## Defending African Maritime Sovereignty With Finite Resources: The Prospects and Power of Drones and AUV’s?’

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# ABSTRACT

Security… stability… prosperity. For aeons Africans, have followed the rest of the world, focusing on being land-centred for resources, growth, development and peace. With Operation Phakisa, South Africa aims to develop a marine economy, based on education, research and resource potential. This radical change presents the challenges of defending South African and African maritime sovereignty with finite resources and choices. Each action creates an opportunity cost. From climate change to piracy, poaching, migration and disasters. From search and rescue, to expanded infrastructure monitoring, to ocean exploration to Cape water security to species monitoring; the pressures on our maritime assets and those resources invested to monitor, understand, protect and expand them; are surging! Globally, similar issues paralyse and plague stakeholders. In response, this report proposes evaluating the ascent of drones –unmanned aerial, surface and underwater vehicles, currently being invested in globally as possible substitutes. It identifies potential characteristics for the drone industry and stakeholder requirements, translating from a global context to a South African/African perspective. It examines stakeholder requirements, comparative advantages, disadvantages, risks, constraints and potential opportunities. It analyses whether we can learn from historical successes and failures to preserve our African sovereignty… or whether by automating functions, we become more obsolete.

Table of Contents

[ABSTRACT 2](#_Toc508986111)

[CHAPTER 1: INTRODUCTION AND BACKGROUND 5](#_Toc508986112)

[CHAPTER 2: LITERATURE REVIEW 7](#_Toc508986113)

[2.1: Defining Drones: Existing Laws and Policies 7](#_Toc508986114)

[2.2: Maritime Security Stakeholder Requirements 12](#_Toc508986132)

[2.3: Historical Successes 17](#_Toc508986134)

[2.4: Historic Failures 22](#_Toc508986150)

[CHAPTER 3 THE PROSPECTS OF UAV’S, UUV’S+ USV’S FOR AFRICA’S MARITIME FUTURE 25](#_Toc508986153)

[3.1: History 25](#_Toc508986154)

[3.2: The Present State of the Global and South African’s Maritime Domain 26](#_Toc508986155)

[3.3: Advantages of Drones 33](#_Toc508986186)

[3.4: Disadvantages of Drones 42](#_Toc508986235)

[3.5: Risks 51](#_Toc508986237)

[3.6: Opportunities 56](#_Toc508986251)

[CHAPTER 4: THE FUTURE? INTERIM CONCLUSIONS 67](#_Toc508986270)

[4.1: How to Ensure Successful Drones 67](#_Toc508986271)

[4.2: Applications to the Maritime Sector 68](#_Toc508986272)

[REFERENCES 69](#_Toc508986273)

LIST OF TABLES AND FIGURES………………………………………….…………...……………...……….3

[Figure I: The Legal Status of Drones Globally. 9](#_Toc512221421)

[Table I: International Policies on Drones 9](#_Toc512221422)

[Table II: Stakeholder Priorities For Drones and the Maritime Sector 12](#_Toc512221423)

[Figure II: AUV REMUS 100 19](#_Toc512221424)

[Figure II: Envisioned Strategic Significance of US Drones 2007-2032. 21](#_Toc512221425)

[Table III: Global Market Demand For Maritime Autonomous Vehicles. 27](#_Toc512221426)

[Figure IV: Global Market Demand For Maritime Autonomous Vehicles $ Millions. 27](#_Toc512221427)

[Table IV: Top Ten Nations Supplying Drones 28](#_Toc512221428)

[Table V: Global Drone Industry Supply By Region (No of Firms). 28](#_Toc512221429)

[Table VI: Existing Global Offshore Patrol Vessel Fleet Capacity 2017 30](#_Toc512221430)

[Table VII: Future Global Offshore Patrol Vessel Fleet Demand 2017 30](#_Toc512221431)

[Table VIII: South African Drone Suppliers 31](#_Toc512221432)

[Figure VII: Dynamics Seeker 400 32](#_Toc512221433)

[Table IX: Popular Global Drones 40](#_Toc512221434)

[Figure IX: US Navy Current Maritime Drone Abilities. 41](#_Toc512221435)

[Table X: Drone Battery Technical Characteristics and Limits 45](#_Toc512221436)

[Figure X: Increased Container Vessel Automation and Cybersecurity Risk Exposure 52](#_Toc512221437)

[FIGURE XI: Global Drone Armed and Unarmed Operations 55](#_Toc512221438)

[Table XI: Marine, Underwater and Coastal Assets of South Africa 56](#_Toc512221439)

[Table XII: Potential Maritime Security and Ocean Governance Stakeholders in South Africa 57](#_Toc512221440)

[Figure XII: South African Oil and Gas License Concessions 58](#_Toc512221441)

[Figure XIII: African Maritime Communication Links. 59](#_Toc512221442)

[Figure XIV: Rhino Poaching in South Africa 2000-2013. 60](#_Toc512221443)

[Table XIII: Marine Protected Areas of South Africa 62](#_Toc512221444)

[Figure XV: South Africa’s Underwater Cultural Heritage 63](#_Toc512221445)

# CHAPTER 1: INTRODUCTION AND BACKGROUND

1000,000 Jobs by 2033. US $17.7 billion to GDP. As with so many other African countries, South Africa is investing in its maritime education and economy, as the catalyst of hope, development, opportunity and prosperity. The 2050 African Integrated Maritime Strategy (AIMS) aspires ‘*To foster increased wealth creation from Africa’s oceans and seas by developing a sustainable thriving blue economy in a secure and environmentally sustainable manner.”*  Whether through aquaculture, marine and cruise tourism, our own shipping fleets and repair yards, R100 billion giant dug out port expansions for Durban, oil rigs and a specialised South African International Maritime Research Institute the development of Maritime Clusters, education programmes and policies; South Africa pioneers Africa in expanding its maritime potential. With over 300,000,000 tonnes of cargo, one of the only 3 African countries with maritime universities, significant financial resources, potential specialists, professional associations and other assets, South Africa is the most excellently positioned nation in Africa and one of the few in the Southern Hemisphere to truly develop a sustainable maritime knowledge economy.

However, despite these advantages, over 80 oil rigs, 24 prototype aquaculture projects, over 2700 km of coastline, the strategically positioned Cape of Good Hope shipping route, the first 3 newly registered ships in 7 years for a South African fleet, leading expertise in maritime law and sovereignty, we and our assets remain highly vulnerable to an uncertain world. We are proposing to expand our EEZ of over 1,500,000 km2 and invest in maritime assets, without considering the future of Marine Protection Services and Ocean Governance. As this report will illuminate, South Africa and Africa are already experiencing significant constraints in defending our maritime sovereignty with finite resources. From religious extremism to financial crises, cybersecurity to mass migration, political instability, social tensions, technological disruptions, crimes, wars and chaos, problems demanding our attention appear immeasurable and unresolvable. For Africa, we have experienced poaching, Somalian and Gulf of Guinea piracy, to a storm and tsunami ravaging Africa and the Southern hemisphere’s greatest port; to drought induced catastrophe that may result in evacuating Cape Town, the Mother City after 365 years of settlement, the first in the world.

This report cautions we in Africa are failing to prepare. The 2050 AIMS Strategy proposes a Combined Exclusive Maritime Zones of Africa, proposing safety, security and good ocean governance. However the policy document completely ignores reality –the challenges all African nations, with few navies, maritime research, information, specific policies, laws, incentives and law enforcement capabilities will have in implementing and defending this aspirations. Specific resources have not been channelled into this pivotal need to defend the very assets that will secure our future against climate change and foreign investment uncertainty. Capability building and wealth creation is superfluous and frivolous, if we cannot shield it from other global pressures that have eyed our continent for centuries for their own self-interests. South Africa’s Ocean’s Act, its Draft Marine Spatial Planning Framework, its proposed 2017 Maritime Road Map for Skills and Research and the 2013 KZN Integrated Maritime Strategy, all ignore how ocean governance and knowledge can actually be generated and preserved against other stakeholders. Objective IV may prioritise ‘*We utilise our resources sustainably and protect our natural resources in the EEZ.*’ Objective 7 may focus on ‘*We prioritise safety and security and military protection within and beyond our EEZ’*. It is equally silent in the 2017 Comprehensive Maritime Transport Policy. The TETA Sector Skills Plan additionally does not mention the specific skills and education necessary. South Africa’s vision for Marine Spatial Planning proclaims ‘*A productive, healthy and safe ocean that is accessible, understood, equitably governed and sustainably developed and managed for the benefit of all.”*

Other global maritime navies and stakeholders incur challenges to defend their maritime legacy, with severe constraints. More and more, global attention has focused on whether drones may offer the solutions to safeguarding stakeholders and species, monitoring treasures, analysing mysteries and being proactive for risk management, development and growth. This report proposes the first independent enquiry as to whether Unmanned Underwater Vehicles, Unmanned Surface Vehicles and Unmanned Aerial Vehicles, can save Operation Phakisa and our desire for an Ocean Economy Destiny. As our stakeholders dedicate even more towards the oceans and shores rather than the hinterland, this report considers it an opportune time to see if South Africa can set a precedent for Africa and example for Africa globally, as to whether Drones can be practical, or present too much uncertainty…

# CHAPTER 2: LITERATURE REVIEW

To ensure that any decision to implement drones profits from past experience and that stakeholders can determine/understand whether it provides the answer to the future of South Africa/African maritime security and Operation Phakisa, this chapter considers it necessary to define drones (Section 2.1). It outlines stakeholder requirements for our marine sector (2.2), which might be affected by its enactment. It therefore provides a literature overview of historic international successes (2.3) and failures (2.4) to emphasise how cabotage policies (or their absence) may be learned from to minimalize externality, opportunity and maladaptation costs for stakeholders.

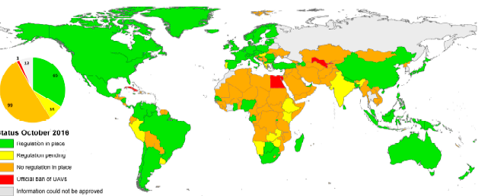
# 2.1: Defining Drones: Existing Laws and Policies

Although no consistent definition of drones exists, sources agree on several common characteristics. This report classifies drones as ‘*Self propelling aerial, surface or underwater vessels capable of transmitting information and cargo, either remotely operated by an external authority or autonomously programmed to undertake a set mission and route, w*ith sensors, transmitters and equipment responding to various elements, risks and conditions.” It avoids a human presence on board as networked computers and devices with less weight and lower emissions, environmental footprints and noise. This distinguishes them from tethered immobile platforms such as balloons, aerostats or mobile airships, remote piloted aircraft or manned craft/submarines. Kites and balloons are not self-powered. This report specifically concentrates on maritime applications for drones via UAV’s, USV’s and UUV’s. ICAO (2011) defined UAV’s as “*unmanned aerial vehicles or system either remotely and fully controlled from another place or programmed and fully autonomous. It contains elements necessary to enable and control navigation, including taxiing, take off and launch, flight and recovery/landing, and sensors and equipment for data acquisition and transfer to accomplish mission objectives; including devices for precise location where necessary.”* These are further sub-divided into fixed wing craft necessitating a runway, operator or mechanical launcher for take off/landing and rotary wing, capable of hovering at a set altitude, vertically. Flapping wing UAV’s are small, flexible with morphing wings.

US Department of Defence defines drones as “*A powered aerial vehicle that doesn’t carry a human operator, uses aerodynamic force to provide vehicle lift, fly autonomously or be piloted remotely, can be expendable or recoverable, and carry a lethal or non-lethal payload.” AIAA Committee of Standards “An aircraft designed or modified not to carry a human pilot and is operated though electronic input initiated by the flight controller or an on-board autonomous, flight management control system that doesn’t require flight controller intervention.”* EASA (2016) mention drones as aircraft operating with no pilot abroad. Bryson and Williams 2015 indicated UAS applies to UAV’s when the vessel conjoins with ground based infrastructure (Section 2.2) These typically consisting of a remotely piloted aircraft, its associated station, command and control links and any other system required at any time for flight operations. For low risk drones, they must be flown under 500 m/direct visual line of sight (VLOS) an altitude not exceeding 150 metres and outside of flight restricted areas. Flights above crowds are prohibited but not people’. Many are categorised by varying levels of automation from complete automation to management by exception to management by consent to operator managed (Hopcroft et al. 2006). This is influenced by the extent to which human input is involved for decision making, actions and responses with aims of minimising human error and uncertainty, to reduce workload/reallocate attention and resources.

Although drones are currently ignored by international maritime regulations, policies, laws, standards, research and organisations, increasing concern has been prioritised for aerospace. The 1944 Chicago Convention introduces concept of UAV regulation. “*No aircraft capable of being flown without a pilot over the territory of a contracting State without special authorisation by that State and in accordance with such authorisation. Each contracting State undertakes to ensure the flight of such aircraft without a pilot in regions open to civil aircraft shall be controlled as to obviate danger to civil aircraft (Article 8).”* Although UK and Australia provided the first legal drafts in 2002 and the EU set up a joint creation of UAV Task Force, JAA (Joint Aviation Authorities) and EUROCONTROL (European Organisation for the Safety of Air Navigation), regulations were promulgated only in 2012 (Stocker et al. 2017). These aspired to the collective aims of minimising risks to aerospace users, needing reliable information and consistent industry design standards/education/awareness. ICAO aims ‘*to underpin routine operations of UAS’s throughout the world in a safe, harmonious and seamless manner comparable to manned operations.” I*MOCOLREGS international regulations designed to avoid collision between vessels, only applies to autonomous surface vessels not underwater. From 2012-2017, 53 nations rapidly investigated legalisation of drones and operational guidelines, many requiring authorisation. Figure I aims to aid stakeholders by illuminating various nations’ status over international drones. Drones are officially banned in Cuba, Egypt and Uzbekistan.

## Figure I: The Legal Status of Drones Globally.



## Table I: International Policies on Drones

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Weight Limit** | **Altitude** | **Technical Equipment** | **People** | **VLOS** | **Training** | **Insurance** |
| **Australia** | 2/30/150 kg | 120 m | NA | 30 m | Permit | > 2kg | Yes |
| **Canada** | 2/25 kg | 150 m | >25 kg Anti-Collision | 90 m | NA | Pilot | Depend |
| **China** | 7 kg | NA | 100 kph limit | NA | NA | Certificate | Yes |
| **France** | 2/8/150 kg | 150 m | >2kg, BVLOS, towns | Crowds |  | Depend | NA |
| **Germany** | 20/25 kg | 200 m | BVLOS | Crowds | Permit | Pilot | Yes |
| **Japan** | NA | NA | NA | 30 m | NA | NA | NA |
| **New Zealand** | 15/25 kg |  |  |  |  | Depend | Yes |
| **Nigeria** | NA | NA | NA | NA | NA | NA | NA |
| **Poland** | 25 kg |  |  |  |  |  | NA |
| **SA** | 7/20 kg | 122m |  | 50 m | BVLOS permit | Pilot training | NA |
| **Sweden** | 25 kg |  | Registration/labelling  Manual override |  | BVLOS permit |  | Yes |
| **Ukraine** | 20 kg |  |  |  |  |  | NA |
| **UK** | 7/20/150 kg | 122m | Collision Avoidance | 50 m | 500 m | Pilot | Yes |
| **USA** | 0.25/25/150 kg | 122 m | NA |  | BVLOS | Certificate | Depends |

Based on Acosta 2016, Stocker et al. 2017.

Various countries provide drone specific policy guidelines to minimise risk and uncertainty, particularly for public safety and other externality costs. In Australia, “*A UAV may only operate above an altitude such that if the vehicle were to sustain an engine failure it would be capable of clearing a populated area before hitting the ground. Noise abatement regulations; area clearance for launch and recovery.”* Canada requests operator identification, contact method, routes, altitude, duration, operation type and purpose for flight mission authorisation. Israel proposes register, manufacturer name, aircraft type, model, serial number and UAS authorisation status and registration number on fire resistant license plates. Many include Sweden focus on drone operator contact details including name, phone and certification number. South Africa civil aviation technical standards even detail colours, fonts, location, allocation and specification of markets, nationality, registration marks to increase accountability during collisions, technological, environment or human failure. Sweden’s drone equipment insists on protection against ambiguous signals, weather, anti-collision and transponder availability. Whilst Europe has several webpages over all requirements and potential legislation, this report recommends one is established to overcome this absence for South Africa. Many define commercial operations as flights for purposes other than the flights itself. Human resource training, technical standards, insurance and other policies have yet to be specified for the maritime sector in South Africa and globally as a significant regulatory gap. The 1951 Merchant Shipping Act and others specify passenger and cargo craft require crew which would have to be modified. Most ignore data privacy and ethics regulations for drones. However, the 1985 SA Admiralty Jurisdiction and Regulatory Act grants legal sovereignty over all vessels and territorial waters, whether manned or autonomous, potentially modified for future maritime drone-unique policies and operations. It applies to equipment, crew, inspection, safety and navigation standards.

Civil Aviation Authority (CAA) regulate air drone use with powers under the 2015 amended 2009 Civil Aviation Act. In South Africa one has to be a minimum of 18 years old passing medical, radiotelephony, UAS pratical assessment and English language proficiency tests (ELP level 4). Commercial uses require professional background and criminal record checks. Flights are banned over national security strategic interests specified under the Key Points Act. National legislation defines drones as remote pilot aircraft *“unmanned and piloted from a remote pilot station excluding model and toy aircraft.”* Drones do not require registeration for personal and private uses without any commercial consequence. Otherwise South African Civil Aviation Regulations (CAR) Part 101 ensures flights cannot be 50 metres or closer from people or property, near manned aircraft or within 10 km of a registered airfield, above 7kg or in controlled, restricted or forbidden airspace and public roads. It cannot deliver payloads or objects. Local councils may require additional policies. Craft are restricted to VLOS, daylight and clear weather at 100 feet. Class 1A are <1.5 kg, 1B <7kg and 1C/2A >20 kg. Operators are legally responsible for any collisions, human injuries or physical property damage. However private uses do not require maintenance, insurance, qualifications and other commercial/research/general purposes of drones.

RPA’s in South Africa are legally permitted for private, commercial, corporate and nonprofit objectives require a letter of approval and registration certificate from CAA. This includes design, level or system safety standards and manufacturer’s operating manual. This includes information about RPA type, structure, composition, flight envelope capability, RPA dimensions/measurements and mass with drawings. It includes mass and balance, payloads, use of frequencies, remote pilot station, ground support equipment and flight recovery system. Authorisation needs maximum altitude, endurance, range, airspeed (take-off, cruise, stall, landing and maximum, climb and descent rate, bank angle and turn rate limits. The propulsion system type needs to be specified. In controlled airspace, RPA’s need functioning navigation lights, strobe lights, altimeter and mode C/S transponder with singular squawk code in a radio line of sight. Drones need permits beyond visual line of sight (BVLOS), flying in swarm formation, towing or aerobatic performances. For commercial operations, permission is conditional upon demonstrating ‘fit to fly’ conditions with logbooks, first aid kit, power reserves, fire extinguishers, maintenance qualifications; People can specialize in Aeroplane, Helicopter and Multi-Rotor but it needs a revalidation check every 2 years. Training must be sufficient to prove the capacity for RPA’s to fly along a predetermined route. Sale restrictions apply only for a packaging labelling but not for training/insurance or any other requirement.

Aerial drones have become increasingly popular although not specifically aligned to the maritime sector. In May 2015, South Africa pioneered drone standards ahead of ICAO. In Jan 2016-2017 registered drones increased from 216 to 465. Remote pilot licenses increased from 33 to 368 as more became enamoured with multiple purposes, inexpensive cost, accessibility and other advantages. South Africa was the first global nation to initiate RPL training (Stopforth 2017). Pro-Wings Training was the first accredited operator/designated flight examiner, instructors’ ratings and training/material CAA estimated however, for “*every registered and licensed RPA, two or three are doing so illegally.”* Many enthusiasts and entrepreneurs apparently exist with limited knowledge of aviation, risks and regulations. However, violations of regulations can cost stakeholders a 10 year prison sentence, R50,000 fine or both. South African courses insist on Navigation; Principles of Flight; Human Factors, Radio Telephony, Flight Performance and Planning; Operational Procedures, Mechanics and Propulsion, remote pilot station requirements; Risk Assessment; RPAS, CARs and CATS 101 –Aviation law, regulations and safety. These mirror formal pilot and air traffic control licences, where many other nations such as in Table I, are far less stringent accepting less rigorous certificates or not detailling formal training standards as mandatory. Since 2016, 256 registered RPA’s, 130 RPL’s, 35 applications, 1 remote maintenance technician, 4 schools, 18 air service licenses have been accredited. Yet many companies appear to outwait documentation. In contrast, Australia CASA Remote Pilot Qualifications Australia requires a Remote Pilot Certificate, theory and training. A UAV Controller’s Certificate is more complex with Aircraft Radio Operator’s Certificate of Proficiency, PPL theory, Instructor Rating Exam pass, Manufacturer’s type training UAV platform and 5 hours flight time –or flight crew/military/air traffic control license equivalents.

The US Federal Aviation Authority are one of a surprising number of nations that lack formal guidelines on drone flight training. However, 24 US states proposed UAS test sites, passed or drafting legislation*.* Civil operators can gain US ‘experimental airworthiness certificate’ for research and development, flight demonstrations and training. Public operators can get a certificate of authorisation (Evans 2013). Drones beyond visual line of sight are expected to have a chase plane. Other domestic policies need to be investigated to consider drone connections. For example the 1972 US Marine Mammal Protection Act bans efforts to **“***harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.”* Japan permit domestic application but due to international weapons control agreements, prohibit exports (Sasaki 2009). Future legal policies in South Africa and internationally could consider promoting research, technology, entrepreneurship and exports overcoming existing market and regulatory barriers. Processes including flight/mission authorisation, registration and renewal could be notified electronically. People could gain greater privacy by design and data protection currently ignored. Underwater, climate and other hazards could receive risk management guidelines with SAMSA and other partners. Existing legal liability may be conveyed to the owner, operator and underwriter for drones. Public awareness campaigns on safety and other regulatory aspects could be publicised.

# 2.2: Maritime Security Stakeholder Requirements

If drones are to serve as the future of African ocean governance and maritime security, our stakeholders have certain expectations and requirements needing to be provided. Drones primarily exist to complete pre-programmed mission objectives, involving continuous transmission of commands and information to the UAS/telemetry and receiving data related to the payload and vessel status (Cox et al. 2005). It needs physical and cyber-security, resilient to external risks. This includes sufficient integration into existing air and marine traffic systems, awareness to recognise and adapt to projected threats or obstacles (anti-collision capabilities). This may extend to beyond visual line of sight communication. Many requirements remain mission specific, influencing payload, sensors and technical characteristics/performance. Most drones require reprogrammable software and hardware to limit demand for permanent human intervention as for manned craft but also to replicate situational awareness as much as feasibly possible.

## Table II: Stakeholder Priorities For Drones and the Maritime Sector

|  |  |
| --- | --- |
| **Provider Requirements** | **Commercial/Individual Expectations** |
| Provide sufficient information | Availability |
| To Consistently update information | Promptness/swiftness of services/infrastructure |
| Security | Allocative/Productive Efficiency |
| Cost Competitive | Modernise functions continuously |
| Productive/Efficient – swift and accurate processing | Direct service/connections exist |
| Reliable/frequent functions of sufficient quality | Productive, trained labour responsive to needs |
| Satisfying unusual requests, flexible to changing circumstances | Sufficient Capacity exists  Efficient – utilises capacity |
| Sufficient quantity of functions exist | Endurance, Speed, Mission Technical Specifications |
| Secure, Swift Communication | Equitable in satisfying the user pays principle |
| It avoids delays/strikes etc | Minimises negative externality costs –noise, sound |
| Capacity for Human Intervention/Manual Override | Degree of Automation |
| Satisfy Legal Requirements | Insurance |
| Commercially profitable | Training |

Physical UAV, UUV’s and USV systems require similar physical characteristics, networks, supporting infrastructure and personnel, irrespective of mission objectives. Each requires the vessel, ground based operators and communication/information processing network with control, navigation, recovery and launch capabilities. Data requires modems, transmitters and amplifiers, satellite, fibre optic or other communication equipment. It’s also advantageous to have transportability, fuel and maintenance/spare parts access where possible. Klimkowska, Lee and Choi (2016) indicate transponders assist aerial safety, with voice relays to airspace users. When determining the most appropriate autonomous device, stakeholders may be interested in size, weight, altitude, speed, fuel consumption, range, sensor/payload and data processing capacity, other technology plus launch and recovery systems, not just cost-effectiveness. (Bryson and Williams 2015). For marine surveys, the Scan Eagle cost $3,950,000 per four with a catapult and skyhook launch and recovery system. It possessed 24 hours flight time at 25-41 m/s, 100 kilometre range, weighing 20 kg including payload and 3.11 m wingspan. It hosted infrared and zoon lens camera sensor abilities. In contrast, Cyber Eye II utilises only a short unpaved runway with 20-45 m/s and 100 kilometre range. It offers equivalent sensors but longer 4.5 m wingspan, weighs 80 kg maximum and flight duration endurance of only 10 hours. The Silvertone Flamingo costs a mere $100,000 with similar launch and recovery and speed of 14-40 m/s but offers only a 7 hour endurance, 10 km range and 5 kg payload. it has a 4 m wingspan and 20 kg weight.

NASA developed more sophisticated SIERRA at the forefront of current civilian drone potential. Its sensors are capable of high resolution cameras, GPS and intense detail for ecosystems, biomass, vegetation, even sandbar morphology, surf zone dimensions and rip channels. It extends over 1000 kilometre range, 3600 metre altitude and 148 kph with high precision, digital elevation models and nocturnal/thermal imaging. It can withstand take off and landing in6 0 kph winds, -50 m off ice, and -40º. In 2016 NOAA improved UAS Coyote to collect data below 300 foot, creating a 17 hour record and 115 kph range. Atlas Maridan (2006) devised the flatfish shaped and modular hulled Sea Otter using real time data for more accurate responses rather than delayed reactions. This enables missions to be updated, revised and reprogrammed/re-planned. It possessed aDoppler inertial positioning system, commercial side scan sonar, multi-bean echosounder and sub-bottom profiler. A revised version has redundant electronics for its inertial navigation system to reduce technological paralysis and errors. It includes an emergency strobe, VHS and pinger. For fisheries monitoring, equipment needs synthesis with vessel monitoring systems, Automatic Identification Systems, IT software, Internet and satellites to provide effective ocean governance and enforcement. This extends to information sharing and cooperation with registered users (Selbe 2014). One restriction with drones is that many countries physically require an actual official aboard for enforceable prosecution of any laws and regulations. ROV’s require an actual vessel, airfield or platform structure to be secure. Renewable energy provides greater autonomy and mission radius opportunity. Elevated cost awareness would assist stakeholders to decide if investments are worth the persistent effort.

When creating a drone fleet, stakeholders need to consider physical location, climate, environment, proximity to mission targets, possible risks, drone and equipment technical limits, accessible routes, space, wireless and electronics capacity and actual maintenance plan. Vessels incorporate a variety of dimensions, sizes and configurations/designs. They differ in range, altitude, endurance and payload capacity. US classifications include Micro, Hand-held, Close, NATO type, Tactical, LALE –low altitude, low endurance, MALE, HALE, Hypersonic, Orbital, Stratospheric, Exo-Stratospheric and CIS Lunar. Commercial –low altitude, short endurance. Design is influenced by size, weight, layout, endurance and payload; limit of power propulsion or renewable energy. UAV maritime security sensors include search radar, synthetic aperture, Electro- Optical/Infrared imaging sensors, optical cameras, GPS and AIS receivers. Waterproof and climate element casing magnifies resilience to hazards, collisions and incidents. Drones are vulnerable to spoofing, GPS jamming and hacking cybersecurity. Bryson and Williams (2015) estimate each mission mandates 2-3 operators for deployment and recovery per 10 gliders. Candeloro (2016) suggests creating Permanent Docking Stations for ROV’s to economise on needing a ship for ocean expeditions. It advised subsea operations need repair, inspection, maintenance, communication and information networks and systems. Head Mounted Displays are advised to provide more remote operators with greater telepresence of risks and situational awareness of underwater operations.

This report proposes establishing experimental AUV, USV and UUV/drone facilities to research actual vessels, associated technology, train human operators, enhance performance, investigate applications, repair, maintain, produce and export. It would benefit from experimental hydrodynamic, structural, electronic and other test laboratories, open test banks and scenario simulators. This could be integrated with AUS, satellites, underwater laboratories and stations. AUV’s American Bureau of Shipping (2016) provides individual drone characteristics, marine engineering could augment in South Africa and Africa, given unique location risks and operational demands. Examples include design depth, pressure, mission time, launch and recovery system, manipulator, pressure hull/boundary; fire restricting materials, paints, corrosion/thermal protection, and internal/external materials. Pre-mission model risk scenarios could be simulated. These could extend to all operational phases and emergency scenarios envisioned to assure resilience and performance against projected risks. Human psychology to investigate similarities and differences in remote piloting versus actual navigation is paramount to ensure the degree to which automation is practical. Future research could investigate amphibious capacity, biological propulsion, minimal electricity, renewable energy, sensor fusion, hover to sea and hybrid AUV-ROV capacity operating 24/7 (Korulla 2016). It could examine payloads, LBL/USBL network systems, DP buoys and underwater satellites to link multiple AUV’s. Component redundancy, miniaturisation, nanobiotechnology and biosensors enhance drone potential to conduct underwater human and ecological asset surveying.

Previous operations have indicated specific wishes for drones to be capable of promptly and efficiently conducting operations. This includes minimising recharging and turnaround time between missions. Networks need robustness under multiple environments, climates and a reasonable endurance time, (preferably 24 hours and more) and continuous hovering capacity. Stealth, size reduction and minimal sound are further advantageous for military and research purposes. Power sources need consideration for reliability, recharge speed, availiability, cost, efficient consumption, total distance for life of pack, range and cycle life (Fernandes et al. 2003), influencing mission operating costs. Drones need to benefit from experience, resolve uncertainty and ambiguity when issues surface. Cummings (2017) considers drone AI will need the capability to undertake tasks that normally require human intelligence such as visual percpetion, speech recognition and decision making. Hopcroft, Burchat and Vince (2006) outline not only automation but human factors, training, equipment, missions and operators are advised to be cautious about. Fatigue, stress, pressure, misinterpretation and sensory isolation of operators can influence active outcomes and corresponding level of pragmatic automation. Design and requirements can influence the extent of resources that will complete mission targets. A minimum of 2 crew -1 sensor operator/1 pilot and 2 shifts may be desirable.

Griffiths (1999) mentioned high end users demand less than 1 hour per week down time; energy efficient propulsion/lightweight pressure vessels. Although not compulsory in many nations, adequate risk insurance coverage can minimise legal liability and other hazards. Griffiths et al. (2007) details factors affecting insurance cost including team experience, operating environment, potential risks and automation capacity. Bose, Hayes and Griffiths (2007) summarise user needs as sufficient capital, land, equipment, training, insurance, management and safety. NATO (2009) insist on coordination, intelligence, surveillance and reconnaissance beyond visual lines of sight with low acoustic and electromagnetic signatures plus low surface profiles.

Limited data bandwidth and delayed video imagery are easily resolvable glitches. Hopcroft, Burchat and Vince (2006) advise aviation displays at remote ground stations incorporate psychology. These include 1:Principle of information need (More frequently needed information should be more conspicuously present. 2: Principle of legibility –brightness, illumination and volume. Principle og display integration/proximity/compatibilty and 4: -Principle of pictorial realism. Ease of access is critical along with ordinary work environments that minimise noise and distractions. It includes operability –to fly when, where and how one wishes to conduct the mission. Ship autonomy ranges from manual navigation to automatic course steering, decision support and remote operated navigation. It extends to partial autonomy (vessel evaluates risks and scenarios and advising navigator who ultimately decides even when not physically present) to full autonomy Blanke, Henriques and Bang (2017). As automated craft become more dependable, research can investigate applications to other areas such as small ferries, tugs, barges, AUS, offshore and subsea structure inspection; supply vessels for drilling and ocean renewable energy. The extent to which drones might benefit from the proximity of relevant industries, research institutions and training colleges could benefit stakeholders further.

Automated vessels offer commercial prospects but still are subject to several international law requirements insisting on physical presence. Oceanographic vessels and underwater robots have offered greater attention, especially gliders lacking engines, propellers and other traditional vessel equipment requirements, being dependent on automated systems and electronics more than mechanical-propulsion and power processes. KIVH, (2015) recommends effective inertial control and navigation systems with GPS and Doppler Velocity Log avoiding dead reckoning considering sea currents, pitch, roll and heave, position and altitude. Existing drones remain highly confined in their payload and duration capacity, unable to replicate the abilities of tramp steamers, let alone bulk carriers, reefers or container ships. Although individually faster and more agile, many are constrained by limited duration, fuel and power requirements. However more automated vessels are learning to replicate mooring systems, piloting, docking, anchor handling, navigation and other, former human only activities. MUNIN tested an unmanned bulk vessel Rolls Royce unmanned containerships and Norway ReVolt –an unmanned container feeder vessel (Voker 2013). Other challenges for future design include supporting live cargo, disasters, tugs, repairs and maintenance, cargo safety and security.

# 2.3: Historical Successes

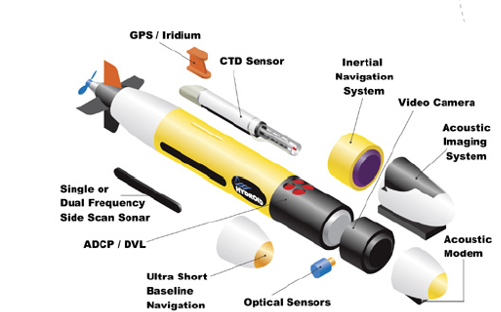
Drones are receiving increasing attention globally in their envisioned prospects for solving numerous global problems for the maritime sector. Kraken Sonar Systems estimated a $4,800,000,000 market in 2018 for underwater drones Shell Ocean Discovery XPrize providers a deep sea competition for AUV ocean exploration. NOAA formed a $100,000 bonus prize for establishing underwater origins of chemical and biological signals. This report advocates South African and other stakeholders could critically examine and learn from historical successes whenever similar issues manifest. This enables swifter resolution, more effectively implemented service delivery and duplicating costs. Sigler (2014) identified 60-80% of all maritime pollution, (over 280,000,000 tons of plastic) with lethal consequences for aquatic wildlife. Elie Ahovi proposes autonomous devices including towing trapping nets to extract plastic. This could be returned to producers for legally mandated recycling, as the EU recently (2018) enacted. As port expansions receive priority and nations become increasingly interdependent on seabourne trade, shipping and maritime supply chains, asset security may further benefit from UAS, UUS and USV’s. Abkal, Talas and Shaw, 2017 mention how Kuwait port security has deployed vessels for risk monitoring and surveillance with properly registered and trained pilots. To provide cybersecurity, legal and other risks, it insisted on registration of all drone and port users so others couldn’t retaliate and reciprocate. This register mandates all accredited UAV flights, pilots and training are centrally available. Whitacre (2017) considers maritime assets have been even more successfully protected when attached to convoys of sea drones but over 50,000 vessels exist globally. Each cannot receive a drone escort

Hyakudome (2011) provides one of numerous illustrated examples where drones have been effective in conducting simple tasks with missions and payloads; including a detailed oceanographic survey. Designs are becoming more robust and performance inmagnesium alloy and super carbon fibre. Vibrations, energy efficiency, technical performance and other indicators are gradually improving. I.e. Threat-Detect employs acoustic communications and verification via an AUV to probe marine infrastructure and assets including cables, ports, aquaculture and minerals. It aims to simplify manual maintenance and observed data recording with more updated and accurate risk pre-emption against climate change and other uncertain hazards. It sent field trials off Haifa coast and Galveston, Texas. Optical cameras and sonar process images, evaluating until 2020. Schill (2014) indicates scientific research application successes. Drones augment ocean governance by chartering coastal zones, coral reefs and marine ecosystems. One student designed a 5 pound, amphibious drone for $2000 to assist Caribbean surveys for the Nature Conservancy. It has a Go-Pro camera, GPS autopilot and waterproof Tupperware casing. It retains flexibility as a hybrid ROV-AUV, permitting regularly scheduled observations.

Australia tested 7 flights for the ScanEagle UAV, to evaluate a dugong habitat Census in Shark Bay, Western Australia. 95% dugongs were positively attributed, unaffected by UAV altitude. This UAV comprises a 3.22 metre wingspan, 1.7 metre length, 23.1 kg empty, 20 kg full at 25 m/s using GPS/inertial navigation, petrol powered. It ‘s maximum altitude is 5944 m and cruise speed of 25m/s. Aside from marine mammal research advantages, UAV’s were favoured to minimise core risks including climate, observer injury and death, aircraft chartering and training costs. 11 researchers died during previous aerial surveys. It minimises observer bias and species error in missed animal classification. UAV visual and audio sensors can become increasingly more sophisticated in location tracking and detail. Drones increase the opportunity to research more remote or hostile areas. Sea trials affirmed its value for surveying species. Phillips et al. 2017 indicates successful miniaturisation for low cost, ecoSub drones powered by renewable energy designed to probe ocean, physical and biogeochemistry variables. Drones below 5kg, length 917 and diameter 120 mm can operate over 24 hours endurance. It offers over the horizon communications to overcome VOS requirements. Sorensen (2015) clarified multiple applications to Arctic marine research including mining, exploration, oil and gas prospecting, offshore renewable energy, shipping, archaeology, rescue operations, fisheries, biology and ocean sciences

Norway’s National Technical University has a specialised Centre for Autonomous Marine Operations and Systems. Specialised facilities extend to an ocean basin, towing tank, cavitation tunnel, marine cybernetics, structural and hydrodynamics laboratories, AUV’s, USV’s, UUV’s and equivalent training simulators. This researches automation and polar/marine environments. If South Africa is to extend ocean governance, equivalent applications could be formed for SANAE. It affirmed ROV advantages of compiling high resolution information for seabed cartography, a high powered umbilical connection for data transmission and contact; sampling manipulator arms and a range of 0-6000 metres. For future research it endorses ROV’s permanently submerged without host vessel and docking seafloor docking; Hybrid ROV and AUV mode. Yet ROV’s remain limited to 1000 metres when tethered and expensive operator costs. Figure II illustrates an AUV example for marine exploration. Optical sensors incorporate (ideo, Pin hole camera, sensor, underwater hydrospectral imaging; Gas detectors, Magnetometers; (Light Manipulators and Grips. Acoustic sensors add Side scan sonar, Sub bottom profiler and coustic Doppler Current Profile. In situ sensors exist for small object samples.It provides latitude, longitude and depth 3D mapping along with greater autonomy advantages. This increases susceptibility to catastrophes, obstacles, collisions and signal interruptions.

## Figure II: AUV REMUS 100



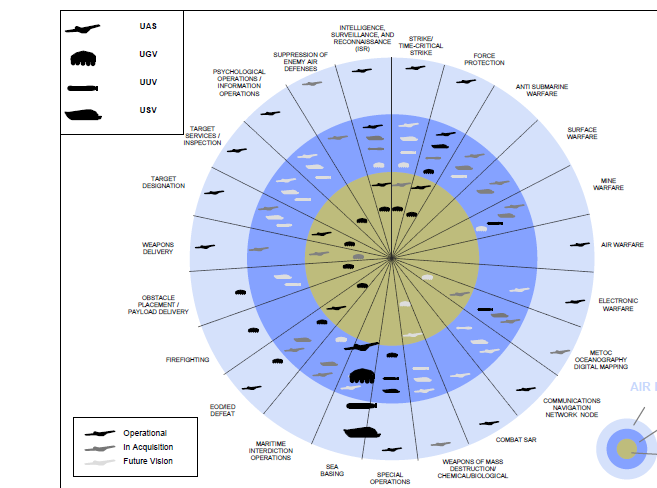
Other case studies recommend increasing autonomy as less susceptible to human error, creates more robust and resilient processes. Accredited and trained operators may be limited. Automated vessels and equipment can withstand more intense, extreme and isolated terrains. However any proposed solution needs to consider the past, present and future, conducting field technology trials, social, economic, legal and other factors. Armed forces are becoming increasingly concerned with drones to manage more divergent yet copious threats. Houssineau (2016) applies multiple-input, multiple-output, sonar systems with a HISP filter for multi-object tracking to port security and other strategic assets. This enables threats to be sorted, ascertained and prioritised, manpower to be targeted towards greater needs. It supplements stationary cameras and sources for higher value property. Although delayed continuously in Canada, its armed forces motivate their need for UAV’s and coastal protection (Lang and Jaffer 2017). Drones must “travel vast distances, operate autonomously, collecting intelligence surveillance and bring it back to those who need it,” as early forewarning systems for the Army, Navy, air force and coastguard.

Drones offer cost-effective advantages to enhance ocean governance of EEZ’s, maritime ecosystems and sanctuaries. Although ultimately dismissive of their potential, Pew Charitable Trust (2015), for a Pitcairn Islands marine reserve, considers 25000 voluntary reporting, an appointed Overseas Territory Maritime Security Officer costs 150,000 pounds compared to 4000,000 pounds for 2 months patrol boat charter. In contrast, remote sensoring buoys and cameras with a 30 km range cost 3500 pounds each plus 10,000 annually linked to satellite coverage and regional enforcement partnerships. It places greater emphasise on more stringent usage of drones in legislation, including legally testifiable evidence, third parties, voluntary reporting and prosecution in absentia. Any vessel entering would need a remote tracking mechanism paid by user fees, specifically aligned to the AUV’s and satellites. Fines would include a minimum 75% boat value plus catch. Haddel and Gertler (2010) cite the successes of the US Customs and Border Protection investing in 1 marine and 6 land, low to medium altitude, Predator B AUV’s for remote border surveillance. Although experiencing issues of higher operating and costs ($32,000,000 for 2 UAV’s) and poorer weather, it reduces the needs for fewer physical agents and extended flight mission capacity over 30 hours. In 2003, the first pilot tests, Predator B captured 22 illegal migrants, 3 vehicles and 2300 pounds marijuana -17000 metres. It offers prolonged hovering capability and thermal detection sensors for harsher terrain/nocturnal observation. NASA’s ERAST program deployed UAV’s for pollution and ozone level reports. MIT develop GPS and video camera for toxic substances. Department of Energy has 2 drones to investigate nuclear reactor radiation threats

Drones are forming recognisable parts of nation’s maritime security strategies not just South Africa. In France, several core elements indicate increased attention to how drones can be utilised across variegated areas. To improve ocean governance it divides into A: ‘Control Our Maritime Areas (Monitor areas, enforce rights, prevent maritime threats); B Protect Our Nationals and Our Ships (Anticipate Cyber Security, Combat Piracy, Prevent Maritime Terrorism), C: Fight Illegal Trafficking at Sea (Drugs, Arms, Migrants): D: Defend Our Economic Interests (Ensure Our Strategic Supplies, protect our energy and communication infrastructures, Preserve the Environment and our resources, Strengthen cooperation). To prepare for the future it suggests improving ocean governance by sponsoring drone technology, operational efficiency and forging public-private, military –research –civilian partnerships. Dikmen, Atalay and Gumas (2016) cite the presence of UAS for extending effective maritime domain awareness of navies as deterrence and increasing strategic, tactical and performance intelligence.

The US Department of Defence prioritises drones from 2007 over the next 25 years. From 2007 to 2013, Congressional budgets expanded from $49,800,000 to $630,000,000, including potent lobbying interests. Figure II summarises multiple functions, drones are estimated to be worth researching and financing. This includes increasing interoperability and integration into existing armed forces, agencies and logistics support, appeasing current needs. This extends to a Joint Capabilities Integration and Development System. It proposes drones can serve as persistent Threat Detection Systems i.e. for chemical, nuclear, biological and radiological warfare, where humans aren’t endangered. It aims to improve communications to be more robust and secure. Drones are becoming more popular based on cited advantages of being apt for “dull, dirty and dangerous” missions as substitutes for conventional armed forces. “Dull” reduces crew fatigue pressures, enabling longer, less-disturbed voyages and objectives; whilst “ dangerous” minimising human, social and political costs from greater remote access capacity. “Dirty” avoids environment impurities, hazards and contamination. The Minerals Management Service and Navy project created UUV for underwater pipelines and structures by magnetometers and fibre optic telemetry.

## Figure II: Envisioned Strategic Significance of US Drones 2007-2032.



Source: Dikmen, Atalay and Gumas (2016)

India’s Navy also are diverting attention to drones after existing AUV successes pursued by the government, Defence Research and Development Organisation, Council for Scientific and Industrial Research, Larsen plus Toubro, and Hindustan Shipyard Limited. Underwater mining is being probed by UUV’s under the Deep Ocean Mission by the Ministry of Earth Science. China has encapsulated it, based on existing successes of others, to secure its continued relevance and hegemony in ocean governance since the 1980’s. It follows the maritime brinkmanship, reciprocating the efforts of others to secure its own resources, charter strategic intelligence of others and continuously become aware of ever-altering risks. Its offshore defence strategy has produced the Explorer, Intelligent Water and Petrol to minimise dependency on external markets and technology, enforcing maritime sovereignty up to 5000 metres deep. In 2016 Qianlong 2 ventured beyond its territorial waters to exploit minerals in the international seabed, southwest Indian Ocean. Manned probes target the Yap and Mariana Trenches for exploration and resources, recognising no depth is too far to secure a maritime future in the upcoming decades. Many AUV’s possess subsea docking, vision, infrared and acoustic sensor capacity and high pressure, element resilient materials. Land reclamation and artificial islands in the South China Seas are being protected by covert sensors to supplement landmasses overwhelmed by population natural carrying capacity. It aims by 2030 to establish a permanently occupied ocean floor, research station for 12. This would be fuel cell or nuclear powered.

Tsering (2017) concludes China recognises drones as indispensable to subsea infrastructure, systems, species and intrusions. It recognises the maritime sector as the next economic horizon; as humans and linked climate change desecrate and plunder Earth’s terrestrial ecological capacity to replenish. China’s One Belt One Road or new Silk Road Strategy insists on economic security via political and physical security. Effective ocean governance requires drones to secure resources, considered indispensable to retaining unsustainable, short term extractive economic growth, dominated by China not its neighbours. In the 1980’s the China Ocean, Mineral Resources Research and Development Association (COMRA) decades prior to others. In 2012 its Jialong AUV reached 7000 metres below surface. The Haiyan 7000, underwater glider passed sea trials in 2014 and is surveying the Mariana Trench. It includes pressure and tilt sensors, GPS and magnetic compass. China’s example could inspire other nations to follow investment in drones to probe remaining maritime mysteries or at least preserve remaining resources from total obliteration. Russia dismantled its stations as did the US military. However, India is also contemplating its own sensor network equivalents. The US NOAA in 2018 possess the only officially acknowledged, deepwater research station globally.

# 2.4: Historic Failures

For Africa to improve ocean governance through drone technology, this report advises learning from historic case study failures. Drones do not only preserve maritime security, their presence can heighten existing conflicts and geo-political tensions and catalysts for warfare if insufficiently prepared. In 2016, China intercepted a Seaglider underwater drone in the South China Sea, blaming a possible collision to international shipping and violation of territorial waters. It returned the drone with a warning, prompting a diplomatic incident with US President Trump over allegations of tinkering by China. The US insist on the right to operate drones in the South China Sea but China maintain they will oppose this. Singapore considers drones could destabilise regional power balance, given uneven technological capacity and decrease opportunity costs and inclinations for war. It has avoided pressures to invest in drones as frictions may flourish given the uncertainty of how people will react to increased drone stealth, numbers and camouflage. Challenges exist in preserving peace when people cannot distinguish between intrusive military, intelligence and espionage gathering and innocuous scientific, personal and commercial drone uses.Borchert, Kraemer, and Mahon (2017) indicate whilst the US and Russian Navies are heavily investing in AUV’S, USV;s and UUV’s, this presents an opportunity cost to multiple purposes of manned submarines (including law enforcement capabilities). Increased connectivity threatens cybersecurity and physical vulnerability for networks, especially those unable to defend themselves in real time as remote probes

Drones have yet to be perfected, experiencing numerous technical errors and system failures, increasing risk, reducing capabilities for manual override. In contrast, human maritime enforcement and abilities have been tested over millennia of experience. Comparatively few assessment of problems exist compared to sources eulogising the advantages of maritime drones; complicating impartial assessments for African nations to investigate. Brito (2015) conducted a risk and reliability analysis of AUV Autosub 6000 in the UK from 2007-2012. It experienced an 11.8% mission failure rate (8/68) based on GPS and battery faults, requiring expensive early mission termination and reconfigured technical designs. 110 flaws were identified including climate limits, problems of introducing new technology and endurance below 3000 metres. It estimated a 20% probability of battery failure on any assigned mission in a year. The challenges of integrating multiple systems components and mission requirements was noted. NTMU noted challenges for human capacity to rectify errors as levels of automation increase and path planning (Johansen et al. 2014). An AUV was monitored by USV in a Norwegian fjord but kept drifting off course due to technical sensor issues unable to adjust to changing wave motions and UAV roll and pitch. It experienced communications transmission errors.

Kemna et al. (2010) identified limits to AUV’s for littoral surveillance. GLINT10 (Generic Littoral Interoperable Network Technology), field trial results illuminated challenge of information sharing and cooperation across multiple information systems, devices and stakeholders. It used 2 Ocean Explorer AUV’s 4.3 m long, 0.53 m wide with a 300 metre maximum operating depth, 7 hours and 1.2 m/s, indicating multiple physical constraints, needing priority if these are to replicate the capacity of surface vessels, submarines and aircraft. Sea trials indicated how expensive these were as it only managed to detect moving targets once yet static targets three times. The source mentions autonomous vessels significantly underperform human operated craft in three crucial areas. These extend to Adaptability (to adjust to environment, learn or evolve from mistakes, failures and successes); Self-sufficiency (over an extended period of time) and Situational Awareness (acquiring physical environment, conditions and craft solely through sensors). Batteries, acoustic communication and bandwidth data processing also limit range.

Pilot projects continue to emphasise limitations of UAS’s when applied to protecting maritime security and sovereignty. Dikmen Atalay and Gumas (2016) highlight challenges in replicating the same situational awareness of risks and information to fluctuating conditions, as being physically present. These have less capacity than actual patrol vessels. Drones, probes and other networks are less resilient as remote, primarily unarmed targets unable to implement deterrence and enforcement action Battle (2016) investigates how problematic ocean governance remains when investing in autonomous crafts capable of minimising noise, externalities and operating in all climates and environments. Many experience the same design restrictions as the ZRay lacking resilience, redundancy (a single ballast pump), speed (Buoyancy system) and physical operating depths (currents etc). Payloads are reduced. Von Ellienrieder (2015) further observes ROV, USV and UUV disadvantages. Remote Operated Vessels tethered to a moored platform or ship require far more continuous human management and mooring systems to avoid pressures and entanglements, even if they possess greater data and power transmission capacities. Mobility limits restricts potential for thorough inspection of underwater assets and marine ecosystem recording. USV’s experience greater mobility from many sources but more vulnerable to obstructions, other equipment, species and vessels. Speed limits and endurance restrict the extent of ocean missions. In congested environments including ports, multiple vessel interaction can overwhelm processors, sensors and anti-collision software systems. One cannot pre-program all risks, situations and reactions to anticipate human, mechanical and other species expectations and actions.

# CHAPTER 3 THE PROSPECTS OF UAV’S, UUV’S+ USV’S FOR AFRICA’S MARITIME FUTURE

# 

# 3.1: History

Since Daedalus and Icarus, humanity has sought to conquer the Aether. Leonardo Da Vinci devised a helicopter prototype. Unmanned flight notably began with the Montgolfier brother’s hot air balloon flight over Paris in 1783. In 1916, World War I under AM Low produced the first remotely operated aircraft flight with aerial torpedo and automatic stabilising-steering gyro. In the 1920’s Britain developed the Messenger as a remote piloted aircraft. During the 1930’s, the Queen Bee drones served as target practise (Abid et. al 2014). In 1944, Clarence Johnson believed the history of aerial warfare would be dominated by UAV’s (Cox et. al 2005). Drones collected radioactive data from nuclear tests from 1946. In 1957, SPURV managed 4 hours at 10,000 for oceanographic research missions by the US Navy and University of Washington. In 1962 DARPA and US Navy managed test projects for military drones achieving vertical take off and landing for the QH150 drone. NASA experimented with civilian applications but retained a pilot. Successive projects included Teal Rain Prairie and Calero. The first applications were primarily martial for warfare, intelligence and espionage including the Fire Bee and Lightning Bug during the Vietnam War and the Israelis against Syria in 1982. The Gulf/Afghanistan Wars, Balkans and Kosovo. NASA’s ERAST program diverted resources to high altitude, long endurance craft. In 1996 DARPA MAV began a Micro program with drones reaching 6 inches and ounce weight. In the 2000’s, the ARES program managed unmanned VTOL craft for logistics support. By 2002, the first recorded drone strike without humans and using a US Predator, murdered 6 in Yemen.

Maritime and civilian applications of drone technology have a far more recent, less documented history since examining atomic remnants off Spain for the US and France in Polynesia during the 1940’s-1970’s. Dmitri Rebikoff devised the first internationally recognised ROV –POODLE in 1953. As oil exploration developed during the OPEC 1970’s crises, Work AUV’s emerged to investigate alternative sources. ROV’s grew rapidly from 20 in 1974 (17 government) to 500 in 1982 to over 35,000 by 2017. Scientific expeditions increasingly deployed autonomous craft to charter the Mid-Atlantic Ridge, the Galapagos rift. In 1985 the ROV Argo famously located the wreck of the Titanic, followed by the World War 2 Bismarck battleship. UUV’s located Air France 447, Egypt Air 990 and other aircraft wrecks. In the 1990’s Israel’s Heron intercepted a drug smuggling vessel. In 2004, NASA develops a coordinated response to understanding maritime climate, geophysical and ecosystem hazards such as coral reefs. Over the past three decades, drone popularity has surged as people discover increasingly more applications to adapt to, including maritime operations, research, logistics and tasks formerly undertaken by human navigated aircraft, submarines and vessels at present.

South Africa’s drone history originates with its pre-1994, apartheid emphasis on preserving its territorial borders and existence against multiple adversary nations and liberation minded guerrillas. Olivier (2005) dates it back to 1977 for the Champion surveillance drone, created by the Council for Industrial and Scientific Research and tested in Rhodesia’s bush civil war. In 1986 an Air Force squadron was formed using over 12 Israeli manufactured Scout UAV’s, deploying drones across Zimbabwe, Mozambique, Namibia, Angola and elsewhere, countering multiple missiles. In 1991, the SA Air Force discontinued the squadron and since then has lacked separate UAV capacity as with the Navy. In 1994, Denel deployed drones to monitor the pivotal 1994 elections and transition to ANC lead, multi-party, multiracial democracy. Paramount took over another drone company’s (Advanced Technologies and Engineering), threatened bankruptcy and 250 jobs. From 1996-1998, the Seraph system managed an 80 kg payload, 1300 km range and 40,000 feet altitude before politics reduced armed forces spending. In 2004, Denel advertised a new MALE drone and Seeker 400 with civilian applications. 22 drone companies continue to operate.

# 3.2: The Present State of Global Drone Prospects and South African’s Maritime Domain

Global drone markets are estimated to exceed US$5,200,000,000 by 2022. Markets and Market™ rather optimistically estimate 14.07% average annual industry market growth rate. AUV’s are envisioned to reach US$ 1,206,000,000 (from $309,000,000 in 2016 or 23.19% of market share). Market prospects are becoming more profitable as more drone uses are popularly marketed and discovered. Drones are perceived to be more advantageous at substituting humans in combat, intelligence, reconnaissance, research data extraction and evaluation, recreational diversion and commercially via offshore gas and oil mining, resource prospecting, equipment inspection, aquaculture and maritime security. Navies and fisheries enforcement vessels are deploying them in response to increased maritime hazards from piracy to poaching to marine pollution spills. Comparatively few reports and sources exist to report on the current status of global drone reports including locating such basic information as market demand, supply, share, profits, costs and revenues; complicating independent appraisals of how cost-effective and necessary drones can be when compared to manned vessels, satellites and other alternatives. Military and commercial manufacturers do not provide publically available historic and projected data or cooperation. Reports have ignored specific maritime purposes when compiling market data. Table III and Figure IV

## Table III: Global Market Demand For Maritime Autonomous Vehicles.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **$ million** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **Total** |
| **Military AUV** | 118 | 125.1 | 133.4 | 143 | 154 | 166.6 | 180.9 | 1021 |
| **USV** | 39.0 | 41.2 | 43.6 | 46.4 | 49.6 | 53.4 | 57.8 | 331 |
| **Commercial** | 125.1 | 146.0 | 241.9 | 337.3 | 482.6 | 561.0 | 780.3 | 2674.2 |
| **Recreational** | 1.1 | 1.73 | 2.35 | 2.73 | 2.94 | 3.17 | 3.23 | 17.25 |
| **Research** | 862.6 | 937.2 | 974.1 | 1133.9 | 1244.6 | 1793.6 | 2180.3 | 9126.3 |
| **ROV** | 168.9 | 189.4 | 223.7 | 232.4 | 226.2 | 235.7 | 238.5 | 1514.8 |
| **Total** | 1314.7 | 1440.63 | 3637.05 | 1895.73 | 2159.94 | 2813.47 | 3441.03 | 16702.55 |

## Figure IV: Global Market Demand For Maritime Autonomous Vehicles $ Millions.

Figure IV further illuminates projected maritime demand increasing from $1314.7 to $ 3441.03 million between 2016 to 2022. Although few firms specifically focus on maritime applications, South Africa hosts significant potential in the top ten nations with the largest number of Drone firms (Table IV). Denel consistently high among the world’s pioneering and leading corporations. However, significant global competition exists with 68% market share dominated by Europe and North America (Table/Figure V). Markets can be subdivided further into geography, mission objectives, technology, vessel size, product type, propulsion system and payloads. SESAR (2016) indicates European drone markets may initially experience challenges of high fixed costs, limited specialised industrial capacity and technological uncertainty but market sales turnover will increase from $11 billion to $61 billion in 2020, supporting 70,000 jobs. This is estimated to expand to an additional 10 billion euros annually by 2035 and 15 billion by 2050. These rather optimistic expectations include 100,000 logistics, 400,000 commercial/government and 7 million consumer leisure drones by 2050. SESAR estimate 150-200,000,000 euros in EU research and development is necessary to create a single harmonised drone marketplace and Air Traffic management system for unmanned vessels into manned airspace.

## Table IV: Top Ten Nations Supplying Drones

|  |  |
| --- | --- |
| **USA** | 85 |
| **UK** | 27 |
| **China** | 25 |
| **South Africa/France** | 22 |
| **Russia** | 20 |
| **Israel** | 15 |
| **Germany/Brazil** | 12 |
| **Canada/Poland/Japan** | 11 |

## Table V: Global Drone Industry Supply By Region (No of Firms).

|  |  |
| --- | --- |
| **Africa** | 24 |
| **Asia** | 44 |
| **Europe** | 176 |
| **Middle East** | 26 |
| **North America** | 98 |
| **Oceania/Pacific** | 14 |
| **South America** | 19 |
| **Total** | 411 |

**Figure V: Global Drone Industry Market Share By Region (%)**

Surprisingly, few maritime drones exist across Europe; indicating favourable demand prospects as more nations become apprehensive over drone investments by rivals and increased social acceptance appears. Africa possesses even fewer. The UK, as with other nations prefers using drones to supplement airpower not land or seapower with 576 remote piloted aircraft (Reaper, Hermes 450, Desert Hawk, Tarantula Hawk and Black Hornet. However, as maritime risks and challenges pressurise stakeholders, increasing examples continue to make drones more popular. For example Virginia Tech deployed drones to locate Malaysian Airlines Flight MH370, which disappeared in the Indian Ocean. Manned patrols encompassed over $226 million, several nations, 16 months and over 120,000 km² of ocean up to 6000 metres deep. It proposed 17 km² could be covered via bathymetric survey per day per drone. Drones cost approximately $125,000 per drone as a more cost-effective substitute. The Ocean XPrize contest has also awakened interest in drones and underwater exploration. The challenge involves digital seabed mapping at 5 metre resolution, 4000 metre depth and 500 km² of ocean in 24 hours. SESAR (2016) estimates by 2035, 20% of cargo, business, scheduled airlines and rotorcraft will have remote piloted programming capacity. Duan and Zhang (2014) indicated the advantages of maritime UAV’s from stealth to speed to technological sensor capacity to search and rescue, humanitarian logistics, law enforcement, dredging, surveys, pollution, infrastructure inspections and information. In Shark Bay Western Australia, $3000 drones have monitored dugongs and other marine mammals. Drones will not distinguish between industries from maritime security to disaster relief, commerce, mining, research, forestry, insurance risks assessments, media broadcasts, tourism and recreation.

By 2014, existing demand and opportunities led nations such as the House of Lords to consider compulsory drone user regulations for authorisation (section 2.1). Over 1000 commercial companies received UK permission. Marsh (2015) estimate US$ 1.2 billion for commercial UA drone market for freight markets just from current population growth. Polish Logistics PKP cargo believe drones produced an estimated 44% reduction in 2015 thefts. From a maritime security perspective drones are increasingly favourable as minimising collateral and individual force damage. They provide access to greater intelligence, surveillance and reconnaissance over a broader geographical radius. Navies such as the US are not only increasing orders, they are investing substantially more in research than procurement. ($11,600,000 Geetinga 2016). Observer Research Foundation (2016) notes increasing perceptions of threats encouraging brinkmanship in littoral Asia. In 2009 India’s Navy inaugurated 3 UAV squadrons –Kerala, Tamil Nadu and Gujarat to enforce its Exclusive Economic Zone maritime boundary dominion. China plans 41,000 UAV’s at $10,5 billion between 2014-2023. These include Soar Dragon and Divine Eagle with over the horizon targeting. In October 2016, 18 nation navies participated in Operation Unmanned Warrior, a UK Royal Navy initiative to investigate the future of autonomous and remotely operated maritime warfare.

Both globally and across Africa, the existing inadequacies of maritime enforcement capacity are officially recognised by governments investing in offshore patrol vessels and navies. Table VI indicates just how constrained is the ability to defend maritime sovereignty with finite resources. In response, this report proposes investigating the feasibility of drones, satellites, voluntary incentives and integrated fisheries total resources management. UAV’s, USV’s and UUV’s may have to supplement not only South Africa’s constrained manpowered vessels but across Earth. De Silv (2015) indicates the presence of 24 countries ordering 136 offshore patrol vessels, increasing the global total from 681 to 841. Asia comprises44% of the existing total fleet and 46% of new orders. Japan and India represent 50% of Asian orders. South Africa has merely ordered three under Project Biro to supplement its existing four. 30 countries plan 276 ($60 billion) in the next few years, indicating favourable export prospects for established firms, diversifying into drone production.

## Table VI: Existing Global Offshore Patrol Vessel Fleet Capacity 2017

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **South America** | **Africa** | **Europe** | **Asia** | **Middle East** | **Other** |
| Argentina 10 | Angola 5 | Belgium 2 | Azerbaijan 2 | Iraq 6 | Australia 11 |
| Brazil 31 | Cameroun 2 | Denmark 3 | Bangladesh 15 | Lebanon 1 | Cook Islands 1 |
| Chile 3 | Cape Verde 2 | Estonia 2 | China 58 | Oman 5 | New Zealand 2 |
| Columbia 8 | Congo 4 | Faroes 2 | India 119 | Qatar 2 | Canada 5 |
| Dominican Republic 1 | Equatorial Guinea 5 | Finland 4 | Indonesia 19 |  | Mexico 34 |
| Ecuador 5 | Gabon 2 | France 23 | Japan 107 |  | USA 67 |
| Falklands 1 | Ghana 8 | Germany 6 | Kazakhstan 3 |  |  |
| Guyana 1 | Ivory Coast 1 | Iceland 3 | Malaysia 2 |  |  |
| Panama 2 | Kenya 4 | Ireland 11 | Maldives 1 |  |  |
| Peru 6 | Mauritania 3 | Italy 21 | Myanmar 2 |  |  |
| Surinam 1 | Mauritius 3 | Latvia 1 | Pakistan 4 |  |  |
| Trinidad and Tobago 3 | Morocco 17 | Lithuania 3 | South Korea 20 |  |  |
| Uruguay 1 | Namibia 6 | Malta 1 |  |  |  |
| Venezuela 14 | Nigeria 6 | Netherlands 4 |  |  |  |
|  | Senegal 5 | Norway 10 |  |  |  |
|  | Seychelles 1 |  |  |  | **Total 776** |
|  | South Africa 4 |  |  |  |  |
|  | Tunisia 9 |  |  |  |  |

Source: Based on De Silv 2015.

## Table VII: Future Global Offshore Patrol Vessel Fleet Demand 2017

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **South America** | **Africa** | **Europe** | **Asia** | **Middle East** | **Other** |
| Brazil 46 | Morocco 3 | Cyprus 2 | Bangladesh 1 | Lebanon 2 | Australia 20 |
| Columbia 4 | Nigeria 10 | France 20 | India 4 |  | New Zealand 1 |
| Uruguay 3 | South Africa 4 | Greece 1 | Japan 6 |  | Canada 8 |
| Venezuela 3 |  | Iceland 3 | Philippines 18 |  | Mexico 4 |
|  |  | Ireland 11 | Russia 23 |  | USA 35 |
|  |  | Italy 21 | Sri Lanka 11 |  |  |
|  |  | Malta 1 | South Korea 6 |  |  |
|  |  | Ukraine 1 | Thailand 5 |  |  |

Source: Based on De Silv 2015.

The South African Drone Industry has been developed decades before the 2015 onwards set of regulations, primarily specialising in aerial, military and land applications. The South African Civil Aviation Authority ‘State of the Drone Report’ which implicitly excludes Operation Phakisa and marine economic sectors estimates possible economic advantages of R2.05 billion in revenue supporting 3,600 jobs. It anticipates another 30,830 jobs could be generated. Table VIII summarises existing accredited industry manufacturers. These and emergent companies could learn from experience to investigate other drone maritime advantages and opportunities as conveyed in this report. Existing South African demand extends to 55,000 estimated drones; of which 3382 are commercial (6.15%).

## Table VIII: South African Drone Suppliers

|  |
| --- |
| 1. BAC Helicopters CC |
| 1. Compact Aerial Services (Pty) Ltd |
| 1. Darkwing Aerials (Pty) Ltd |
| 1. Denel Dynamics |
| 1. DC Geomatics (Pty) Ltd |
| 1. Flightpoint (Pty) Ltd |
| 1. Fortune Air (Pty) Ltd |
| 1. Gillcor CC |
| 1. LS Multi Copter Projects and Services (Pty) Ltd |
| 1. Paramount |
| 1. Premier Aviation CC |
| 1. Public Display Technologies (Pty) Ltd |
| 1. Rocketmine (Pty) Ltd |
| 1. Salaria CC |
| 1. Scarab Industries CC |
| 1. Skybot CC |
| 1. Skyhook (Pty) Ltd |
| 1. Timeslice Cinematography |
| 1. UAV & Drone Solutions (Pty) Ltd |
| 1. UAV Industries (Pty) Ltd |
| 1. Visual Air Productions (Pty) Ltd |
| 22: VPM SURVEYS CC |

South African drones have limited commercial experience as permits remain conditional on a per user basis rather than formally secured. However, Transnet Freight Rail have proposed Denel drones for increased railway security, given crimes of over 800 trucks hijacked in 1 year. This responds to passenger hijacking, protests and other risks to cargo. Many drones are restricted to Visual Line of Sight aside from aerospace and military corporation Denel Dynamics. Existing drones have proven themselves in land military tests and exercises. South Africa’s most prominently manufactured drones, exported internationally include Denel’s UAV Seeker series. It includes up to 50 kg payload, 250 kilometre range and mission duration of 10 hours. It weights 310 kg and needs 2 pilots per shift, optical payload observer and communications technician. The Skua is a target drone with VLOS 200 kilometre radius, 70 kg payload including missiles, 10,000 metre altitude and maximum speed of Mach 0.86. It has been used in the SA Navy and Brazil. These contrast significantly with the US Air Force RQ-4 Hawk with 1,360 kg payload, 18,300 metre altitude and over 32 hours endurance or the PD-1000 Black Hornet –Royal British Army with 16 g, 10 cm long and 2.5 cm high. Denel also produces the Hungwe. Systems include mission control, tracking and communications units, UAV payloads, field support equipment and ground station. It has recently promoted the Seeker 400 to assist in vaporising piracy.

## Figure VII: Dynamics Seeker 400

[](http://www.uasvision.com/wp-content/uploads/2011/10/Seeker-400.jpg)

Source: Denel Dynamics 2018

Its competitor Paramount was founded in 1994. Paramount’s UAV’s include the Vulture, [the Sentinel](http://www.engineeringnews.co.za/topic/the-sentinel)-LE, the Kiwit and the Roadrunner for the South African and other armed forces. The reprogrammable Vulture has a 200 kilometre range, 30 kg payload, over three hour endurance with gas detection and infrared sensor abilities. The Sentinel is adapted to airstrips, Kiwit is limited to5 km at an altitude of 150 m for 45-60 minutes, while the Roadrunner is similar in limitations. Paramount created the Persistence Surveillance Tethered Drone (Figure VIII), advertising its capacity to reduce poaching, probe chemical exposure, border defences, monitor crowds and avoid piloting needs. It weighs less than 15 kg but flies only between 45 minutes to 2 hours. The Civet UAS system offers similar aerial imagery, logistics, disaster and research capacity. It also designs Helio-balloon Kites claiming wind resistant up to 35 knots and 30 kg payloads. Tellumat offers a UAV video-datalink radio system for BVLOS plus point to point link systems. As with other operators, Aerovision mentions manufacturer responsibility for research, servicing and repairs. CSIR and South African university, UAV [projects](http://www.engineeringnews.co.za/topic/projects) have included the Indiza, Sekwa and [Modular](http://www.engineeringnews.co.za/topic/modular) research UAVs. (Defence Web SA 2018). Denel supports around 3000 jobs, Paramount another 250.

**Figure VIII: Paramount’s Persisted Tethered Drone**

**

Denel’s vaunted piracy drone solutions would target a ‘find, fix and finish” strategy. This would integrate with other maritime enforcement agencies with intelligence. The Bateleur UAV also could aid to marine boundary domain awareness and intelligence for less overt threats. It proposes arrests and surveillance until manned vessels can reach suspects. In 2010, the Soccer World Cup reportedly gained from an Edge Tech 4200, towed side scan sonar system and a SB 424 towfish, for the SAS Protea hydrographic survey vessel. This formed a R38.7 million shallow water route survey system In 2015 the South African navy and Armscor Institute for Maritime Technology tested UAV’s for mine countermeasures over 2.5 hours for 800x400 metres. It cost R 2,500,000. The South African Navy mentions plans under Operation Phakisa to augment existing capacity of 4 Department of Environmental Affairs and Tourism patrol boats over 2700 kilometres of coast. Project Biro will add offshore patrol boats, Project Hotel the SAS Protea but no indication of drones has been indicated.

# 3.3: Advantages of Drones

If South Africa and Africa are to implement autonomous vessels for a continental maritime economy and supply chain; this report cautions they will need to investigate various reputed drone advantages, to see if these can be replicated. Creating an extensive drone sector could offer various economic, environmental, research, maritime and general security/law enforcement; technical, human, social, safety and other general or mission specific advantages. Various economic opportunities could extend beyond the initial R2.05 billion proclaimed for the overall drone sector. If indigenous entrepreneurs actually proactively seize the opportunities in this report and elsewhere under Operation Phakisa, South Africa’s and Africa’s market share could easily exceed Asia’s 5% (Figure V). The industry could increase employment opportunities for pilots, electronics industry, technicians, payload operators, photography, weapons specialists, marine, aerospace, security, insurance, research, surveying, consultancy, logistics and other applications. Examples extend from design and construction to value adding, operation, maintenance, repair and upgrade throughout a drone’s lifespan. This could indirectly stimulate economies further via the multiplier effect, enhancing exports, consumption, savings, investment and tax revenue. Drones are frequently perceived as more cost-effective to build, purchase and operate than piloted technology and vessels. As economies of scale and production develop, drones are estimated to become even cheaper and profitable to users.

Drones are considered to save maintenance, operating and risk monitoring costs for oil/gas pipelines, surveys and other underwater assets. It can aid renewable and other energy and plumbing/sewerage networks. Financially, they can investigate mineral/other resources and aid in insurance risk and real estate valuations. It can track less accessible and remoter infrastructure. It saves physical crew inspection costs and downtime, prioritising more urgent risks. South Africa has extensive mines. SESAR (2016) highlighted drone logistics could be profitable for 5000-90000 deliveries per drone, assuming 10 euros income per parcel and 10,000 euros annually in minimum cost, minimising intermediate transport, retailer and wholesaler costs. It could prioritise fragile, rare or time sensitive cargo given existing Post Office slowness, especially in remoter/rural areas reducing opportunity and delayed costs to businesses, government and individuals. It estimates 60% of European parcels weight 2.5 kg or less –perfect for drones. It estimates expansion from 15,000 to 70,000 by 2030 and 100,000 by 2050. Ramadass et al. (2015) is one of many to indicate mineral prospecting for deep sea mining; although this has significant unknown ecological externalities associated with it. It mentions technical characteristics of a ROSUB 6000 for hydrothermal deposits, operated as an ROV from a vessel with area scan, mechanical, mineral and electromagnetic sensors. Papua New Guinea are investigating underwater silver and gold mines. The Cook Islands are pursuing cobalt extraction.

In 2014, the first US commercial drone use was approved for oil and gas pipeline monitoring. BP used a hand launched, battery powered Puma AE with LIDAR and EO/IR sensors for 3D mapping of Prudhoe Bay oil fields. This has proven more cost effective than human manned helicopter equivalents. TAM charges $85,000 and 1.3 kg fuel for 1800 km of Baku-Ceyhan pipeline compared to $3000 per hour for a helicopter. Drones endure in -33ºC and 50 km/h winds. Drones have potential for aquaculture, agriculture crop spraying and forestry inspections and parallel companies’ products with services. South Africa may benefit from economic opportunities from presence of US export controls for drones. These ban any autonomous systems for convertible martial use, sensors and navigation systems; even foreign partnerships. General transport costs could be lowered as crew wage, provisioning, welfare, space and other possible costs decrease. Potential economic applications have prompted greater international investment in drones. SESAR estimate EU spending of US$ 500,000,000 under Horizon 2020. The US Congressional budget allocated $1,400,000,000 on drones and drones NASA/FAA -$20,000,000. Valenti (2016) notes how UUV market forecasts have accelerated from $1.2 billion in 2014 to $4.8 billion by 2019 from investor expectations, economies of scale and historic technology price reduction over time prompting greater utilisation. Basic recreational drones cost as cheaply as $50 or $130 (for Amazon). Commercial Drones start from $1500-2000.

Many drones are anticipated to serve multiple benefits if usage is rationally expanded into areas not served by human navigated equivalents. China has realised economic sovereignty of the future can only be ascertained and secured through investing in intelligence, surveillance and reconnaissance (ISR) capability. This provides martial security and research advantages simultaneously. Its Undersea Great Wall Project (Tsiring 2016) aims to provide a government integrated sensor and vessel subsurface oceanographic observation network, capable of recording data including drones. It includes sensor nodes, ground stations, drones, ROV’s, satellites, patrol vessels, underwater working stations and seismic monitoring system. Environmental and research advantages of drones will enable greater monitoring of pollution, climate and ecosystem conditions for continuous risk assessment and awareness, improving responsiveness and adaptability to climate change and other emergent risks. It improves ecological awareness and responses to sustainable ocean resource management. Oceaneering (2017) using a laser micro bathymetry system, is one of numerous sources emphasising the value of drones in digital seabed elevation mapping with high resolution sensors. Niu et al. (2007) and Bayat et al. (2017) mentions how drones can aid in attributing localised consequences of individual environmental effects for offshore petroleum monitoring. Sensors can include Temperature, Salinity, Turbidity, Dissolved Oxygen, Chlorophyll, Nutrients, Particle Matter, Hydrocarbons, Dissolved Gasses, Minerals –Range/Dimension, and Depth. Drones are perceived as quieter, less emissions intensive and producing fewer environmental costs than heavier, manned equivalents.

Although park agencies from the US to Mozambique and Kenya have banned drones; they offer certain environmental advantages at species monitoring, conservation and counter-poaching to offset isolated rangers scattered over hundreds of thousands of acres. Sandbrook (2016) mentions major biodiversity conservation advantages including mission specific safety, affordability and flexibility to users for 100-200 kilometres surveyed over 1-3 hours. Drones offer mission specific, ecological advantages of being less intrusive, expensive and resource/risk intensive than continuous human observance. Drones offer greater physical endurance and aptitudes from deserts to tropical humidity to under/over polar ice 4000-5000 metres. Drones are flexible and versatile to multiple operating environments and diverse mission requirements. They can aid polar exploration, as at the University of Tasmania Antarctica Gateway Project. and Italian Sara They can increase operational efficiency and performance over manned missions Hugin et al. (2014) mention successful surveys over 600,000 km to 4500 metre depths for 80 hours including assessing gas and chemical composition, physical inspections and debris clearance. Drones can investigate water quality, gases and particles, temperature, salinity, turbidity, currents, oil spills, collisions and other maritime risks or accidents.

Drones offer other research advantages across the curriculum. New South Wales have monitored sharks. Woods Hole Oceanographic Institution conduct the Remote Environment Monitoring Units Program since before 2005 (Cox et al. 2005).  Others conduct Wildlife Censuses, invasive plants, vegetation and biodiversity. Sensors have recorded cloud and aerosol measurements, stratospheric ozone chemistry, tropospheric pollution and air quality, Water Vapor and total water measurement and coastal ocean observations. Coastal Patrols, land management, water discharge and forest fire damage assessments have been assisted by drones. Existing tests include active fire emissions and plume assessments, gas flux measurements, vegetation structure, composition and canopy chemistry, aerosol, clud and precipitation distribution. Glacier and Ice Sheet Dynamics, radiation, Gravitationl Acceleration and Antarctic Exploration with magnetometer, gravity and LIDAR measurements have also been captured by autonomous data gathering systems. Other research extended to Magnetic Field Measurements Physical Oceanography, Meteorology and Atmospheric Chemistry. Stakeholders can concentrate on understanding natural disasters, hurricane formations, and Extreme Weather Focused Observations at high altitude. Examples include Cloud Microphysics, Snow and Soil Moisture.

National Geographic in 2017 pointed out drone and ROV potential to research deep sea species such as the Marianas’ Trench. One explorer David Lang launched 1000 Trident drones for research and teaching. Project examples included assessing changing California marine ecosystems and coastlines at Pelican Cove, defending Caribbean grouper and snapper spawning against Mexican overfishing; understanding ancient British Columbia glass sponges and using tracers on mussels for Gulf of Maine changing coastal conditions. Schill (2014) details coral ecosystem surveys designed for amphibious quadcopters by a student on a $2000 budget. “Henri” was validated in northern Haiti with a Go-Pro, GPS and waterproof Tupperware compartment. The future of US and Australian marine mammal research has been to investigate drone consequences for physical and psychological behaviour and environments of species. The United States Marine Mammal Commission (2016) conducted field tests and stakeholder workshops for UAS vehicles, sensors, software and technology types. It proposes a centralised UAS acquisition, operation, maintenance and training system to assist universities and other research institutions. Woods Hole Oceanographic Institution sample whale blows, metabolic condition and disease. As with other missions, drones are estimated to have cost and safety advantages both to species and field researcher contacts. Sources invariably cite automated technology advantages in obviating the need for continuous real time data assessment, more accurate and precise data observations and the physical presence of researchers. They are especially prized at replacing humans on missions especially “dull, dirty or dangerous,” reducing risk.

Kao et al. 2017 advocate the formation of an Internet of Underwater Things” one day as accessible as the satellite aerial equivalent as a drone and interconnected wireless sensor networks. It may succeed if equipment is sufficiently resilient and waterproof, secured against cyber risks and long propagation delays, low reliability, narrow bandwidth are solved communication barriers. Drones also host further potential to monitor environments, ensure legal protection, prevent species abuse, poaching, illegal waste discharge and harvesting/extraction commercial operations (Bayat et al. 2017). They are advised as crucial in administrating marine reserves and protected areas as part of maritime sovereignty with finite resources. James and Moses (2015) mentioned the increasing need to prevent marine resources from being raped and plundered, including bycatch and bottom trawling violations. Aside from drones, solutions include stakeholder consultation, increased parks, penal sanctions and greater financial incentives for reporting violators, mass communication and outreach, more rangers, satellites and coordinated sensor networks. Social media and mobile apps/electronic record technology can also aid in maritime conservation and protection. Only 2.12% of the world’s oceans remain legally protected. Defending ecosystems as ecological capital and ecotourism reserves, ensures species remain for the future, given how many species are threatened with extinction within South Africa and beyond.

With limited financial, staff and other resources; drones offer certain maritime security and defence advantages to aid law enforcement and naval capacity. Extensive maritime boundaries create high legal enforcement costs and remain challenging to define. Drones can assist traditional naval roles and responsibilities including maritime defence; warfare; fisheries and maritime resources protection; coastal law enforcement; intelligence, surveillance and reconnaissance; search and rescue, anti-piracy; humanitarian logistics and emergency/disaster relief. It includes civilian assistance, evacuations, maritime interdictions, peacekeeping, sanctions and embargoes (NATO 2009). Drones work most effectively when integrated and coordinated with other stakeholders with increased operability. As substitutes for “dull, dirty and dangerous” missions they can be pre-programmed for tasks that minimise human errors, damage, fatigue, boredom and other risks. It can magnify situational awareness from additional sensor capacity, lessen crew overtime, training, logistics and equipment inventory costs for missions. Stealth offers higher probabilities of observing and interception successes. They can enter less accessible/remoter areas less intrusively. Austin, Fox and Hussain, (2014) detail how drones are deployable in tracking targets, migration of people, vessels, technology plus species and countering smuggling/other customs violations. Shah (2016) focuses on physical safety and security by supplementing vessel traffic monitoring systems. These can increase efficiency whilst reducing shipping lane and port congestion. With greater risk and information awareness, missions are more likely to be successful.

Civilian and military maritime security applications are extensively detailed as the most cited advantage of drone systems. Cox et al. (2005) details increasing research priorities to autonomous multivessel operations, drones capable of long range missions, high endurance and altitude or technological component miniaturisation. NASA’s Aerosondes reached abilities for missions of 2000-3000 km, 10-30 hours and 7 km height. Altair reached 15.2 km height and 30 hours, 300 kg payload internally and 1361 kg externally. Altus I managed atmospheric sampling at a 19.8 km height, 24 hour endurance with a nose mounted payload. The US Navy have a specialised administrator and commander for unmanned systems/underwater drones, although it has yet to develop its own squadrons unlike India. The US armed forces are researching 251 unique configurations and 144 vehicle platforms. Technology applications include underwater mine detection and clearance since 2003 Iraq. More controversially it is deploying other species such as dolphins and sea lions to aid searches. Mugg, Hawkins and Coyne, 2016, note manned aircraft are far less practical over 3 oceans and 37000 kilometres of Australia maritime terrain. It hosts a mere 50 aircraft costing from $6162 to 19,325 per flight hour. It argues broad maritime domain awareness would demand 400,000 km of EEZ per boat 24/7, mandating drones and other substitutes. It is investing in the MQ-4C Triton with over 24 hours endurance. Yet a single Triton cost $120,000,000 or 400 Wave Gliders with towed array passive sonar which is renewable energy powered and more efficient.

Although drones have yet to be formally revived as an airforce squadron, this report endorses researching drones to assist South African aerial, land, logistics and naval support capacity. Drones have potential to more effectively conduct the following core objecties (South Africa National Defence Force, 2017): I: Defend and Protect South Africa, II: Safeguard SA and III: Promote Peace and Security. Drones could aid IV Developmental and Other Ordered Tasks including Terrorism, Weapons of Mass Destruction, Cyber Threats, International Crime, Conflict; Joint Command and Control capability. It can assist overseas peacekeeping missions, defence diplomacy and Special Forces operation as more credible deterrence. Drones could assist protection of ports and other underwater coastal assets (section 3.6), International Hydrographic and Nautical Charting Obligations, ocean territorial borders and Exclusive Economic Zone/adjacent international waters free access. They can provide weapons, information, communications and logistics support with abilities to pre-empt South African marine, aerial and land threats. It can assist the defence industry and Aerospace, Marine and Defence Industry Association of South Africa in generating more market demand and competitive, profitable exports.

South Africa could learn from international stakeholders preoccuplied with similar maritime security challenges. Australia’s Navy, University of Tasmania and CSIRO organisations proclaims its aspirations *“to create self-contained, robust, intelligent decision-making robots that can be built at affordable costs.”* These would primarily be solar, wind and wave powered with real time, data feed information to analysts, enforcement agents and other users. Autonomous decision making and risk profiles can determine the most optimal, efficient and sustainable deployment of manned vessels, given human processing constraints. Autonomous vessels are increasingly being proposed for merchant and naval fleets amongdeveloped nations. The first fully automated cargo vessel with zero emissions discharge is expected this year –the Yara Birkeland followed by the first fully automated offshore patrol vessel. It self-advertises itself as reducing the emissions of up to 40,000,000 urban truck equivalents. The International Maritime Organisation and International Association of Classification Societies are currently drafting collision avoidance and other legal issues to permit for these possibilities.

SESAR, (2016)*,’* indicate additional public safety and security advantages for drones provided they are reliable, insurable, affordable and operate securely in controlled airspace. In particular this adds the capacity of multiple drones to be operated under a single operator. Although becoming socially popular, drones still experience requirements for affordable insurance, operating costs and public awareness/legal education and training. Seagliders can offer social advantages of increased safety, reduced crime, light, noise and emissions, powered by wing and buoyancy changes. They extend maximum depth to 6000 metres but transmit acoustic monitoring and other data via surface satellite telemetry. Popular martial purpose USV’s and UAV’s are summarised in Table IX. Drones not only provide additional port, vessel, sensor and other maritime asset protection but can address unexploded mines and anti-submarine warfare, countering other system assaults and cybersecurity threat, improve navigation, transportation and information. The Australian Senate (2015) recommended forming an Unmanned Platforms Centre for Defence, engaging with industry to allocate additional research, funding, vessel design performance and human training. It would learn from various projects including the US’s DARPA Legged Squad Support System –voice command operated. It includes the Israeli Gardium, its Protector (inflatable boat version) and Kongberg’s Remus –remote laptop accessed for mine clearance. Proclaimed advantages include lighter weights, reduced fuel consumption, condensed pilot fatigue, smaller size, fewer costs, greater mission time, flight endurance and geographic terrain range. In contrast, crewed vessels and transport managed 6-12 hours on shifts not 20-40 hours.

## Table IX: Popular Global Drones

|  |  |
| --- | --- |
| **UAV’s** | **USV’s** |
| A5 Sea Eagle, A6 Golden Eagle | Barracuda, |
| AD-150 High Speed VTOL UAS | Blackfish |
| Aesir VTOL, Aid-H Series Helicopter | Boomeranger |
| APID 160, ASN-7, 105B, 209, 212, 215, 216 | C-CAT 4 |
| ASN-229A, ATRO\_X VTOL, AutoCopter | C-STAT Mobile Buoy Systems |
| Blue Horizon II, Blueye Soft-Wing | C-SWEEP |
| Butterfly, Camcopter S100, CH160 | C-Target |
| Copter 1B, Copter Mosquito, CQ-10B | FIAC RT (Fast Shore Attack Craft Representative |
| DP-X, Dragonfly, E950, Fury 1500, G15, | Fleet Class CUSV |
| G18 Aeolus, G3, GC201, HD65, Heroes | Hammerhead |
| IAV1/IAV2, Firefox, Integrator, ITI 80-5 TH | HSUSV (Harbour Class High Speed USV) |
| KOAX X-240, LUNA NG, MANTA B | USV Inspector |
| Model 706 Sea Bat | Interceptor |
| Musceo Helicopter Drone, NEO S-300, | Kingfisher M200 |
| NEO S350, Orbiter 3 STUAS, Panther | Piranha |
| Pelicano, RemoH-C100, RemoH-M100, | Piraya |
| Mosquito, RPH-2A VTOL, RPAC Condor, | Rodeur |
| SA200 Weasel, SA400 Jackal, Scorpio 6 | Sarpal |
| Scorpio 30, Scorpion, Scout B1-100, | Sea Owl Mk VI, SeaFox MK1, Seastar. |
| Shadowhawk, SkyAgent I, Spinwing, SR30, | Sentinel, Sentry, Silver Marlin, Spartan Scout |
| SR200, SR500, Star-Lite T21, TAG, | Stingray, Tianxiang One, u Ranger, USSV-HS |
| TU-150 Hybrid VTOL, UAV Emperor, U8E VTOL, | USSV-HTF, USV-450, USV-600, USV-1000 |
| UAV 35, V750, Vantage Dragon Worrier, | USV-2500, USV 5000, Venus 9, Vigilant USV |
| Velocity Raptor, Vigilante 496/502, Vindicator II | WAM V, X Class, XG2, |
| X13, X200, X-Copter, Z2/Z3 | Z-Boat 1800. |

Source: Viau 2013.

These drones aim to provide defence against future ocean and coastal threats to improve survivability and asset protection. From 2015-2016, US Navy drone spending increased 58.97% from $146,200,000 to $232,900,000 concentrating on adversary submarines, ($83,400,000) –DARPA’s Distributed Agile Submarine Hnting, underwater explosive ordnance disposal and remote mine hunting ($87,600,000). Project Nemo allocates funds to biomimetic UUV’s repplicating fish motions for more sophisticated camouflage. Project Hydra aims to replicate China’s Great Undersea Wall in miniature. Upward Falling Payloads aims at remote activating payloads to surface and descend swiftly with weapons or equipment. China has over 15 drone university projects, whilst Russia is reputedly modifying nuclear missile armed submarines to operate autonomously. In 2017 US military drone spending increased to $4.61 billion, primarily targeting the Air Force’s General Atomics MQ-9 Reaper and the Navy’s MQ-4C Triton. Northrup-Grumman’s Triton is classified as a HALE aircraft with 24 hour mission endurance capacity, operational range of 8200 miles and 16,000 kilometre altitude potent enough to scan over 2000 nautical miles with 360 degree surveillance for all sensors (Viau 2013). It represents the pinnacle of globally currently available technology for maritime missions but costs a phenomenal $120,700,000 per unit. Figure IX summarises its characteristics

## Figure IX: US Navy Current Maritime Drone Abilities.

|  |  |
| --- | --- |
| |  | | --- | |  | |
| |  | | --- | | [Triton Capabilities](http://www.northropgrumman.com/Capabilities/Triton/Documents/pageDocuments/Triton_Capabilities.pdf) | |

# 

The MQ-9 Reaper or Predator B drone is the aviation equivalent of what African industries face if competing globally for autonomous maritime technology. It possesses a 1746 kg payload, 50,000 foot altitude limit and 42 hours mission endurance. Systems are triple redundant with thermographic cameras, and modular designs enable flexible conversions to multiple mission requirements. Individual units cost $16,900,000. It is popular among NASA, USA, Royal and other European air forces. Both drones have been tested against asylum seekers in Australia, India’s UAV squadrons, Middle East conflicts and German signals intelligence. The Dominican Republic has chosen it against smuggled drugs, Italy in Libya, Kosovo and intercepting Mediterranean illegal migrants from North Africa. Drones serve other potential advantages beyond physical, economic and ecological maritime security. They can protect and investigate underwater assets for maritime culture, heritage and archaeology. One drone located a $4-$17 billion Spanish galleon sunk in 1708. Sea Drone in 2015 located a hurricane, sunken missing cargo ship in the Bahamas. They can supplement media news, documentary and film production capacity (Duncan 2014; Australian Parliament 2014). Drones also offer a more sophisticated approach for African militaries to assert maritime sovereignty rather than being dependent on aid donations, expensive manned fleets or the presence of foreign navies. Dikmen, Atalay and Gumas (2016) and Fanshawe (2017) highlight increasing values of UAS against climate uncertainty, terrorism, poaching, piracy, marine pollution and other maritime law violations. As more vessels become autonomous, (Blanke, Henriques and Bang 2017) autonomous capacity may be needed merely to repel others, respond appropriately and counter any potential shortages of seafarers and related crews. They can reduce high human accident error rates, increase productivity, reduce monitoring and maintenance costs. Drones have been proposed to collect harbour waste in South Africa and deliver emergency services/supplies across Africa.

# 3.4: Disadvantages of Drones

The decision to endorse UAV’s, USV’s and UUV’s as a solution for Africa’s maritime hegemony is increasingly challenged when the majority of reports and literature sources act as self-publicising eulogies. Fewer concentrate on drone disadvantages or specific maritime applications. As this report aims at a more objective appraisal for various stakeholders, this section analyses the most probable or cited disadvantages of investing in drones over current manned alternatives. Disadvantages include economic, environmental, educational, research/technical, legal, military, ethical/social, individual and others. As with establishing any sector; the most pivotal economic disadvantage to drones includes opportunity costs to existing employment, expenditure and tax revenue. The most threatened individuals are those involved in traditional flying or those who would have manually operated, inspected and undertaken tasks. Automation presents a significant disadvantage for those displaced and not retrained; given high South African unemployment figures and a global surfeit of human labour. There are potentially high initial sunk costs and limited maritime consumer awareness to generate economies of scale in South Africa. Cheap drones may encourage their proliferation by untrained professionals creating further risks of insurance damage and costs to lives, properties and other assets. Drone costs range from $350,000 for Shadow UAV to 4,500,000 for Predator. However, drone operating costs may not actually be cheaper when personnel costs are factored in. Aslansefat, Latif-Shabgahi and Kamarlouei (2014) caution marine research missions may involve up to 20 support staff per UAV for pilot shifts and data analysis Manned costs rate from $8,600,000 helicopter to $36,000,000 for P3. Drones experience high insurance, skilled labour, research and development costs (Slocombe 2017). New entrants face market barriers.

Creating autonomous substitutes to human piloted operations entails unknown externality costs and other environmental disadvantages. As drones expand production and frequency of missions this entails a degree of sound, light, land and marine pollution costs. More consistent speeds/more efficient routes could lower carbon emissions. Drones could contribute further towards ravaged marine environments if experiencing human, climate and technical failures, especially litter, debris, species entanglement of suffocation on pieces. Their presence could interfere and modify with natural habits from breeding to migration routes to nutrition. Over 300 million tonnes of plastic are produced each year -75% infecting shorelines. Drones might add to this creating over $13 billion loss per year (Williamson, Smythe-Wright, and Burkill 2016). Drone capacity still may require multiple devices deployed across vast ocean distances to understand climate change and marine ecosystems. Limited research and development budgets exist in many African nations to develop customised maritime drone capacity. Understanding multi-stressor interactions with limited sensors and insufficient analytical capacity; complicates research over direct human participation. Most marine ecological research systems including human and satellite observation have yet to be coordinated with autonomous software observations. Sensory deprivation induces potential researcher bias. Drones experience disadvantages in taking effective countermeasures against maritime ecological crimes to deter poaching, overfishing, marine polluters and defend protected areas, unless armed.

Various drone applications encourage exploitation of resources without bothering to investigate if these new economic developments are ecologically sustainable. Examples include aquaculture, deep sea oil exploration and mining. Williamson, Smythe-Wright, and Burkill (2016) consider sulphides, polymetallic nodules, cobalt, metal rich and marine phosphates from the South Atlantic to the Cook Islands. New Zealand rejected a phosphate license for environmental reasons in 2015. Increasing global pressure exists to access even deeper and remoter ocean resources to supplement extractive models of land economic growth and unsustainable population figures globally. As humans we lack experience with drone environmental consequences as a recently proposed technology. Many intended drone operators lack corresponding awareness of basic maritime law and eco-literacy or remain legally responsible for the consequences of drones on any maritime asset, including ecological areas. Examples include physical disturbance, water mixing, suspended sediment plumes; mining vessel/infrastructure impacts and possible accidents/failures. A lack of suitable regulations such as mandatory environmental impact assessments; is conspicuously absent for the Oceans, occurring only for land developments. Drones need to incorporate principles of reducing, recycling and renewing.

Maritime drones require assemblage, conversion, monitoring and other forms of research, education and training. One South African disadvantage is the legal requirement of extensive, significant, pilot-equivalent training to be authorised. However few training, education and research facilities exist that are CAA registered. None are SAMSA accredited for the maritime sector. This presents research disadvantages as conventional academics, government, media and commercial sector may remain unfamiliar with drone technology characteristics, abilities and legal/other requirements for missions. Compliance may be far more stringent and arduous than simply undertaking the research either directly on ground or with a piloted aircraft/ system that research, ethics, businesses and laws recognise. Adapting experiments and mastering proficiency with technology may be more intensive than time and other resources permit, especially when ethics becomes even more rigorous over privacy and other disadvantages. Drones remain subject to technical limits. Most researchers may not be able to filter which are the most appropriate drones that meet requirements listed in Section 2.1 and how manufacturers need to customise them to be mission and user specific. They may be ignorant of true costs actual comparisons as basic information and statistics is not reliably and freely accessible on the Internet, physical archives or reputable, less biased stakeholders.

Duncan (2014) indicates Cape Town is already conducting drone tests. It remains unknown how expensive tests will be and whether they will require exhaustive stakeholder/community consultation, given issues of potential damage, legal liability and other risks. Drones experience technical disadvantages in relying upon highly reliable Internet and electricity capacity for sensor processing, not always available even in urban areas of Southern Africa. Manley (2008) mentions convolutions developing in notifying potential users and considering interactions with shipping and human uncertainty/unexpected actions, simpler to project and react when physically active. Psychological isolation affects drone response rates, costlier and riskier at times than actual human reactions. Knowing when to act, where and high is something that not even the most sophisticated and automated technology cannot sufficiently replicate –for research, commerce or warfare. McGillivray et al 2008 indicates challenges of human processing of multiple data inputs and coordinating several devices. Royal Australian Navy exercises affirmed technical challenges remain in replicating many sizable, manned aircraft tasks, guaranteeing datalink reliability, countering cybersecurity threats, battery limits, ensuring sufficient levels of redundancy and in continuously enacting software updates. Viruses, glitches and cybersecurity remain significant costs that affect research. Many drones are unable to perform sufficient real-time data feed monitoring.

Project Hunter/Outrider experienced payload configuration and other technological/mission specific challenges based on user and other limitations, requiring human intervention rather than devolving capacity, initiative and decision making to drone systems. One major social-technical disadvantage of drones is that of “requirement” creep, where missions are expected to undertake more and more objectives, requiring even more re-designs, sensors, crew and resources, often jeopardising original targets. The more demands placed on maritime, remote operated and autonomous vessels; the more challenging these become to construct. Ambiguous purposes complicate performance efficiency. Determining when human intervention is paramount to override autonomous systems has been insufficiently critically examined. Real time data is imperative Vessels aiming at stealth, still remain traceable via their emissions. Drone operation still remain vulnerable to climate and marine environmental challenges but unlike manned vessels, repairs and operations; become far more arduous to adapt from the event. Many commercially available drones operate at slow speeds and ranges. Sensor payloads are limited in the data types and volumes of collectable information System integration becomes even more complicated and expensive. Fernandes, Stevenson and Brierley, (2002) mention disadvantages for research vessels including accidents, collisions, explosions, lithium ion battery range and aerial, surface plus undersea risks. Battery costs depend on maintenance, repair and support. Battery characteristics are summarised in Table X. Autonomous vessels are also limited in the degrees of freedom they can flexibly turn.

## Table X: Drone Battery Technical Characteristics and Limits

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Battery Type** | **Specific Mass**  **KJ/kg** | **Cost (Euros)** | **Energy cost per km (Euros)** | **Cycle Life** | **Range per charge (km)** |
| Sealed lead acid | 110 | 21000 | 0.59 | 300 | 150 |
| Nickel Cadmium | 140 | 60,000 | 0.26 | 1500 | 190 |
| Nickel Hydride | 350 | 134,000 | 0.23 | 1500 | 430 |
| Silver Zinc | 50 | 254,000 | 5.31 | 80 | 750 |
| Lithium ion | 470 | 254,000 | 0.63 | 800 | 610 |
| Manganese Alkaline | 490 | 7000 | 14.91 | 1 | 640 |
| Fuel Cell 1 | 720 | NA | NA | NA | 940 |
| Fuel Cell 2 | 360-540 | NA | NA | NA | 470-710 |
| Fuel Cell 3 | 370 | NA | NA | NA | 480 |

Fernandes, Stevenson and Brierley, (2002)

Remote Operated Vehicles still experience disadvantages of requiring physical connections to a floating vessel or infrastructure with power requirements. McGillivray et al. (2012) warns of how drone projects can experience additional unexpected research and adaptation costs in responding to “requirement creep.” Between 1980-2002, the US allocated over $2 billion dollars to drone research ad development, with few developed successful prototypes with satisfactory performance and financially viable in the long run. Problems remain in relying upon continuous military and government spending as catalysts for research and development. Aslansefat, Latif-Shabgahi and Kamarlouei (2014) identify a number of technical faults as disadvantages for underwater gliding robots. These include power, leak detection, environmental, communication, sensor, computer, cybersecurity, mechanical, navigation, collision avoidance, propulsion, driving, redundant and operating system faults throughout a mission. It extends to physical and psychological health faults from sensory deprivation, fatigue, stress, boredom, trauma and indifference or apathy in being socially –emotionally attached. Insufficient research has investigate climate and environmental long term consequences for drones from salinity to oxidation, icing, wind, storms, fires, waterproofing and other hazards (Allard and Shahbazin 2014). Drones may be especially susceptible to other disadvantages, lacking information sharing, coordination, cooperation and interoperability between other users, assets and systems. Without these, drones may possess finite capacity to contribute towards heightened maritime domain awareness. Limited attention has prioritised how existing research systems, vessels, assets, users and projects will be affected or need to respond. Instruments possess limited storage capacity.

As skies host even more drones; those interested in registering will experience numerous legal disadvantages and requirements with high regulatory compliance costs as section 2.1 conveys. Drones present numerous social public safety, privacy and personal liberty rights concerns along with significant legal ambiguity and uncertainty in core areas. In South Africa Duncan (2014) echoes these factors in which military and civilian, personal, research and commercial drone uses lack sufficient regulatory attention to protecting citizens’ constitutional rights. Drones threaten physical and psychological threats; risks of insufficient data storage and cybersecurity, can be intrusive, infringing upon personal liberties whether buzzing vocally or quietly unobtrusive with stealth capacity. Many are operated by those with limited or no training and experience. There are few guarantees to ensure personal information is not recorded and that claimed drone missions are those actually undertaken (“Mission creep)”. The source also refers to undervalued impacts on human psychological behaviour when feeling persistently observed without peace, solitude or freedom. Drones hovering experience ethics issues if operated without informed awareness and consent of people who may be adversely affected, including sexual intercourse and other pursuits. The source recommends following the American Civil Liberties Union where drones require warrants and reasonable criminal evidence and monitored missions require candid disclosure of purpose and supervision. It advises public awareness of any policies and missions relating to drones. Existing legislation needs updating to incorporate specific references to drones under the Protection of Personal Information Act with privacy, security, cybersecurity and data protection specifically part of CAA drone stipulated obligations not just its current legal narrow focus to aerospace, safety, security and training.

Australian Parliament (2014) launched a full inquiry into public fears of legalising drones. In 2 October 2013, a drone crashed into Sydney Harbour bridge train line and received a $850 fine In March 2014 a Newcastle rescue helicopter narrowly evaded a drone. In April 2014, triathlete in Geraldton Western Australia, was assaulted during a race. The malefactor alleged channel hopping hijacking by a remote access hacker. UAS were advised as lacking sufficient technical standards being $650 and cheaper and poor civilian quality that lacked anti-collision or fail safe, revert to user arrangements. The inquiry concluded the challenge of integrating RPA’s into Australian airspace and competing with other users, ensuring public safety and security. Consumers lack training and understanding without aviation backgrounds. Drones have received poor publicity with connotations of warfare, targeted assassination and espionage influencing community perceptions. Many users, manufacturers, imports and exporters are unregulated and unregistered. Citizens need to be able to protect personal information, against drone misuses for stalking and harassment, voyeurism, child abuse, trespass, nuisance or breach of confidence. They need a right of recourse and appeal if privacy is violated. Australia CASA recommended privacy law information should be distributed to RPA vendors.

Internationally, using drones over manned vessels and aircraft creates legal and other disadvantages as their use remains ambiguous or even prohibited by many relevant maritime conventions. Deketalaere (2017) is one of a plurality of sources to detail the looming legal challenges of unmanned vessels including STCW, SOLAS and other laws of the sea which specifically require a Ship’s master to be present and take responsibility –with the autonomy to do so. Land based, remote operators lack the same risk awareness, responsibility, accountability and skills capacity. Automated vessel technology cannot replicate all vessel operations needing a Master and crew to the same accuracy, performance and risk reduced conditions, especially when factoring environmental, risk and human uncertainty. Roll’s Royce Advanced Autonomous Waterborne Applications Initiative aims to work on economic, technical, legal and social challenges for autonomous shipping to produce fully automated vessels and obviate the need for a crew or physical port operators. However commercial contracts would have to be legally amended including the Hague, Hamburg, Hague-Visby and Rotterdam Rules/South Africa’s Carriage of Goods Acts. The carrier ensures the vessel is seaworthy and delivering complete cargo intact to its destination within time, regardless of being remote piloted or not. Sea tests need conducting in different operating and climate environments;

Although no legal standards currently exist, the Committee Maritime International are preparing for autonomous vessels without requiring crew, superstructures, accommodation and supplies, saving operating and fixed costs, reducing pollution, weight and fuel required. However, current international maritime conventions indicate the need for an actual master and crew. SOLAS 1974 determine crew as *“the masters and members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship.”* 1978 STCW –a seafarer is defined as ‘a person who is employed or seeks employment, as a master, officer or rating on board a ship.” The 2006 Marine Labour Convention denotes seafarers similarly. UNCLOS Article 94 “*Every state needs to take the necessary measures for ships flying its flag to ensure safety at sea with regard to the construction, equipment and seaworthiness of ships and the manning of ships, labour conditions and the training of crew, taking into account the applicable international instruments. One of the measures a state must take to ensure that each ship is in the charge of a master and officers who possesses appropriate qualifications in particular in seamanship and navigation.”* UN Registration Convention Article 9 insists upon “The manning of ships” requires a crew on board not ashore. Remote operators and infrastructure cannot feasibly be equivalent yet.

A ship’s master has significant legal discretion and autonomy but this legal privilege may be amended or revoked if the vessel is unmanned directly. The 1992 amended Civil Liability for Oil Pollution Damage, 1924 Warsaw Convention too International Carriage by Air, 1972 Preventing Collisions at Sea Regulations; MARPOL. 1976 Convention on the Limitation of Liability for Maritime Claims,1986 UN Convention on Conditions for Registration of Ships and 1999 International Convention on Arrest of Ships. International Convention on Salvage 1989, have yet to be amended for autonomous vessels. There is no guarantee of extracontractual liability –if third parties are damaged by an unmanned vessel. Unmanned vessels cannot render assistance to those in peril or disaster on the sea. However, STCW Article IX allows for technical developments and vessels provided capacity and training establish safety and security at sea, which could be interpreted to include drones.

In June 2011 the University of Texas hacked a Department of Homeland Security drone, spoofing the GPS for less than $1000. If Henderson (2006) indicates further legal uncertainty for drones in accidents, product liability, negligence and misuse. Insurance needs to consider director’s and officer’s liability, employer, product and professional indemnity liability. Does blame accrue to the flight operator or the other airspace user/individual? Although statistics are not available for South Africa, the US FAA noted drones incurred a mean 52.7 accidents per 100,000 flight hours compared to 7.11 accidents for general aviation and 0.149 per 100,000 for commercial. Registered users are comparatively few compared to actual users, extending underlying systematic risk to safety and security. More realistic virtual cockpit and operator training standards are cautioned. The source advocates all drone licence applicants should describe drone purpose, types of information connected; anticipated use and disclosure of information; possible privacy implications and proposed applicant solutions. Individuals responsible should be outlined and a contact point for any complaints to get paid. These report advises increasing legal certainty through a national UAS, UUV and UUV database of operators, stakeholders, flight missions, security policies, technical standards, legislation, training, contact and complaint information.

Carr (2013) affirms the limitations that humans can expect of drones for security and defences. Drones are reputedly lacking in true Artificial Intelligence and automation or “the independent capacity for knowledge and expert based reasoning.” Many corporations including Facebook, Apple and Amazon mention diversifying into drone companies but remain under-examined and unregulated. Only few institutions specialise in robotics, related electronics, computing, engineering and technology making it problematic to adjust for demand. As with any technology, introducing drones offers institutional, cultural, administrative and organisational barriers to those ignorant, indifferent, sceptical or hostile. Many lack faith in AI and abdicating control to technology. Humans are simpler to respond to if problems develop. Cho et al. 2015 warns against the loss of personal human interaction, possible rage, anxiety, confusion, discord and tension over a lack of transparency, public misunderstanding and miscommunication.

The most significant maritime security disadvantage of Africa deciding to favour drones, is that humans are necessary to actually act as a deterrent, solicit an arrest or take action. Coordination with other agents can be trysting and ineffective. Even where drones are used; they have been challenged in courts. For the US in July 2011 drones were used to determine the unarmed status of cattle thieves. However the defendant claiming illegal drones were used, initiated legal action against the police. Weaponisation of drones and admissibility of drone captured evidence remains banned or legally ambiguous by many nations as controversial. However, without protection, drones can lack being effective deterrents and remain vulnerable to theft, abuse or sabotage. Legal implications of using lethal force whether in peace, war or law enforcement remain independently uncertain. For example, do UUV’s enjoy sovereign status exemption? Can they sail in territorial waters? Many drones may be subject to arms controls, diminishing export opportunities (Slocombe 2017). As drones become cheaper, they remain vulnerable to cybersecurity risks, too simple to construct and operate. Stealth may protect drone users but provides disadvantages to those seeking to protect themselves.

A fully autonomous vehicle is defined as one able to perceive its environment, determine its route and self-propel to its destination without continuous human interaction and supervision (Lloyds 2014). Klimkowska (2016) provides examples of limited local and international drone legislation guiding warfare, espionage, cybersecurity and assassination. In 2008, several Georgian UAV’s were shot. In 2011 Iranian captured a HALE stealth UAV from the US Air Force. Drones detach operators from physically being present, dehumanising conflicts as targets not living beings. Indirectly they possess disadvantages of reducing personal cost consequences likely to enhance brinkmanship, arms races and probability of warfare. Drones however remain more vulnerable than manned naval and aerial defences with slower reaction times; too much dependency on battery power, a narrow spectrum and high bandwidth satellite datalinks. They are sensitive to spoofing, jamming, interference and being overridden. Far fewer insurance products are available given a lack of familiarity with drone usage and risk assessments (Lloyds 2014).

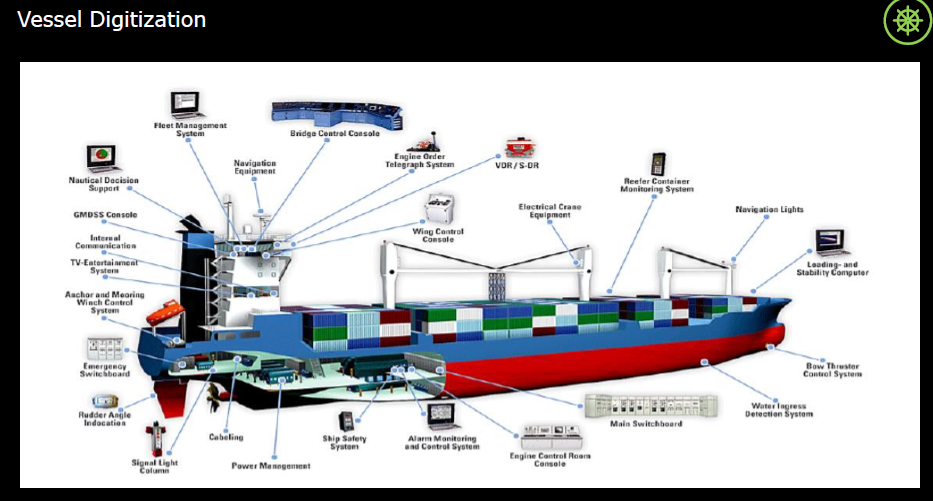
People remain uncertain as to drones substituting all aspects of maritime operations and replacing shipping. Drones experience marketing and public perception/social disadvantages. Many people are conservative enjoying quintessential parts of our heritage and being physically engaged on the water, maritime environment and supply chain networks. Yet drones are increasingly being proposed as substitutes and complementary across various maritime security programmes including the EU’s Horizon 2020 (Natchef 2016). It budgets 20 million euros per year to cybersecurity excluding drones and 24,000,000 euros in autonomous border security, focusing on enhanced 3D command and control, greater climate resilience, data and airspace/ocean use integration. Australia remains concerned from its high proportion of maritime assets and 36,000 km coastline (Rodgers 2016). Although drones can improve maritime security, there are international humanitarian law obligations which may affect their use under Geneva Convention Article 6.Technology remains potentially prone to failure. The more “dull, dirty and dangerous” tasks drones undertake, the less point there remains to functioning as humans. The less we retain the capacity and motivation to undertake these tasks alone. Can we trust drones entirely with the capacity to anticipate, proactive and react? (Elbit Systems 2014). Is the Intelligence, Surveillance and Reconnaissance it provides adequate and effective for decision making? Ultimately drones cannot understand and respond to human and natural uncertainty and so some degree of human observance and intervention remains vital to preserving maritime resources, sovereignty and survival.

# 3.5: Risks

If South Africa wishes to guarantee ocean governance through drones as part of Operation Phakisa, this report forecasts certain emergent risks that need to be resolved. Climate change and environmental uncertainty, cybersecurity; social-religious/other tensions, fluctuating economic and technological cycles; actual AI and automation; legal risks and increased prospects of militarisation and warfare all threaten to undermine any arising advantages and opportunities. Of all factors threatening future drone operations; human induced climate change creates the most uncertainty for assets, ecosystems, trade and human populations for “business as usual” forecast conditions. Aside from normal climate-environmental factors; long term risks for drone activities, maintenance and repair include sea level rise, changes in ocean acidification and salinity; air, surface and sea temperature. It includes changes in wind, species migration, evapotranspiration, soil composition and sedimentation, currents, El Nino and precipitation. Increased durations, frequencies and intensities of climate-related natural disasters include storms/superstorms, cyclones, floods, droughts, earthquakes, tsunamis, gales and volcanoes. Utne and Schjolberg (2014) emphasise reduced technical performance, functionality, safety, and other costs

When even US Department of Homeland Security, British Royal Navy and luxury megayacht systems have been hijacked by remote operators; one of the foremost risks to increasing drone dependency includes cybersecurity. Drones were even considered a realistic threat for the London 2012 Olympics. Ionides (2017) projects the first remote controlled, unmanned coastal vessel by 2025 and remote controlled ocean going vessel by 2030. Rodseth (2016), indicates a proposal for an autonomous Handymax dry bulk carrier costing 2.9 million euros by 1 September 2023. Increased vessel digitalisation presents risks as many current systems are not protected. AIS, ECDIS, VMS and GPS offer no authentication or integrity checks and completely expose the vessel’s presence. With no crew and frequently unarmed, vessels become more susceptible to being seized electronically and physically. Figure X emphasises just how much of a vessel can be digitised and automated –and hence controlled when no crew can manually intervene. Cybersecurity risks include the accessibility of vessel data including locations, actual hijacking, AIS spoofing –creating fake or mimic vessels or simulating a drowned man or other incident alerts. Others include electronics warning, deception and network jamming and false target generation. Therefore manual override systems are advised as a level of redundancy. UAS can be protected against hackers –encrypted data communications links; redundant navigation systems and GPS receivers. If one fails –can use another ground control station

## Figure X: Increased Container Vessel Automation and Cybersecurity Risk Exposure



Source: Ionnides 2017.

Drones have the possibility to amplify social-political-economic risks if deployed to contain strife and other issues, given community and individual suspicions towards drones and leadership tension. As they become legalised, cheaper, more flexible and accessible, they provide greater temptations to be used instead of utilising and employing people; which may ire people more. The risks of automation can be offset against limited range of tasks and missions can be partially offset against those currently technologically possible. Drones require sufficient redundancy, highly reliable technical systems and rapid repair, integrated shore support network/infrastructure, interconnected, safe and secure ICT systems. One example conducted over 6000 miles from Shanghai to Los Angeles include a dual propulsion container vessel of 1000’s TEU’s. It used hybrid biofuel-methanol fuel. Demographics and increased global population growth may enhance friction. They may prevent further risks to social stability from religious fundamentalism, political and civil society extremism, deployed without concern for responsibility or accountability. They could easily aggravate attacks or be misused. Drones could promote kinetic energy discharges, epidemics, medical, nuclear, chemical and biological warfare. They could promulgate electronic warfare. Cox et al. (2016) details how civilian usage can be expropriated and queries how can people prepare? Projected drone growth forecasts remain conditional upon fluctuations in economic activity and uncertain rates of technology innovation, influencing demand and supply as a prime uncertain risk.

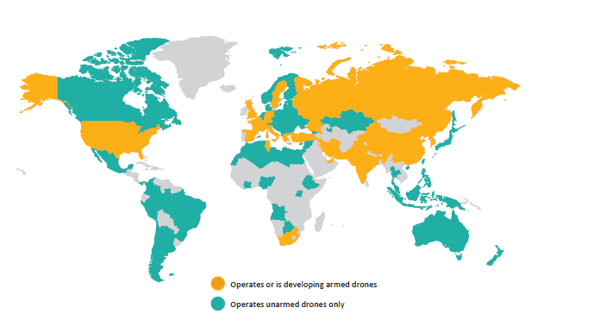
How many accidents are socially, environmentally, economically and politically acceptable? What do stakeholders perceive and how will they react? Physically and psychologically this remains unknown, complicating preparation. How aware, familiar, experienced and prepared are with drones? How do we react? Utne and Schjolberg (2014) forewarn of various drone operation hazards with unforeseen consequences including Operator, operation, recovery and design hazards. Operator Hazards include Manual handling, Sensory isolation, Noise, Vibration, Heat, Stress, Fatigue, Incompatible hand controls, Radiation, Psychology. Operation Hazards extend to use of hazardous tools, hot and cold surfaces and fluids, open flames, voltage, radiation, collision and electrostatic energy. Unarmed drones experience crime risks. Recovery challenges involve logistics coordination, fuel, sensors, pressure vessel leak, battery failure, transponder beans, equipment loss; poor GPS, power supply, buoyancy and propulsion system failures. As more systems become automated, risks remain unless people are correspondingly retrained and educated. Artificial Intelligence may imperil human capacity to perform even the simplest of tasks, when it malfunctions.

A lack of sufficiently integrated airspace regulation encompassing all UAV types has not been implemented. Ribeiro and Molenaar (2014) emphasise significant legal risks and related administrative/enforcement compliance costs to ensure European maritime security and environmental risks remain. Limited enforcement, time and resources exist to ensure legal requirements and technical standards are addressed for policies. Schmitt and Goddard, (2016) affirm the legal and military risk presented by drones during conflict under UNCLOS and warfare. Ocean governance has not entirely incorporated drones into enforcement. Drones present unknown risks as to whether they add prosecution and law enforcement or divert resources away from more effective alternatives. How effectively can existing craft be converted into drones or civilian drones weaponised and should they be? Under UNCLOS Article 94: “*Each ship flying the flag of a flag State must possess appropriate qualifications in seamanship, navigation, communications and marine engineering and that the crew is appropriate in qualifications and numbers for the type, size, machinery and equipment of the ship. The master, officers and to the extent appropriate, the crew must be fully conversant with and required to observe the applicable international regulations concerning the safety of life at sea, the prevention of collisions, the prevention, reduction and control of marine pollution and the maintenance of communication by radio.*

USV’s and UUV’s engaged exclusively in government, non-commercial service are sovereign immune craft –during peace not war. Vessels immune from attack include hospital ships, small coastal and medical rescue craft; cartel vessels designated for prisoners of war, engaged in humanitarian missions; transporting cultural property under special protection. They include civilian passenger only carrying vessels and charged with non-military scientific, philanthropic or religious missions; small coastal fishing and trade vessels, marine environment pollution, surrendered vessels and life rafts/lifeboats. These apply whether armed or autonomous. Data fusion complications from multiple sensor and payload capacity However, the legal and military risk is will automated vessels be able to determine or differentiate between neutral and actual targets? Will they be able to recognise the need for surrender or aid? Can they avoid automatically reacting hostile when in neutral waters? What steps can be taken to protect underwater, coastal and other maritime assets with boundaries? Abkal, Talas and Shaw (2017) for Kuwait port security mention further risks in coordinating and cooperating in information sharing, given crime, cybersecurity and other risks.

Drone strikes created 40% of Middle Eastern civilian deaths in 2014 (Sustainalytics, 2014). In response drone companies experience considerable public relations, marketing and social risks aside from possibly being held legally liable. TheUS hosted political protests and UK NGOs/social media called for divestment from armed drone companies too ensure human rights are observed and business accountability. American Civil Liberties Union (2011) and Sustainalytics (2014) proposes responsible investors ensure drones are operated ethically, suggesting certain questions to enquire. These ask about if there are any restrictions on the sale of drones and drone technology; do they liaise with regulators; do they observe privacy, data security and international humanitarian laws; are they involved in drone weaponisation and do they monitor drone use? How do they address vulnerabilities such as hacking? Risks exist of academia or other individuals penetrating military and classified data for AUV missions –sensitive target University of Birmingham Policy Commission (2014) considers do individuals, businesses and communities actually want drones? Courts focus on government drone use not commercial enterprises. Figure XI illustrates the extent to which drones have become increasingly popular globally. One core risk is that nations will participate in an arms race. Unarmed drones will become increasingly pressurised to become armed. Armed drones will become even more autonomous, lacking individual human restraint or norms before reacting.

## FIGURE XI: Global Drone Armed and Unarmed Operations



Source: Sustainalytics, 2014

Many nations are responding to uncertain risks of not investing or failing behind, even when actually not threatened. McCaslin 2017 notes the brinkmanship in several Asian countries in response to China planning investment over $10 billion 2014-2023. E.g. India’s drone investments range from the 5 hour endurance, technical Nishant with 160 km and 3600 feet altitude limits for intelligence; to the Rustam 2 MALE with 24 hours endurance, combat and intelligence capacity up to 500 kilometre radius and 30,000 feet altitude. Pakistan, Russia, China and Japan are all favouring drones Yet Predator drones operate for 48 hours but most are limited to an hour or less battery –lithium ion polymer. Other risks include many objectives face discriminatory targeting based on operator prejudices. Drones offer the potential to overswarm prey. Automated Law enforcement or warfare without human intervention experiences technical glitches, lack understanding of humanity, ethics, norms and psychology to pronounce reasonable judgements and decisions. ISR policies need transparency and certainty. Drone regulations for remote maritime areas and ecosystems need drafting (Brooke, Lim and Ardron 2010). Additional bandwidth is needed. Other maritime law enforcement options could consider VMS, electronic monitoring systems and logbooks, AIS, long range identification and tracking lRIT, radar and optical imaging sensors –satellite, infrared/ultraviolet. Yet, significant risks exist when relying upon other nations for arms and other critical technology such as drones, where access can be revoked at any time. Otherwise African nations would face problems of import substitution, scarce foreign exchange reserves being depleted and ensuring quality control as further risks when either developing an indigenous drone industry or importing from others.

# 3.6: Opportunities

With over 2967 kilometres of coastline and 1,200,000 km² of Exclusive Economic Zone, South Africa’s maritime economy emphasises significant opportunities. This report considers for drones to be truly effective at ocean governance they must assist existing naval and patrol vessel constraints to protect the numerous maritime assets of South Africa (Table XI) and Africa. Further economic and maritime security opportunities exist if the 22 existing drone firms, any new market entrants, industry and researchers consider opportunities to assist related maritime stakeholders, summarised in Table XII. Through protection, maintenance, inspection, repair, research and assistance, drones can preserve any existing and future assets from projected threats. This section contends drones may offer South Africa economic, environmental, educational, research, maritime law enforcement/security, legal and other opportunities to exploit if aligned with stakeholder requirements and related legislation/policies.

## Table XI: Marine, Underwater and Coastal Assets of South Africa

|  |  |
| --- | --- |
| 37 Aquaculture Farms | > R160 billion of seaborne trade |
| 8 Commercial Ports, tugs, pilots and equipment | Over 260,000,000 Tonnes of cargo |
| Fishing Vessels | > 600,000 tons of fisheries annually |
| Marine Protected Areas | R 0.7 billion of fisheries and aquaculture economic activity |
| Oil Rigs | 2,227 aquaculture employed |
| Pipeline length | 12,122 fisheries |
| Registered Vessels -3 container | 224,000 foreign seafarers |
| Shipwrecks 2000-3000 | 12,0000 foreign vessels |
| 4 Submarine Cables | 4 offshore patrol boats |
| 22 shipyards | SA Agulhas, SAS Protea hydrographic ship |
| SA Naval Base Simonstown/Durban | 4 Crude oil refineries –SAPREF, ENREF, NATREF, CHEVREF |
| SA Naval Station Port Elizabeth | Petro-SA’s GTL Base |
| Unknown Coastguard Bases/Lighthouses/navigation aids | SANAE Antarctic, Gough/Marion Island research stations |
| 4 Fisheries Protection Vessels | SAS Simonsberg, SAS Saldanha, SAS Wingfield |
| 6 coastal fisheries offices –Jacob’s Bay, Hermanus, Gans Bay, Cape Town, Port Elizabeth, East London | Alexander Bay –De Beers concession restricted port |
| Simon’s Town Marine Warfare School | Acoustics Tracking Array Platform |
| Any Marine National Key Points | Marine Science Platform DST |
| SATS General Botha, SA Naval College | South African Environmental Observation Network |
| Natal Maritime Museum ships | Unknown marine ecological capital |

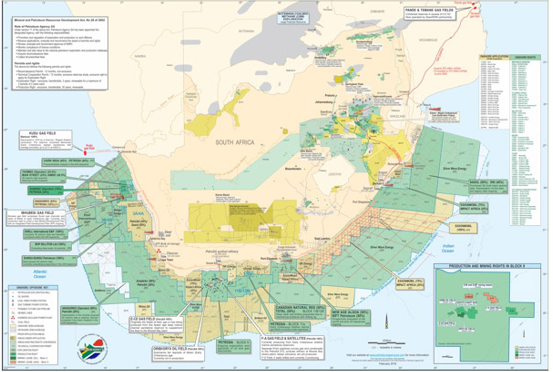
## Table XII: Potential Maritime Security and Ocean Governance Stakeholders in South Africa

|  |  |
| --- | --- |
| 16 Aquaculture Association of South Africa linksFish South Africa, Ornamental Fish Producers, South African Pet Traders Association , Abalone Farmers Association of Southern Africa (AFASA),  Catfish South Africa, South African Farmed Abalone Export Council, South African Koi Traders Society, Tilapia Association of South Africa (TAASA), Western Cape Tilapia Growers Association, Western Cape Trout Association, Mpumalanga Trout Forum, Marine Finfish Farmer’s Association of South Africa (MFFASA), Mussel and Oyster Forum, The Crocodile Farmers Association | South African National Department of Transport, Public Enterprises, Public Works, DHET, DEAT, DTI, Economic Presidency, Environmental Affairs, Water and Sanitation, DAFF, Tourism, Science and Technology, Energy, Defence, Foreign Affairs, Development National Ports Regulator Authority of South Africa., TNPA (Transnet National Port Authority), Transnet Port Terminals/ Freight Rail, Sanral, PRASA,  (KZN) Department of Agricultural and Environmental Affairs, Department of Tourism  Ethekwini, Richard’s Bay, Nelson Mandela Bay, Cape Town, East London etc Municipalities |
| 200+ Members of South African Oil and Gas Alliance | KZN Tourism, East Cape Tourism, |
| 18 shipping companies, 1 regular cruise company | National Research Foundation of South Africa |
| Members of SAASOA, SAAFF, | CSIR, Petro-SA, SASOL, SANCOR, |
| 22 members of South African Association of Ship Operators and Repairers | CPUT, University of KwaZulu-Natal, Durban University of Technology, Nelson Mandela Metropolitan University |
| Indian Ocean Observatory | International Ocean Institute |
| South African Weather Service | South African International Maritime Institute |
| SAMSA | SA Maritime School/SAMTRA |
| South African Institute for Aquatic Biodiversity | Transnet Port Maritime School of Excellence |
| Benguela Current Commission | SAMSA |
| San Parks | Cape/Durban/Nelson Mandela Bay Chamber of Commerce |
| SARS Customs and Excise | South Africa Chamber of Mines/Chamber of Commerce |
| South African Marine Science Symposium | SAIMI, South African Maritime Chamber of Commerce |
| TIPS, TIKZN | South African Marine Research and Exploration Forum |
| TETA, SETA, MERSETA | Water Research Commission |
| COSATU, SATAWU | Ethekwini Maritime Cluster |
| NASASA: National Association of Stevedoring Associations of South Africa | South Africa Shipper’s Council |
| Seafarer’s Employment Organisation | South African Marine Industry Association |
| Transport and Logistics Employers’ Association TLEA | Aerospace, Maritime and Defence Association South Africa |
| Warehousing and Distribution Employer’s Association | South African Army, Air Force, Navy, Denel, Armscor, 22 drone companies |

Vessel blockages or wrecks may have paralysing economic consequences, which drones can help to resolve. Protecting underwater assets, preserves and enhances economic activities. However drone producers and intended users are advised to undertake cost-benefit analysis or feasibility assessments. For example, drones could aid in fisheries enforcement –i.e. preserving rock lobster from poaching. At a cost of US$ 38-42 per kg, it contributes $20 million to economy but is heavily poached, as with abalone. The SA Merchant Navy is estimated at R5 billion worth, the SA Navy R3 billion and SAMSA budget R300 million. Significant economic opportunities exist to aid Operation Phakisa targets of $10-15 billion or (R129-177 billion) by 2033 and 800,000-1000,000 jobs, via expanding the existing drone industry to the maritime commercial, defence, research and recreational sectors. Insinna (2015) forecasts increased competitor risks however as China aspires to40% of the global drone market by 2025. Yet China lacks the same experience, training, aviation and quality control standards of South Africa. For Africa to achieve trade creation and diversion it needs to focus on publicity, marketing and salesmanship as many customers lack familiarity with drone technology potential for the maritime sector.

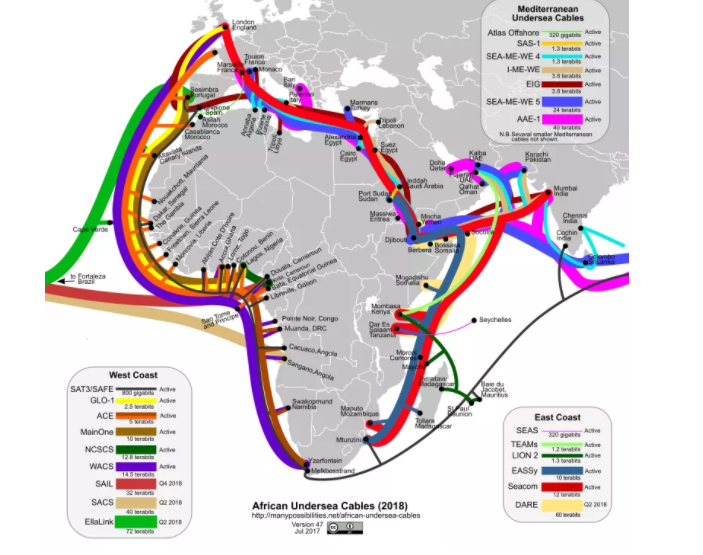
One of Operation Phakisa’s goals is to similarly focus on oil and gas exploration. However, Figure XIII: illuminates many existing and looming fields that could benefit from this technology economically, environmentally and for risk management. Many foreign firms such as Oceaneering are also focusing on lucrative oil and gas rig pipeline contracts in West Africa. Nigeria’s National Petroleum Corporation remain concerned about crude oil theft, endorsing drones. This report argues to reduce external dependency, South Africa and Africa should focus on import substitution and patriotic purchasing. Global communication with the African continent depends highly on 24 undersea submarine cables (Figure XII), of which South Africa hosts 4. Future drone opportunities include the capacity to continuously investigate and improve the condition of these cables. No nation can attain effective ocean governance unless they retain the capacity to protect all assets and retain strategic control of intelligence networks. Market prospects are not just confined to South Africa’s Operation Phakisa as more countries provide export chances for the ROV, AUV, UUV and USV industries.

## Figure XII: South African Oil and Gas License Concessions



Source: Share 2017.

## Figure XIII: African Maritime Communication Links.

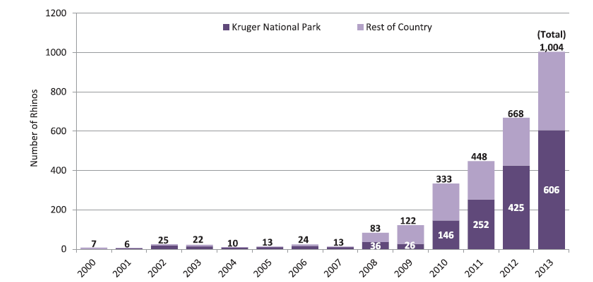


Source https://www.flickr.com 2018.

Developing drones may offer the above related stakeholders and others certain environmental opportunities in procuring and analysing ocean and coastal information. Byrne (2015) emphasises how they can be used to preserve marine ecological functions and sovereignty through greater awareness of the status of resources. Greater drone capacity for maritime law enforcement and data aids South Africa’s constitution capacity “*to have the environment protected for the benefit of present and future generations through reasonable measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources.”* It can assist environmental impact assessments pivotal in determining future marine spatial planning, ecological conservation and economic activity. South Africa currently lacks an online Oceans and Coastal Information Management System, proposed under the Department of Environmental Affairs’ 2008 Integrated Coastal Management Act, ‘Coastal’ and ‘Ocean’ White Papers. They could legally assist 1998 National Environmental Management Act, and 2003 South African Spatial Data Infrastructure Act. Drones could form part of an integrated sensor network linking autonomous, manned vessels, buoys, sensors and satellites with real time data feed for the marine environment. The system would have to consider interdisciplinary fields from climate change to oceanography, marine spatial planning, maritime law, economics, infrastructure, trade, supply chains, risk management, integrated vessel tracking –poaching/piracy/smuggling/security and coastal viewing maps. Drones can monitor threats from poaching to water quality, harmful algal blooms and invasive species. They could form a part of academia including NMMU’s 2016, Marine Apex Predator Research Units (Nelson Mandela Metropolitan University, 2017). This would especially aid ocean governance for Operation Phakisa. It provides opportunities for industry, universities, government and related businesses/communities to consider timely, useful and understandable information. National databases and systems would aid long term government and other participants’ monitoring, research agendas, and technology developments.

One of the most urgent opportunities to which drones could prove themselves for South Africa and Africa is assisting in counter-poaching, to prevent species extinction, especially for maritime and land reserves, whether private, public, community or research. Over 20,000 elephants were slaughtered in 2012. Finite resources protect wildlife with limited information sharing, cooperation, enormous reserves and scarce ranger capacity threat to tourism and reputation. (South Africa recommends employing 60 –or 1 every 50 kilometres of coast and no fisheries patrol stations exist north of East London). South Africa has already attempted to respond by a Seeker Seabird and Seeker 2 specialised reconnaissance drones donated by Denel for rhinos (Humphries and Smith 2015). Kruger Park as Africa’s largest park hosts the largest remaining trove of rhinos. Between 2000 to 2013 rhino poaching proliferated from 7 to 1004, by Vietnamese and Chinese eco-genocidists in Figure XIV (Lunstrum 2014). Rhino horns are worth US $65,000 per kg on black market as a falsely claimed virility treatment, paying poachers $1000-$9000. No rhinos were killed during the March 2015, Kruger Park test. Maryland’s Falcon UAV tracked 2 rhinos and a poacher nearby. (Bergenaas, Stohl and Georgieff, 2013). However 2 drones are clearly insufficient to protect sovereignty and national heritage. The implications of this technology could expand to protecting local fisheries, aquaculture and fisherfolk from outside plunderers. However drones remain banned from national parks and marine sanctuaries for apparently disturbing wildlife.

## Figure XIV: Rhino Poaching in South Africa 2000-2013.



Source: Lunstrum 2014

In 2014, Kenya banned private drone surveillance in its national parks on the basis of protecting wildlife but in 2015 amended this to charging $1000 per licence (Onalaja 2015). In July 2015; drones aided controlled elephant migration into Tanzania reserves. March 2015, Jacaranda FM tested drones for news monitoring. In May 2015 the city of Cape Town utilised surveillance drones to aid law enforcement against drugs. Drones can further aid ecological protection and law enforcement of 73 South Africa, extensive marine protected areas (Table XII) and projected plans to expand maritime boundaries to the continental shelf. For example in April 2013 Prince Edward Islands -180,000 km2 7th largest in world and first offshore MPA. It shares 1 patrol boat with the Western Cape and offshore islands at present. Other economic opportunities exist to expand into protecting African territorial waters and reserves, given limited existing naval and fisheries defence capabilities. Drones could enforce South African Antarctic Treaty obligations (Sidropoulos and Wheeler 2016) against possible illegal mining, monitoring against mass tourism incursions and enhancing scientific research as the only African nation with a base. It could aid treaty cooperation against militarisation, protecting flora, fauna and minerals. More drones reduces pressure on the SA Agulhas II with limited space and logistics to target more pivotal research rather than just logistics. The DEA Oceans Conservation Sub Programme budget cut from R757.4 million to 219.9 million in 2016/2017, pressurising ocean governance further. Drones could be added to enforce the Marine Spatial Planning Bill and 2013 Customs Acts. Finally, as climate change affects future maritime assets, more companies and stakeholders may seek drones for more effective, ongoing risk assessment as surveying economic opportunities.

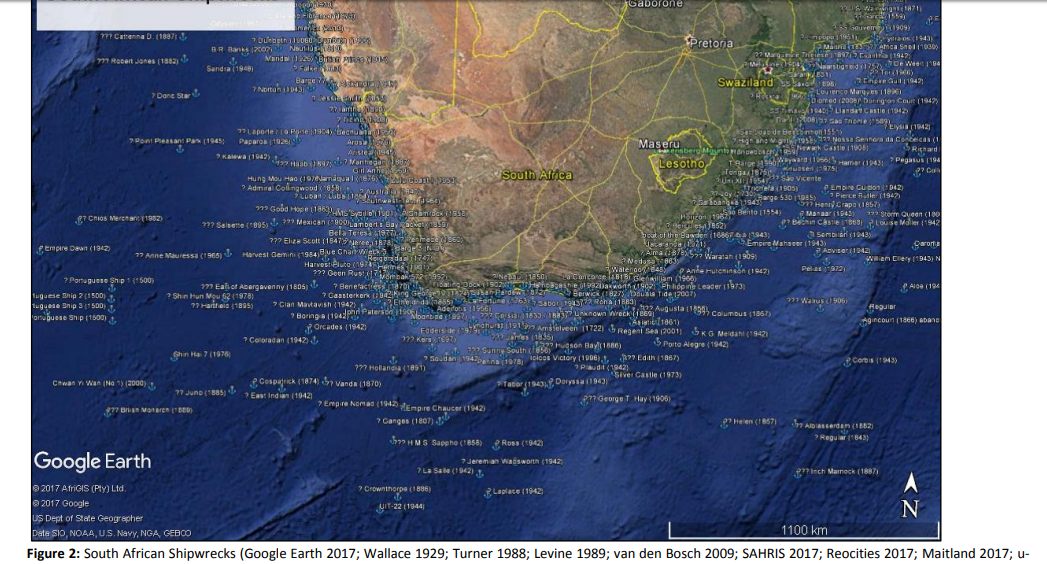
## Table XIII: Marine Protected Areas of South Africa

|  |  |
| --- | --- |
| Addo Elephant Marine Protected Area | Port Elizabeth Corals Marine Protected Area |
| Agulhas Bank Complex Marine Protected Area | Port Elizabeth Shelf and Shelf Edge Marine Protected Area |
| Agulhas Bank Deep Reefs | Prince Edward Islands - Control Zones Marine Protected Area |
| Agulhas Front Marine Protected Area | Prince Edward Islands - Restricted Zones Marine Protected Area |
| Agulhas Muds Marine Protected Area | Prince Edward Islands - Sanctuary Zone Marine Protected Area |
| Aliwal Shoal Marine Protected Area | Protea Banks Marine Protected Area |
| Amathole Marine Protected Area | Richards Bay Provincial Nature Reserve |
| Beachwood Mangroves Provincial Nature Reserve | Robben Island Marine Protected Area |
| Benguela Bank Marine Protected Area | Robberg Marine Protected Area |
| Benguela Muds Marine Protected Area | Sardinia Bay Marine Protected Area |
| Betty's Bay Marine Protected Area | Sixteen Mile Beach Marine Protected Area |
| Bird Island Group Marine Protected Area | Southeast Atlantic Seamount Marine Protected Area |
| Boulders Restricted Zone Marine Protected Area | Southwest Indian Seamount Marine Protected Area |
| Browns Bank Complex Marine Protected Area | Stilbaai Marine Protected Area |
| Browns Bank Corals Marine Protected Area | St James Restricted Zone Marine Protected Area |
| Cape Canyon Marine Protected Area | St Lucia Marine Protected Area |
| Cape of Good Hope Restricted Zone Marine Protected Area | St. Lucia Marine Reserve Nature Reserve |
| Cape West Coast Biosphere Reserve Biosphere Reserve | Table Mountain National Park Marine Protected Area |
| Castle Rock Restricted Zone Marine Protected Area | Trafalgar Marine Protected Area |
| Child's Bank Marine Protected Area | Trafalgar Marine Reserve Nature Reserve |
| De Hoop Marine Protected Area | Tsitsikamma National Park |
| Delagoa Offshore - St Lucia and Mapualand | Tsitsikamma Marine Protected Area |
| Dwesa-cwebe Provincial Nature Reserve | Tugela Bank off KZN |
| Dwesa-Cwebe Marine Protected Area | Umlalazi Provincial Nature Reserve |
| Goukamma Marine Protected Area | Umtamvuna Provincial Nature Reserve |
| Greater St Lucia Wetland Provincial Nature Reserve | uThukela Banks Marine Protected Area |
| Helderberg Marine Protected Area | Walker Bay Whale Sanctuary Marine Protected Area |
| Hluleka Marine Protected Area | West Coast National Park National Park |
| iSimangaliso Marine Protected Area | Addo-Elephant National Park |
| Jutten Island Marine Protected Area | De Hoop Vlei Wetlands (Ramsar) |
| Karbonkelberg Restricted Zone Marine Protected Area | De Mond (Heuningnes Estuary) Wetlands (Ramsar) |
| Kogelberg Biosphere Reserve Biosphere Reserve | iSimangaliso Wetland Park World Heritage Site |
| Langebaan Lagoon Marine Protected Area | Kosi Bay Wetlands (Ramsar) |
| Malgas Island Marine Protected Area | Lake Sibaya Wetlands (Ramsar) |
| Maputaland Marine Protected Area | Langebaan Wetlands Ramsar) |
| Marcus Island Marine Protected Area | Orange River Mouth Wetlands (Ramsar) |
| Nahoon Local Authority Nature Reserve Nature Reserve | Plett Hope Spot |
| Namaqua Fossil Forest Marine Protected Area | St. Lucia System Wetlands (Ramsar) |
| Namaqualand Marine Protected Area | Turtle Beaches/Coral Reefs of Tongaland Wetlands (Ramsar) |
| Namaqua National Park Marine Protected Area | Verlorenvlei Wetlands (Ramsar) |
| Orange Shelf Edge Marine Protected Area | Wilderness Lakes Wetlands (Ramsar) |
| Paulsberg Restricted Zone Marine Protected Area |  |
| Pondoland Marine Protected Area |  |

Drones offer the potential for effective ocean governance in education and research through the ability to understand ocean processes and respond accordingly. Over 750,000 wrecks clutter the Mediterranean. Figure V emphasises how many South African wrecks exist. 2000-3000 wrecks could offer treasure troves, historic answers, species’ homes or ecotourism and recreation opportunities but only if drones supplement human capacity to examine, record and defend underwater cultural heritage, whether for existing or new wrecks. Drones could assist myriad other research missions both for locals and any external organisations seeking to conduct research in Africa. Drones can assist with marine archaeology, tourism and conservation from conditions of floating museum ships to wrecks, port infrastructure, pipelines and aquariums. Comparatively few places offer related education and training for drones in South Africa and across Africa. As demand expands; this report advises the opportunities to create specialised schools and drone ports, especially in aviation, related electronics, technology and manufacturing/repairs, capable of recruiting from across the continent. Bingham et al. (2015) mention future drone research opportunities from renewable energy and greener vessels to underwater robotics to software

Existing sensor networks could be expanded to cover the South Atlantic, Indian and Antarctic Oceans. A mere 3000 floats exist for Global Ocean Observing System Argo (NTNU 2016). Aquaculture risks are also advised to be monitored and ocean floating structures diverted. Research could target sensor fusion, multiple events, real-time data and update capacity, icing protection and path planning for UAV’s. Drones can improve the capacity of oceanographic vessels with laboratories, operator quarters, launch and recovery systems and multiple vessel tracking, control and command capacity. However they present shipyard opportunities in reconfiguring SA Agulhas and other vessel’s design to allow for autonomous capacity Oceanography requires high resolution seafloor mapping. Jakobsson et al.2017, propose underwater exploration advantages in a “*GEBCO-Seabed Roadmap for Future Ocean Mapping.”* This would aid the International Hydrographic Organisation’sGeneral Bathymetric Chart of the Oceans aiming high quality resolution digital mapping, especially deeper than 3200 metres and polar ice. This particularly aims at marine spatial planning, ocean governance, ecosystem protection and climate change

## Figure XV: South Africa’s Underwater Cultural Heritage



Effective drone deployment can facilitate governance through overcoming existing infrastructure constraints and failures, through which South Africa’s aerospace and maritime industry could assist. In 2015 Rwanda became the first global nation with a civilian Droneport specifically devoted to humanitarian and other logistics from medicine to postal deliveries, electronics and commerce (Agence France Presse 2015). Three buildings aim for completion by 2020. Drones will initially be confined to a 10 kg payload and progressing to 100 kgs by 2025. The Drone Port’s design is flexible to adjust for multiple drone requirements and includes an assembling industry. Facilities including safe landing and deployment systems, ground and satellite control stations, postal services, health clinic, repair workshop and stores, offices, digital fabrication shop and e-commerce capabilities. Rwanda’s government and aid donors eventually envision 40 across the nation. This could counter poor historic records of postal and other forms of postal delivery for urgent, expensive, fragile and remote destination cargo, if effectively secure against theft, cybersecurity, sabotage and other risks. Drones could resolve poor roads and other infrastructure conditions. In 2016 Rwanda partnered with Zipline drones for medical deliveries and GAVI/Vaccine Alliance for vaccine and medicine delivery to rural clinics. An $800,000 UPS Foundation grant will establish 21 blood transfusing centres. The droneport aims at over 100 deliveries per day for 10 kg Kevlar/composite fibres -1.5 kg and 120 km radius. It aims for food security via crop spraying.

However, as pressure increases on scarce resources, South African martial industrial experience offers even more maritime security and law enforcement opportunities in converting drones. McGillivray and Taylor (2013) mention drone advantages, deployable from ships, oil rigs and remote islands with minimal supporting infrastructure and staff, reducing the need for aerial or maritime manned patrols Potgeiter and Pommerin (2016) affirm the need to ensure security of aquaculture, mining, natural resource, ports, infrastructure and commerce. It could revive the shipbuilding and aircraft industries with opportunities from piracy to migrants, peacekeeping, smuggling and poaching. It advocates interchangeable spare parts, logistics and training solutions. It can supplement African navies, coastguards and private corporations and lack of enforcement personnel. Toxic waste dumping occurred over African coasts for as cheaply as $2.50 per ton. In 2009 Somalia agreed to other nations patrolling their EEZ. Recently, Somali pirates claimed $800,000 for one South Korean trawler. Mercenary maritime drone escort services could be formed, akin to local paramilitary expertise. Claims of human trafficking to SA, Europe, Middle East also exist.

Africa could also manufacture drones as part of an integrated border surveillance system, as with the EU (Whittle 2011). This would SA used drones for 1994 elections monitoring and crime prevention –Seeker UAS extend early warning sensor capacity and interconnect stakeholders to prioritise security as much as maritime safety, intelligence and risk awareness. The EU budgeted 4,970,709 euros to drones 2008-2011. It aims at ensuring supply chain security through container tracking, drone observance, secure containers and asset detection. UNCOSS –Underwater Coastal Sea Surveyor or a neutron sensor for explosives and other risks cost 4,520,000 euros 2008-2011 whereas SECTRONIC –Security System for Maritime Infrastructure, Ports and Coastal Zones -7,080,433 euros provides a 24 hour sensor network from ship/platform –terrorism, natural disasters, computer hacking, negligence, accidents, criminal activity to cope for Information sharing and cooperation. Countering drones intrusions for vulnerable infrastructure, reserves, individuals and systems presents a parallel opportunity. South Africa has 135 licenced airports, 60 registered, 33 military and 1600 unregistered airfields (South African Department of Transport, 2015) but no registered drone ports. Drones could be either adapted to existing facilities or the safety, transport, maintenance, design, infrastructure, aeronautical information and security.

Global Security Consultants (2010) estimated how global piracy may require even more defences to protect legitimate commerce across the Horn of Africa and Gulf of Guinea. Maritime Terrorism Combined Task Forces could even produce our own African UAV squadrons. The report curiously proposes 29 recommendations to address Somali piracy but conspicuously omits drone technology. Fining illegal dumping may also be profitable. Snyman (2007) warned over a decade ago of future South African Naval requirements included adapting to modernised technology for sea lift support capability, maritime surveillance and naval planning. Access to drone information sharing and cooperation could further improve constrained maritime defensive capacity. More effective use of technology or converting tactics and strategy would create further training and procurement opportunities in acclimatising stakeholders to autonomous systems. However drone warfare has been far less prioritised as an emerging future threat specifically to South Africa and other African nations. A long range, shore based surveillance system would benefit from additional drones, as might logistics. Drones could produce decoy systems in warfare.

Other random opportunities which could benefit from drones include digitised seaports including interconnected seaports, business models, products and services. These would include smart buoys –water depth, current direction, intensity, air pollutants, water temperature aiding risk management, port productivity performance, maintenance, transport coordination, berthing and other operations. This minimises supply chain congestion and disruption costs from Cape Town to Alexandria, Dakar to Dar es Salaam. Kamp Curtin and Bryde (2009) propose uses from commercial salvage to nuclear site inspections. It mentions refueling and deploy gliders at minimal cost especially in too deep or too shallow territorial waters. This can investigate species, corrosion, hydrocarbon leaks, material failure and other risks. They could check aquaculture pens for weaknesses, gaps, adversaries, recover deceased fish. They could monitor desalination and renewable energy. Opportunities may exist for 3D printing, Cloud based data storage, and an Internet of Underwater Things (Gomez and Green 2015). They possess limits to aid search and rescue, merely confirming incidents but still needing human intervention (Waharte and Trigoni 2011). Drones may assist in maritime research of the future, although conspicuously absent from SAIMI and other plans. Africa could establish its own academic research fleet with autonomous vessels included. Drones can assist in a multidisciplinary, multi-investigator capacity. Observatories could be linked More autonomous research stations could be establish to probe remaining African and Southern Hemisphere mysteries from climate change to space to oceanography, marine geology, cultural heritage and risks.

# CHAPTER 4: THE FUTURE? INTERIM CONCLUSIONS

4.1: How to Ensure Successful Drones

In conclusion, to defend African maritime sovereignty and ocean governance, stakeholders will be challenged if they rely on existing human crewed fleets. As global populations increase beyond Earth’s ecosystems capacity to sustain, humanity will pillage the oceans. This report examines whether drones possess the capacity to assist African stakeholder problems, reducing external dependency and ensuring more effective enforcement capacity of our destiny. As Africa’s governments turn to the maritime economy under AIMS 2050 Strategy and as South Africa embraces Operation Phakisa, more extreme tools of governance may be necessary. This report provides the first independent analysis of drones, specifically for the South African and African maritime sector, ignored by many core stakeholders from SAIMI to government to corporations, academia, professional associations and individuals. It contends if drones are to be successful, stakeholders need to follow the legal requirements and obligations under local and international laws (Section 2.1). Existing legislation needs to be updated to specifically include references to drones where applicable.

If South Africa and Africa are to establish a drone sector, this report advises success is conditional upon following stakeholder user and producer requirements (2.2) including cost-effectiveness, mission performance and efficiency, technologically feasible, environmentally sustainable, with sufficient training, sensor capacity, appropriate autonomy, redundancy and system risk management. It advises learning from historic and present failures not just successes (2.4 and 2.3). Although South Africa has a primarily martial and non-maritime history of drone usage (3.1), its existing 22 firms and potential market demand (3.2) offer prospects for increasing Africa’s market share beyond 6-7%. To ensure a successful drone industry, this report stridently counsels maximising where possible the economic, environmental, legal, research, technological, maritime safety, security, law enforcement and other advantages (3.3). It simultaneously proposes minimising adverse externalities and other cost consequences (3.4). The most significant risks requiring drones for monitoring and awareness include the uncertainty of climate change, technological and business cycles influencing uncertain demand and supply. Increasing levels of automation presents humanity as becoming more superfluous and abdicating control, unless precautions are assiduously preserved. Drones offer significant legal uncertainty, limited or negative consumer interest and awareness across Africa and challenges into integrating into manned aerospace. As costs cheapen, they present additional risks of ethics, privacy, cybersecurity, data security, safety, militarisation and brinkmanship. However this report considers if drones are to be South Africa and Africa’s future, they need to consider the extent to which effective governance is actually enacted and secured. They need to assess costs against benefits, comparing drones to international counterparts and their technical standards as performance indicators.

# 4.2: Applications to the Maritime Sector

Stakeholders are advised to seize the opportunities enumerated in section 3.6, converting drones to maritime uses in alignment with needs and priorities, to resolve ongoing and emerging problems. Extensive opportunities range across Africa from protecting 73 marine reserves to any aquaculture and oil concessions to supplementing research ability. Drones may have even greater potential in being motivated in the basis of decades of proven mission success and if sufficiently financed for research and innovation. This could include initiatives such as the Department of Agriculture, Forestries and Fisheries’ Marine Living Resources Fund or the Department of Environmental Affairs’ Green Climate Fund. Earth’s future will increasingly depend upon and empower those seeking to understand remaining mysteries, who preserve and extend ecological capital and continuously monitor existing and projected risks. From inter-species communication to chartering Southern Hemisphere depths to creating giant aquaculture farms, underwater ‘Great Walls’, laboratories and research bases, floating habitats to UAV fleets, drone sensors and technology may dramatically augment human limitations.

African navies and manned patrol vessels are comparatively few; given millions of miles of territorial waters. Drones could assist South Africa and Africa to discharge its proclaimed ocean governance objectives and other legislative responsibilities such as its National Coastal Management Programme (South African Department of Environmental Affairs 2014). Drone training capacity and financial incentives remain absent from DTI publications or the 2011 Maritime Sector Skills Development Report and successors. This is beyond merely proclaimed and published documents existing merely for publicity, if properly supported and designed. Kornegay and Royeppen (2016) affirm marine spatial planning aims for sustainable development; spatial efficiency; cooperative and transparent governance; justice, equity and transformation; ecological integrity, precautionary approach and adaptability. Goal I is unlocking the ocean economy. Goal II is engaging with the ocean. Goal III is ‘ensuring healthy, living marine ecosystems.’ Goal IV is contributing to good ocean governance.’ It could aid the African Unions’ 2050 Integrated Maritime Strategy to ensure ocean governance, commerce, defence, security and sovereignty over Combined Exclusive Zones of Africa.

Drones are conspicuously absent from current research strategies and marine spatial planning (Ramulifho 2014 and Council for Scientific and Industrial Research, 2017). They can extend beyond our 37 existing aquaculture farms. They can further aid in applying the precautionary principle to effective ocean governance, investigating the most extensive exploiters of marine resources and supplementing law enforcement capacity. Drones can improve autarchy, from import substitution so we can conduct our own maritime and continental destiny. Walker (2015) plus Kornegay and Royeppen (2016) affirm true maritime domain awareness can only arise from increased information sharing, cooperation and interoperability; to which drones can add if responsibly managed. Lazarus and Ukpere (2011) mention how cabotage can form a repositioned maritime industry, which AUV’s, UUV’s and USV’s can supplement existing training and other shortages of seafarers. Perhaps cabotage incentives could apply to autonomous vessels, probes and buoys, creating trade diversion from foreigners and trade creation via African exports. They can assist awareness of the consequences of our actions as human beings upon the maritime sector so that we as Africans can consciously discharge our ecological stewardship responsibilities whilst striving for the maximum extent of prosperity, our population and planet ecologically sustainably can attain.

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