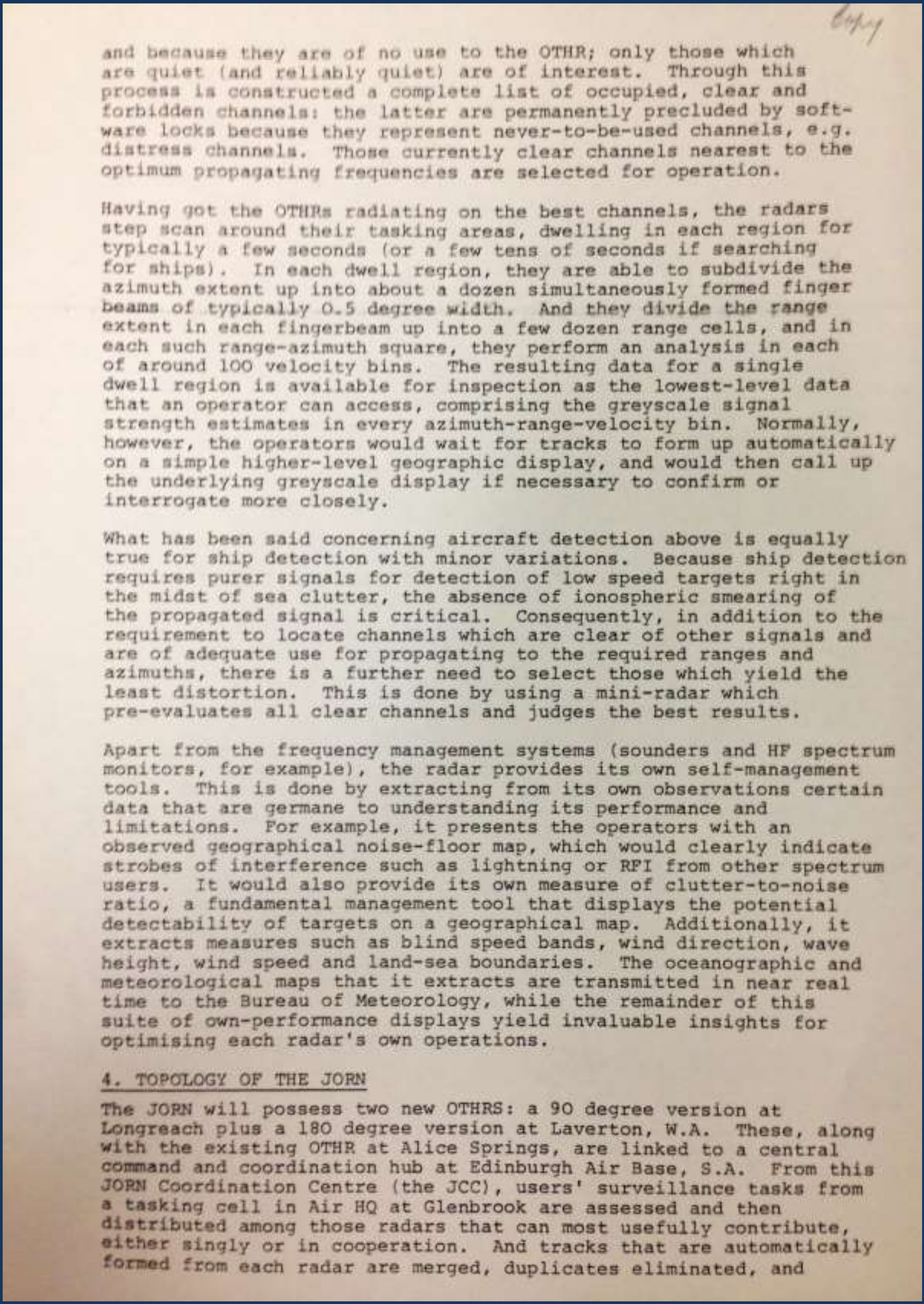
Now the mirror is what gives OTHR its advantage and its problems. It is not a perfect mirror, but it absorbs some of the energy, distorts the rest, wobbles, tilts, and changes characteristics from hour to hour, month to month and year to year. And it frequently imparts its own Doppler shift to any signals. Strong diurnal characteristics also exist, and are exemplified by a plot of the major changes in maximum useable frequency (MUF) to any chosen point on the earth. One generally has to stay close to this changing MUF to obtain adequate performance, so HF skywave radars need to follow the environment; in consequence, they require about a 6:1 frequency range as the MUF varies throughout each day, month and year.

Not only does the mirror behave in such ways, but there are multiple mirrors, from about 100 km to about 350 km in elevation. It is possible to get reflections off all such mirrors (and combinations of them), and it is possible to get multiple hops off the earth's surface. So one generally has some ambiguity concerning whether various returns are just multipath copies from the same target (via different raypaths) or represent different targets. In fact, the distance to any observed target is unknown: all that can be measured is the time of flight of the pulses (i.e. the length of a hypothetical piece of string whose apex is at the reflection point): unless one knows the height of the reflection point, one cannot determine the ground range.

Consequently, OTHRs have to measure the prevailing ionospheric prop erties continuously so as to determine the strength and existence of any ionospheric layers, their heights, and so on. Prediction will not do, since predicting the ionosphere is analogous to predicting the weather: trends and forecasts are useful, but reality is another thing.

Another factor in the OTHR environment is the HF radio spectrum. It is replete with crackles and buzzes, as any ham radio operator knows. The problem is due to man-made noise, remote lightning, and other spectrum users around the world. Additionally, OTHR receives backscatter from meteorites that corrupt a good number of its dwells. To make OTHR work in this environment requires very careful channel management and intelligent signal processing to detect and clean up the corrupting effects.

The way in which an OTHR chooses its frequencies is to sound the ionosphere with backscatter sounders, thus measuring the strength of the surface-backscatter as a function of time delay, and to do this for all frequencies. The resulting 'ionogram' allows the frequency of greatest return to be selected for any nominated time delay (or range); the same process is effected for all azimuths and all ranges at which surveillance may be needed, thus permitting the construction of a map of currently optimum frequencies on a range-azimuth grid. Such sounding is repeated typically every 8 minutes so that ionospheric changes can be followed. Having selected the best propagating frequencies, one then needs to select a nearby quiet channel in which to operate. This is done by continually scanning the HF radio spectrum every few minutes, identifying the noisy channels and the quiet ones. The quietest channels are taken as representative of the underlying background noise floor that would have been used in choosing the optimum frequencies map mentioned earlier. Noisy channels need to be avoided because of a strict good neighbour policy (they are presumed to be in use by legitimate operators)



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and because they are of no use to the OTHR; only those which are quiet (and reliably quiet) are of interest. Through this process is constructed a complete list of occupied, clear and forbidden channels: the latter are permanently precluded by software locks because they represent never-to-be-used channels, e.g. distress channels. Those currently clear channels nearest to the optimum propagating frequencies are selected for operation.

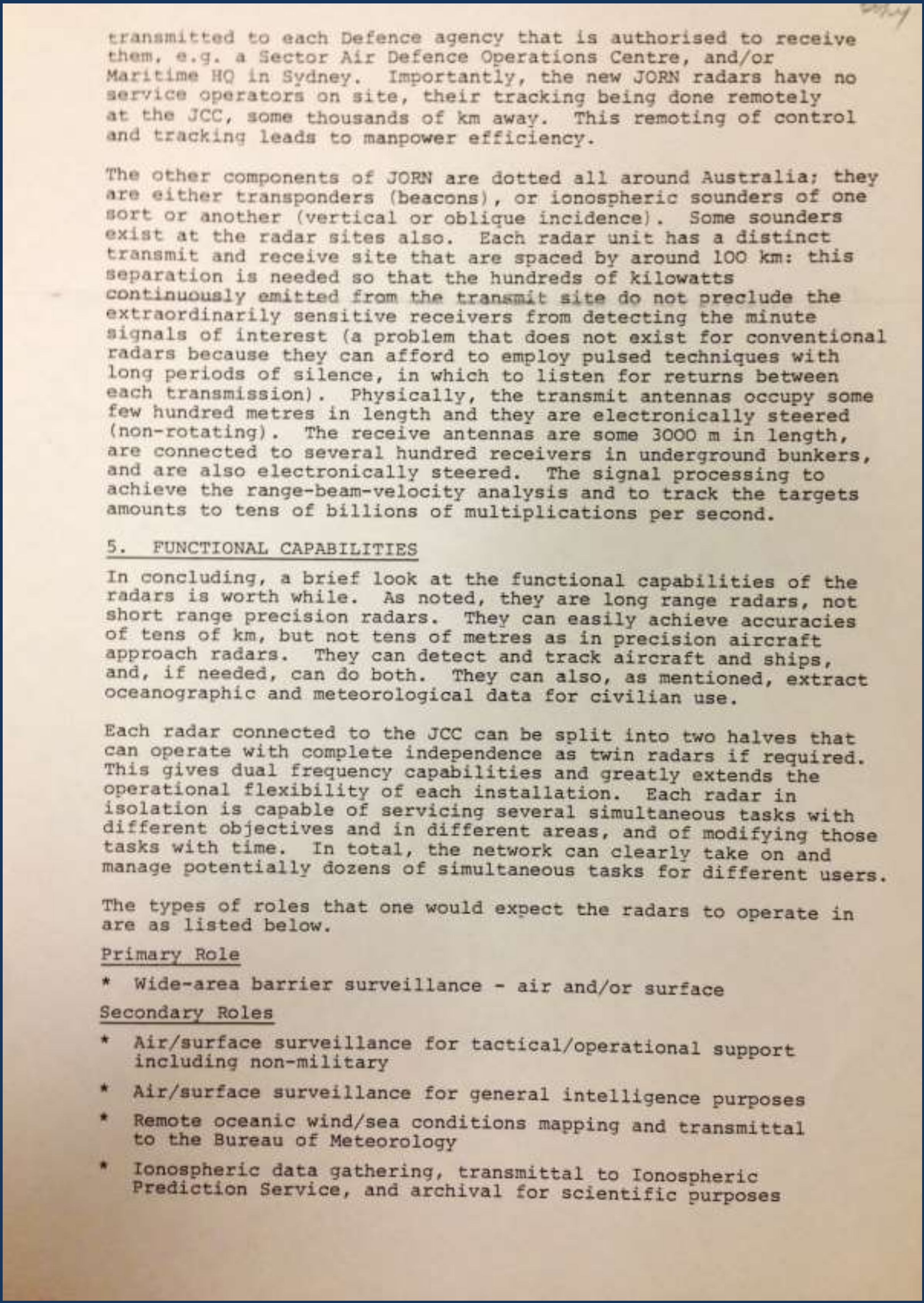
Having got the OTHRs radiating on the best channels, the radars step scan around their tasking areas, dwelling in each region for typically a few seconds (or a few tens of seconds if searching for ships). In each dwell region, they are able to subdivide the azimuth extent up into about a dozen simultaneously formed finger beams of typically 0.5 degree width. And they divide the range extent in each fingerbeam up into a few dozen range cells, and in each such range-azimuth square, they perform an analysis in each of around 100 velocity bins. The resulting data for a single dwell region is available for inspection as the lowest-level data that an operator can access, comprising the greyscale signal strength estimates in every azimuth-range-velocity bin. Normally, however, the operators would wait for tracks to form up automatically on a simple higher-level geographic display, and would then call up the underlying greyscale display if necessary to confirm or interrogate more closely.

What has been said concerning aircraft detection above is equally true for ship detection with minor variations. Because ship detection requires purer signals for detection of low speed targets right in the midst of sea clutter, the absence of ionospheric smearing of the propagated signal is critical. Consequently, in addition to the requirement to locate channels which are clear of other signals and are of adequate use for propagating to the required ranges and azimuths, there is a further need to select those which yield the least distortion. This is done by using a mini-radar which pre-evaluates all clear channels and judges the best results.

Apart from the frequency management systems (sounders and HF spectrum monitors, for example), the radar provides its own self-management tools. This is done by extracting from its own observations certain data that are germane to understanding its performance and limitations. For example, it presents the operators with an observed geographical noise-floor map, which would clearly indicate strobes of interference such as lightning or RFI from other spectrum users. It would also provide its own measure of clutter-to-noise ratio, a fundamental management tool that displays the potential detectability of targets on a geographical map. Additionally, it extracts measures such as blind speed bands, wind direction, wave height, wind speed and land-sea boundaries. The oceanographic and meteorological maps that it extracts are transmitted in near real time to the Bureau of Meteorology, while the remainder of this suite of own-performance displays yield invaluable insights for optimising each radar's own operations.

4. TOPOLOGY OF THE JORN

The JORN will possess two new OTHRS: a 90 degree version at Longreach plus a 180 degree version at Laverton, W.A. These, along with the existing OTHR at Alice Springs, are linked to a central command and coordination hub at Edinburgh Air Base, S.A. From this JORN Coordination Centre (the JCC), users' surveillance tasks from a tasking cell in Air HQ at Glenbrook are assessed and then distributed among those radars that can most usefully contribute, either singly or in cooperation. And tracks that are automatically formed from each radar are merged, duplicates eliminated, and



transmitted to each Defence agency that is authorised to receive them, e.g. a Sector Air Defence Operations Centre, and/or Maritime HQ in Sydney. Importantly, the new JORN radars have no service operators on site, their tracking being done remotely at the JCC, some thousands of km away. This remoting of control and tracking leads to manpower efficiency.

The other components of JORN are dotted all around Australia; they are either transponders (beacons), or ionospheric sounders of one sort or another (vertical or oblique incidence). Some sounders exist at the radar sites also. Each radar unit has a distinct transmit and receive site that are spaced by around 100 km: this separation is needed so that the hundreds of kilowatts continuously emitted from the transmit site do not preclude the extraordinarily sensitive receivers from detecting the minute signals of interest (a problem that does not exist for conventional radars because they can afford to employ pulsed techniques with long periods of silence, in which to listen for returns between each transmission). Physically, the transmit antennas occupy some few hundred metres in length and they are electronically steered (non-rotating). The receive antennas are some 3000 m in length, are connected to several hundred receivers in underground bunkers, and are also electronically steered. The signal processing to achieve the range-beam-velocity analysis and to track the targets amounts to tens of billions of multiplications per second.

5. FUNCTIONAL CAPABILITIES

In concluding, a brief look at the functional capabilities of the radars is worth while. As noted, they are long range radars, not short range precision radars. They can easily achieve accuracies of tens of km, but not tens of metres as in precision aircraft approach radars. They can detect and track aircraft and ships, and, if needed, can do both. They can also, as mentioned, extract oceanographic and meteorological data for civilian use.

Each radar connected to the JCC can be split into two halves that can operate with complete independence as twin radars if required. This gives dual frequency capabilities and greatly extends the operational flexibility of each installation. Each radar in isolation is capable of servicing several simultaneous tasks with different objectives and in different areas, and of modifying those tasks with time. In total, the network can clearly take on and manage potentially dozens of simultaneous tasks for different users.

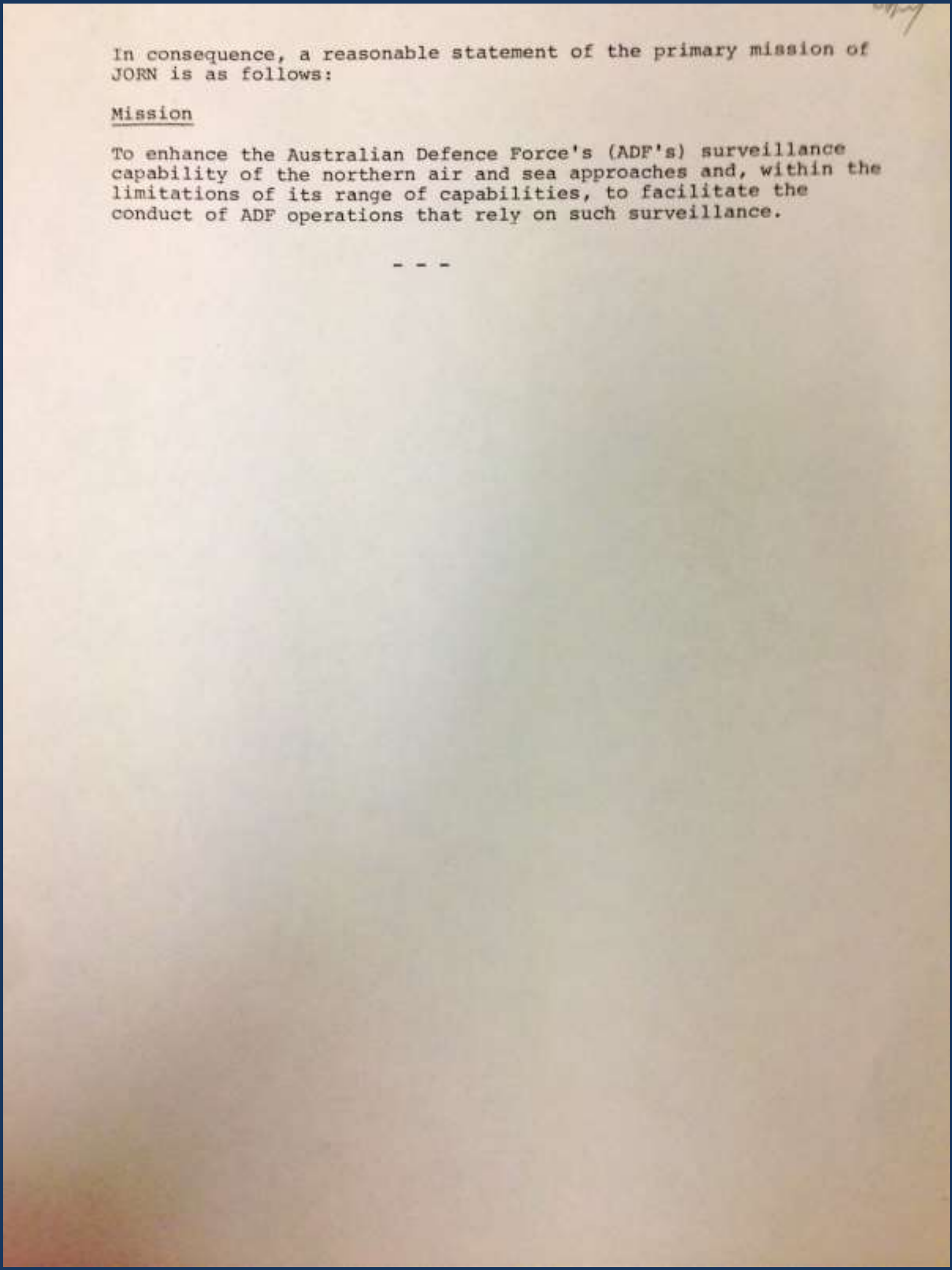
The types of roles that one would expect the radars to operate in are as listed below.

Primary Role

* Wide-area barrier surveillance - air and/or surface

Secondary Roles

* Air/surface surveillance for tactical/operational support including non-military
* Air/surface surveillance for general intelligence purposes
* Remote oceanic wind/sea conditions mapping and transmittal to the Bureau of Meteorology
* Ionospheric data gathering, transmittal to Ionospheric Prediction Service, and archival for scientific purposes



In consequence, a reasonable statement of the primary mission of JORN is as follows:

Mission

To enhance the Australian Defence Force's (ADF's) surveillance capability of the northern air and sea approaches and, within the limitations of its range of capabilities, to facilitate the conduct of ADF operations that rely on such surveillance.

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