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The Possible role of autonomous and semi-autonomous platforms for OPCW verification and investigations of alleged use

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Contents

Abbreviations and acronyms	3
Summary	10
1.0 Introduction	11
1.1. Background and recent developments	12
1.2. Ethical and safety considerations	12
1.3. Security and defence/combat operations	16
1.4. Definitions	18
1.5. Regulatory and normative frameworks	20
2.0 Select systems and development projects	24
2.1. Counter-UAV developments	29
2.2. Development trends	31
3.0 Unmanned platform operating environment	35
3.1. General observations	35
3.2. Civil-military airspace designation and enforcement	35
3.3. Detect and avoid: theory and practice	35
3.4. Trends	35
4.0 Unmanned platforms in a chemical weapons verification context	36
5.0 Unmanned platforms in a nuclear weapons verification context	38
6.0 Chemical Weapons Convention context	39
7.0 Recommendations	41
7.1. Policy	41
7.2. Operational or technical	42
8.0 Conclusions	43
Select bibliography and suggested reading	44

Table 1. UAS/UAV classification according to US DOD	19
Table 2. UAS/UAV classification by range	19
Table 3. UAS/UAV classification by size	19
Table 4. UAS/UAVs by mission, size and altitude	20

Annexe 1. Select autonomous and semi-autonomous platforms	48
Annexe 2. Possible draft mandate for WG on platform technology implications for verification and investigations of alleged use within a CWC framework	62
Annexe 3. US DOD guidelines for review of certain autonomous or semi-autonomous weapons systems	63
Annexe 4. Glossary of terms and select systems	65

Abbreviations and acronyms

A2/AD	Anti-Access/Area Denial
AACUS	Autonomous Aerial Cargo/Utility Systems
AAR	Air-to-Air Refueling/Autonomous Aerial Refueling
AAS	Armed Aerial Scout
AAT	Autonomous Air Taxi
AAV	Autonomous Aerial Vehicle
ABSAA	Airborne Sense-and-Avoid [radar]
ACS	American Chemical Society
ACTUV	Anti-Submarine Warfare Continuous Trail Unmanned Vessel
ADASI	Abu Dhabi Autonomous Systems Investments
AEW	Air Expeditionary Wing
AGL	Above Ground Level
AGM	Air-to-Ground tactical Missile
AI	Artificial Intelligence
AIS	Automatic Identification System
ALIT	China Aerospace Long-March International
APKWS	Advanced Precision Kill Weapons System
ARA	Applied Research Associates
ARDEC	Armament Research, Development and Engineering Center [US Army]
ARL	Army Research Laboratory [US]
ATLND	Automatic Landing and Take-off
AUDS	Anti-UAV Defence System
AURA	Autonomous Unmanned Research Aircraft
AUVSI	Association for Unmanned Vehicle Systems International
AVIC	Aviation Industry Corporation of China
AWES	Airborne Wind Energy System
BAA	Broad Area Announcement
BAMS	Broad Area Maritime Surveillance
BDA	Battle Damage Assessment
BMW	Bayerische Motoren Werke AG
BUAA	Beijing University of Aeronautics and Astronautics
BVLOS	Beyond Visual Line of Sight
CAAI	Civil Aviation Authority of Israel
CAC	Chengdu Aircraft Industry Company
CADI	Chengdu Aircraft Design and Research Institute
CALT	China Academy of Launch Vehicle Technology

CANTAS	CANnard Tail Sitter
CAS	Close Air Support
CASA	Civil Aviation Safety Authority in Australia
CASC/CASIC	China Aerospace Science and Technology Corporation
CBARS	Carrier-Based Aerial-Refueling System
CBW	Chemical and/or Biological Warfare/Weapons
CDR	Critical Design Review
CEO	Chief Executive Officer
CETC	China Electronics Technology Corporation
CFAR	Constant False Alarm Rate [algorithm]
CHRDI	China Helicopter Research and Development Institute
CICADA	Close-in Covert Autonomous Disposable Aircraft
C-IED	Counter-Improvised Explosive Device
CJCS	Chairman of the Joint Chiefs of Staff
COA	Certificate of Authorization [FAA]
COMINT	Communications Intelligence
CONOPs	Concept of Operations
COTS	Commercial-Off-the-Shelf Technology
CRIP	Commonly Recognised Information Picture
CS&C	Control System and Connectivity
CTBT	Comprehensive Nuclear-Test-Ban-Treaty
CTBTO	Comprehensive Nuclear-Test-Ban-Treaty Organization
CTC	Combating Terrorism Center
CTO	Chief Technical Officer
C-UAS	Counter-Unmanned Aircraft System
CW	Chemical Warfare/Chemical Weapon
CWC	Chemical Weapons Convention
CWPF	Chemical Weapon Production Facility
DARPA	Defense Advanced Research Projects Agency
DASH	Drone Anti-Submarine Helicopter
DHS	Department of Homeland Security
DIRCM	Directed Infrared Countermeasure
DIUx	Defense Innovation Unit Experimental
DJI	Da-Jiang Innovations
DPRK	Democratic People's Republic of Korea
DSB	Defense Science Board
DTIC	Defense Technical Information Center
DTRA	Defense Threat Reduction Agency
EDIC	Emirates Defence Industry Company
EC	Executive Council
ECS	Enterprise Control Systems
ELINT	Electronic Intelligence
EO	Earth Observing/Earth Observation
EO/IR	Electro-optical/infrared
EPU	Electric Power Unit
ER	Extended Range

ESM	Electronic Support Measures
ETOP	Electric Tethered Observation Platform
e-VTOL	electric-Vertical Take-off Aerial Vehicle
EW	Electronic Warfare
FAA	Federal Aviation Administration
FOD	Foreign Object Debris
FVL	Future Vertical Lift
GA-ASI	General Atomics Aeronautical Systems Inc.
GAJT	GPS Anti-Jam Technology
GC	General Counsel of the Department of Defense
GCS	Ground Control Station
GIDS	Global Industry and Defence Solutions [Pakistan]
GNC	Guidance, Navigation, and Control
GNSS	Global Navigation Satellite Systems
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HAC	Human Agent Collective
HACMS	High-Assurance Cyber Military Systems
HALE	High-Altitude Long-Endurance
HAPS	High Altitude Proto Satellite
HAZMAT	Hazardous Material
HFE	Heavy Fuel piston Engine
HMI	Human-Machine Interface
KHI	Kawasaki Heavy Industries
IAI	Israel Aerospace Industries
IAU	Investigation of Alleged Use
ICL	Israel Chemicals
IED	Improvised Explosive Device
IFC	Integrated Functional Capability
IFO	Identified Flying Object
IHL	International Humanitarian Law
IIFDS	Improved Interfered Fluid Dynamical System
IMS	Ion Mobility Spectrometry/International Monitoring System
IMU	Inertial Measurement Unit
INP	Innovative Naval Prototype
IOC	Initial Operational Capability
ISR	Intelligence, Surveillance and Reconnaissance
ITAR	International Traffic in Arms Regulations
JCTD	Joint Capability Technology Demonstrator
JIM	OPCW-UN Joint Investigative Mechanism in Syria
JMAC	Joint Multi-Platform Advanced Combat
JMSDF	Japan Maritime Self-Defense Force
JPL	Jet Propulsion Laboratory
JSC	Joint Stock Company
JTARV	Joint Tactical Aerial Resupply Vehicle

KACST	King Abdulaziz City for Science and Technology
KINU	Korea Institute for National Unification
LAR	Lethal Autonomous Robot
LAWS	Lethal Autonomous Weapons/Lethal Autonomous Weapon Systems
LDUUV	Large Diameter Unmanned Underwater Vehicle
LGVF	Lyapunov Guidance Vector Field
LOCUST	Low-Cost UAV Swarming Technology
LOEC	Luoyang Opto-Electro Technology Development Centre
LoS	Line-of-Sight
LRIP	Low-Rate Initial Production
MACS	Mission-Adaptable Chemical Sensor
MALE	Medium-Altitude Long-Endurance
MAV	Micro Air Vehicle
MDM	Micro Designator Marker
MFAS	Multi-Function Active Sensor
MGTW	Maximum Gross Takeoff Weight
MIM	Mobile Interceptor Missile
ML	Machine Learning
MSL	Mean Sea Level
MTCR	Missile Technology Control Regime
MTOW	Maximum Take-off Weight
MUAV	Mini Unmanned Aerial Vehicle
MUM-T	Manned-Unmanned Teaming
NA	National Authority
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAWS	Naval Air Weapons Station [China Lake]
NGPC	Next Generation Patrol Craft
NII	Scientific Research Institute [Nauchno-Issledovatel'sky Institut]
NIIRS	National Imagery Interpretability Rating Scale
NOA	Normal Operating Altitude
NOAA	National Oceanic and Atmosphere Administration
NRL	Naval Research Laboratory [US Navy]
NTM	National Technical Means
OA	Operational Assessment
OEWG-FP	Open-Ended Working Group on the Future Priorities of the OPCW
OFFSET	Offensive Swarm Enabled Tactics
ONR	Office of Naval Research
OPCW	Organisation for the Prohibition of Chemical Weapons
OPV	Offshore Patrol Vessel
OSCE	Organization for Security and Co-operation in Europe
OSD	Office of the Secretary of Defense

OWP	Open Water Power
PAC	Pakistan Aeronautical Complex
PAPI	Precision Approach Path Indicator
PFM	Prototype Flight Model
PGB	Precision Guided Bomb
PGM	Precision Guided Munition
PLA	Peoples' Liberation Army
PLAAF	Peoples' Liberation Army Air Force
PNT	Positioning, Navigation and Timing
POINTER	Precision Outdoor and Indoor Navigation and Tracking for Emergency Responders
RF	Radio Frequency
RFI	Request for Information
RFID	Radio Frequency Identification
RFP	Request for Proposals
ROK	Republic of Korea
RPA	Remotely Piloted Aircraft
RPV	Remotely Piloted Vehicle
RSAF	Royal Saudi Air Force
RTA	Roads and Transport Authority [Abu Dhabi]
RTCA	Radio Technical Commission for Aeronautics
RWS	Remote Weapon Station
SAL	Semi-Active Laser
SALTO	Saltatorial Locomotion on Terrain Obstacles
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar/Search and Rescue
SATCOM	Satellite Communication
SCO	Strategic Capabilities Office
SDAM	Système de Drones Aériens de la Marine [French Navy]
SDF	Syrian Democratic Forces
SEAD	Suppression of Enemy Air Defences
SIERRA	Sensor Integrated Environmental Remote Research Aircraft
SMDR	Système de Mini Drone de Reconnaissance [French Army]
SNC	Sierra Nevada Corporation
SOP	Standard Operating Procedure
SSM	Defence Industries Undersecretariat [Turkey]
SSR	System Readiness Review
S&T	Science and Technology
STANAG	Standardization Agreement [NATO]
STL	Satellite Time and Location
SUA	Special Use Airspace
SUAS	Small Unmanned Aerial Systems
SW	Sky Wing
SWaP	Size, Weight, and Power

SWIR	Short-Wave Infrared
SVBIED	Suicide Vehicle-borne IED
TAI	Turkish Aerospace Industries
TCDL	Tactical Common Datalink
T&E	Test and Evaluation
TERN	Tactically Exploited Reconnaissance Node [programme]
THAAD	Terminal High Altitude Area Defense
TRADOC	Training and Doctrine Command [US Army]
TRL	Technology Readiness Level
TS	Technical Secretariat
TSK	Turkish Armed Forces [Türk Silahli Kuvvetlerinden]
TTP	Tactics, Techniques, and Procedures
TUAV	Tactical Unmanned Aerial Vehicle
UAE	United Arab Emirates
UAPO	Unmanned Aircraft Program Office [FAA]
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCA	Unmanned Carrier Aviation
UCAV	Unmanned Combat Aerial Vehicle
UCLASS	Unmanned Carrier Launched Airborne Surveillance and Strike
UCS	UAV Control System
UGV	Unmanned Ground Vehicle
UMCS	UCLASS Unmanned Control System
UN	United Nations
UPA	Universal Payload Adapter
UPS	United Parcel Service
US	United States
USAF	United States Air Force
USD	United States Dollar
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(P)	Under Secretary of Defense for Policy
USV	Unmanned Surface Vehicle
UTM	Unmanned Traffic System
UUS	Unmanned Underwater System
UUV	Unmanned Underwater Vehicle
UxVs	Unmanned Aerial, Surface and Ground Vehicles
VASI	Visual Approach Slope Indicator
VTOL	Vertical Take-off Aerial Vehicle
V&V	Verification and Validation
WAPSS	Wide Area Persistent Surveillance System
WCCS	Wideband Command/Control Communication Subsystem
WI	Work Instruction

WG	Working Group
WGS	Wideband Global SATCOM
WWF	World Wildlife Fund

Summary

Autonomous and semi-autonomous platforms have wide applications in the civil and defence sectors with unclear legal, normative and societal consequences.[1] Developments in science and technology (S&T) will affect the capabilities and applications of such platforms with implications for the continued effective implementation of the 1993 Chemical Weapons Convention (CWC) and the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT).

The Organisation for the Prohibition of Chemical Weapons (OPCW), the body that implements the CWC, could further consider the treaty regime implications as part of possible chemical weapon threat scenarios, and support for verification activity, including for investigations of alleged use (IAU) of such weapons. OPCW procedures for evaluating and approving inspection equipment and recent OPCW verification experience in Iraq, Libya and Syria are relevant in this regard. This topic is also relevant to the preparations for the 4th CWC Review Conference to be held in 2018 and the mandate of the Open-Ended Working Group on the Future Priorities of the OPCW (OEWG-FP).

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) operates a verification network (International Monitoring System, IMS) of 337 monitoring facilities that employ four technologies: seismic, hydroacoustic, infrasound and radionuclide. The PrepCom is evaluating remotely-controlled measurement platforms, including with respect to the development and testing of remotely controlled/autonomous systems as platforms for the acquisition of optical imagery, gamma monitoring, and acquisition of magnetic data. CTBT onsite inspection procedures and approved inspection equipment may therefore be modified to incorporate some autonomous and/or semi-autonomous technology platforms.

The role of unmanned platforms in combat operations are Iraq, Syria and elsewhere are reviewed. Development projects and applications for unmanned platforms are reviewed. Current international market status and trends are reviewed and *circa* 200 systems are mapped. Guidance, navigation and control (GNC) procedures and practice are summarized for segregated and non-segregated air space. Select national regulations and strategic trade controls in connection with such systems are summarized. Finally, implications for chemical and nuclear disarmament and arms control verification are considered, and policy and operational recommendations provided.

Please see Section 7 for policy and operational/technical points.

This remains a baseline working paper.

[1] Disclaimer: the systems discussed in this paper should not be understood to be an endorsement.

1.0 Introduction

Autonomous and semi-autonomous platforms have wide applications in the civil and defence sectors with unclear legal, normative and societal consequences. Developments in science and technology (S&T) will affect the capabilities and applications of such platforms with implications for the continued effective implementation of the 1993 Chemical Weapons Convention (CWC) and the 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT).

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The Executive Council (EC) established the OEWG-FP to serve as 'an informal mechanism for receiving, discussing, prioritising, elaborating, and integrating ideas and proposals' from the Member States and the Secretariat on future OPCW priorities 'on any aspect of the Convention or developments relevant to it with a view to supplying a holistic, coherent, forward-looking, and action-oriented document'. The group is also tasked to generate recommendations for the 4th CWC Review Conference as 'a contribution to the full, effective, and non-discriminatory implementation of all [of the] provisions of the Convention'.[2]

The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) operates a verification network of 337 monitoring facilities that employ four technologies: seismic, hydroacoustic, infrasound and radionuclide. The PrepCom is evaluating remotely-controlled measurement platforms, including with respect to the development and testing of remotely controlled/autonomous systems as platforms for the acquisition of optical imagery, gamma monitoring, and acquisition of magnetic data. CTBT onsite inspection procedures and approved inspection equipment may therefore be modified to incorporate some autonomous and/or semi-autonomous technology platforms. The policy, legal and operational implications should therefore be further clarified in light of such such work and S&T developments.

[2] 'Decision, establishment of an Open-Ended Working Group on the Future Priorities of the OPCW', OPCW document EC-82/DEC.2, 14 July 2016, para. 1, pp. 1-2.

1.1. Background and recent developments

The range and type of unmanned aerial vehicles (UAVs) are expanding and new applications are being developed. The associated technologies are increasingly embedded in both the civil and defence sectors. Companies, individuals, industry, regulatory bodies, researchers, and security and defence sectors are considering how the technologies should be applied and controlled.

Factors informing the scope of application and degree of absorption of autonomous and semi-autonomous platforms in the civil and military sectors include the role of: (*a*) artificial intelligence (AI) systems; (*b*) sensors, and how they are inter-linked and controlled; (*c*) materials science (e.g., composite materials used in the construction of electric Vertical Take-off Aerial Vehicles, e-VTOLs); and (d) battery storage and weight specifications (e.g., the use of lithium ion batteries).

In the civil sector, UAVs may be used at: (*a*) mining sites, (*b*) port facilities, (*c*) petrochemical facilities, and (*d*) other industrial facilities.[3] Civil sector UAV applications include: (*a*) inspection, (*b*) surveying and mapping, (*c*) security and emergency response support, and (*d*) environmental monitoring (including agriculture).[4] For example, UAVs have been used to study cloud reflectivity (albedo) resulting from aerosol-water vapour interactions.[5]

In the defence sector, UAVs enhance situational awareness and reduce 'the fog of war' inherent to military operations, as well as improving the efficacy of security and defence operations (some of which possess the character of law enforcement or counter-terrorist operations). Interventions or monitoring of autonomous and/or semi-autonomous platforms might be achieved by using helmets with 'heads-up' displays, and via Oculus-type or gloves-based point and control systems. Finally, UAVs continue to provide intelligence, surveillance and reconnaissance (ISR) capabilities and to act as a weapon delivery platform.

1.2. Ethical and safety considerations

Ethical and moral questions have been discussed in connection with UAV autonomy. With respect to military field requirements, Geoff Fein observes:

'Autonomy must earn the trust of commanders who will increasingly call upon unmanned systems to not only provide ISR[,] but [to] deliver weapons also. Comfort with autonomy is being achieved through the continued flights of UAVs and in the

[3] Based on <http://www.airobotics.co.il/>.

[4] Based on <http://www.airobotics.co.il/>.

[5] Roberts, G. C., et al., 'Simultaneous observations of aerosol-cloud-albedo interactions with three stacked unmanned aerial vehicles', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 105, no. 21 (27 May 2008), pp. 7370-7375.

case of the Coyote its use in various mission scenarios, experiments, and proof of concept demonstrations'.[6]

The employment of UAVs also raises questions concerning how the principle of reciprocity in warfare can (or should) be implemented. The principal points to bear in mind with respect to International Humanitarian Law (IHL) are: discrimination, military necessity, proportionality and the so-called Martens clause.[7]

Another open question concerns reconciling the employment of UAVs to kill vis-à-vis the ability (or right) of an opponent to surrender. In addition, if the platform's autonomous functionality yields desired/approved outcomes in, say 95 or 99 per of cases, is such an outcome legally, ethically and/or politically acceptable? In addition, what are the ethical and legal implications of the autonomy-linked failures?

Depending on how one addresses such questions, a government could decide to place its military personnel at increased risk in order to support such principles within a broader framework on the conduct of war or security operations.

Corresponding questions have been posed in the civil sector. For example, how can authorities and the interested public understand and accept the use of an algorithm's 'logic tree' concerning autonomous driving vehicle-caused deaths or the prioritization of an autonomous vehicle's programme to cause a smaller number of deaths in lieu of killing a greater number of people? In practice, insurance sector actuarial calculations may be utilised to prioritise tradeoffs in causing harm to humans, animals or society.

Accidents and the causing of deliberate harm will become increasingly common as the technologies are employed more widely. In early 2017 a 2.2 lb GoPro Karma Quadcopter crashed into a New York City resident's 27th floor apartment window (the operator had registered the device with the US Federal Aviation Administration, FAA).[8] Some also believe that it is only a matter of time before a UAV causes a commercial aircraft to crash.[9]

In 2017 Price Waterhouse Company estimated the degree of autonomy due to machine learning techniques to model the potential impact of AI on employment patterns in select countries.[10] It found that the likelihood of

[6] Fein, G., 'Coyote earmarked for ISR and offensive roles', *IHS Jane's International Defence Review*, vol. 15 (Feb. 2017), p. 25. See also Defense Science Board (DSB), *Summer Study on Autonomy* (Office of the Under Secretary of Defense for Acquisition, Technology and Logistics: Wshington, DC, June 2016), unclassified.

[7] See ICRC, <https://casebook.icrc.org/glossary/martens-clause>.

[8] Celona, L., Prendergast, D. and Fenton, R., 'Drone smashes through woman's apartment window', *New York Post*, 26 Feb. 2017, <http://nypost.com/2017/02/26/drone-smashes-through-womans-apartment-window/>.

[9] Risks can include: (*a*) the susceptibility of engine air intakes to UAV-inflicted damage, and (*b*) a collision. Aircraft (or helicopters) may also have to pass through zones of micro-UAV sensors in both civilian and armed conflict scenarios. A possible future approach to the protection of engine intakes could be to develop retractable foreign object debris (FOD) screens/covers designed for use at reduced air speed during take-off or landing.

[10] Anonymous, 'Up to 30% of existing UK jobs could be impacted by automation by early 203s, but this should be offset by job gains elsewhere in economy, Price Waterhouse Company blog, 24 Mar.

automation is probably highest in the transport, manufacturing, wholesale and resale sectors, and lower in the education, health and social work sectors.[11] It also estimated that approximately 30 per cent of existing British jobs are ‘susceptible to automation from robotics’ and AI by the early 2030s.[12] The corresponding numbers for Germany, Japan and the US are 21 per cent, 35 per cent and 38 per cent, respectively.[13]

Currently, the BMW parent automobile manufacturing plant in Munich is approximately 99 per cent automated overall while approximately 40 per cent of the engine block production line is automated.[14] Some quality control oversight and activity, as well as the engine block and drive train production, are perhaps least susceptible to robotics automation in the automotive industry.

More than 100 billion USD will reportedly be spent on the civil and military drone/UAV market between 2016-2020 of which construction will account for 112 billion USD, agriculture (5.9 billion USD), insurance (1.4 billion USD), and infrastructure inspection (1.1 billion USD).[15] Spending on military drones accounts for almost 90 per cent of all spending on drones worldwide.[16] Approximately 110000 UAVs were sold worldwide in 2016 for commercial use, while approximately 174000 UAVs for commercial use may be sold in 2017.[17] The 2016 C-UAV market has been estimated to be worth 2.48 billion (USD) with approximately 20 companies.[18]

The car hailing app-based company Uber is committed to developing e-VTOLs (‘Uber Elevate’).[19] In March 2017 Elon Musk—the founder, CEO and

2017, <http://pwc.blogs.com/press_room/2017/03/up-to-30-of-existing-uk-jobs- could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offse.html>.

[11] Anonymous, ‘Up to 30% of existing UK jobs could be impacted by automation by early 203s, but this should be offset by job gains elsewhere in economy, Price Waterhouse Company blog, 24 Mar. 2017, <http://pwc.blogs.com/press_room/2017/03/up-to-30-of-existing-uk-jobs- could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offse.html>.

[12] Anonymous, ‘Up to 30% of existing UK jobs could be impacted by automation by early 203s, but this should be offset by job gains elsewhere in economy, Price Waterhouse Company blog, 24 Mar. 2017, <http://pwc.blogs.com/press_room/2017/03/up-to-30-of-existing-uk-jobs- could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offse.html>.

[13] Anonymous, ‘Up to 30% of existing UK jobs could be impacted by automation by early 203s, but this should be offset by job gains elsewhere in economy, Price Waterhouse Company blog, 24 Mar. 2017, <http://pwc.blogs.com/press_room/2017/03/up-to-30-of-existing-uk-jobs-could-be-impacted-by-automation-by-early-2030s-but-this-should-be-offse.html>.

[14] All parts and components are subject to automated quality control, while 3 cars from each series are disassembled every week for an 800-point quality control check to inter alia ensure that the robotic systems are operating within specified parameters. Personal communication, 7 Apr. 2017.

[15] Anonymous, ‘Technology Quarterly, civilian drones’, *Economist*, vol. 423, no. 9044 (10 June 2017), p. 3.

[16] Anonymous, ‘Technology Quarterly, civilian drones’, *Economist*, vol. 423, no. 9044 (10 June 2017), p. 3.

[17] Anonymous, ‘Technology Quarterly, civilian drones’, *Economist*, vol. 423, no. 9044 (10 June 2017), p. 3.

[18] Barone, M. G. and Martin, G., ‘The rise of UAVs and counter-UAV technology’, *Military Technology*, vol. 61, no. 6 (2017), p. 7. Letter to the editor. The original study is not cited.

[19] ‘Uber Elevate’, <https://www.uber.com/info/elevate/summit/>.

Chief Technical Officer (CTO) of SpaceX—launched Neuralink, a company that seeks to link human brains to computers without a physical interface.[20]

Also in March 2017 the Optimus (quadrotor) became the first UAV to be granted approval (by the Civil Aviation Authority of Israel, CAAI) to fly fully automated commercially without a controller.[21] This Airobotics-manufactured system operates in automated Beyond Visual Line of Sight (BVLOS) mode and its first customers are Israel Chemicals (ICL) and Intel in Israel.[22] Its first customer in Australia is the mining company South32; the drone has also been granted a commercial license by the Civil Aviation Authority in Australia (CASA).[23]

Airbus has also recently announced plans to fly an single passenger e-VTOL system under Project Vahana by the end of 2017, and an e-VTOL passenger CityAirbus by the end of 2018.[24] The Airbus Zephyr S is a solar-powered High Altitude Proto Satellite (HAPS). The Zephyr T is scheduled to be introduced to market in 2020.

In 2015 Dow Chemical obtained US Government approval to operate camera-equipped UAVs at its chemical plants (e.g., to inspect 12m high storage tanks at a propylene production facility in Freeport, Texas).[25]

Finally, UAVs must be protected against cyber threats. For example, the US Defense Advanced Research Projects Agency (DARPA) is currently implementing the High-Assurance Cyber Military Systems (HACMS) project in order to evaluate software resiliency against some classes of cyber attacks with a view towards creating ‘tools for developing software mathematically

[20] Muoio, D., ‘Elon Musk has launched a company that hopes to link your brain to a computer’, *Business Insider Nordic*, 28 Mar. 2017, <http://nordic.businessinsider.com/elon-musk-neuralink-connect-brains-computer-neural-lace-2017-3?r=US&IR=T>. As of mid-2017 the company was seeking to fill 18 positions: (*a*) microfabrication engineer (MEMS & sensors), (*b*) mechatronics engineer, (*c*) polymer scientist, (*d*) medical device engineer, (*e*) electrochemist, (*f*) analogue and mixed signal engineer, (*g*) software engineer (embedded systems and firmware), (*h*) software engineer (infrastructure and tooling), (*i*) biomedical engineer, (*j*) harware systems integration engineer, (*k*) in-vitro electrophysiologist, (*l*) in-vivo electrophysiologist, (*m*) microelectronics packaging engineer, (*n*) principal scientist (advanced interfaces), (*o*) senior scientist (brain-machine interfacing), (*p*) senior scientist (neuroscience), (*q*) senior technician for immunohistochemisry, and (*r*) software engineer (medical imaging). The company’s business plan remains unclear.

[21] Airobotics, ‘Airobotics is granted world’s first approval to fly fully-automated, commercial drones without a pilot’, Mar. 2017, Press Release, <http://www.airobotics.co.il/press-releases/airobotics-granted-worlds-first-approval-fly-fully-automated-commercial-drones-without-pilot/>.

[22] Airobotics, ‘Airobotics is granted world’s first approval to fly fully-automated, commercial drones without a pilot’, Mar. 2017, Press Release, <http://www.airobotics.co.il/press-releases/airobotics-granted-worlds-first-approval-fly-fully-automated-commercial-drones-without-pilot/>.

[23] Airobotics, ‘Airobotics is granted world’s first approval to fly fully-automated, commercial drones without a pilot’, Mar. 2017, Press Release, <http://www.airobotics.co.il/press-releases/airobotics-granted-worlds-first-approval-fly-fully-automated-commercial-drones-without-pilot/>.

[24] Warwick, G., ‘Catch the CityAirbus’, *Aviation Week & Space Technology*, vol. 179, no. 6 (20 Mar.-2 Apr. 2017), p. 18.

[25] Everts, S. and Davenport, M., Drones detect threats such as chemical weapons, volcanic eruptions’, *Chemical & Engineering News*, vol. 94, no. 9 (22 Feb. 2016), pp. 36-37

proven to be free of large classes of cyber vulnerabilities'.[26] HACMS software has been tested on Boeing's Unmanned Little Bird H-6U.[27]

1.3. Security and defence/combat operations

Members of the self-described Islamic State (IS) have modified commercial off-the-shelf (COTs) UAVs during the 2016-2017 Mosul Offensive.[28] IS forces in Mosul have used the Da-Jiang Innovations (DJI) Phantom quadcopter to drop IEDs onto Iraqi government forces (normally this UAV is equipped with a GoPro-type camera).[29] (DJI currently controls approximately 70 per cent of the international civilian UAVs market.[30] The company is valued at *circa* 8 billion USD.[31]) IS-affiliate video includes footage of UAVs dropping IEDs onto Iraqi soldiers in Mosul.[32] In at least one case, the air dropped IEDs were used to distract Iraqi government coalition forces from noticing an imminent Suicide Vehicle-borne Improvised Explosive Device (SVBIED).[33]

The Iraqi Federal Police (IFP) is reportedly the first government body to have weaponized commercial UAVs—the DJI Matrice 100 quadcopter—for use against IS forces in Mosul.[34] [The DJI Matrice 100 can hover for circa 13 minutes with a 1kg payload.[35]] During Mosul operations Iraqi forces have experienced difficulties properly identifying whether UAVs are friend or foe.[36] The effectiveness of US-supplied radio frequency inhibitors to be used against IS-operated UAVs has also reportedly been variable.[37]

The United States Air Force (USAF) employed MQ-1 Predator and MQ-9 Reapers for close air support (CAS) and ISR in the 2016 campaign to force IS

[26] Cowan, G., 'Unmanned and under attack: defending UAVs from cyber attacks', *IHS Jane's International Defence Review,* vol. 15 (Feb. 2017), p. 28.

[27] Cowan, G., 'Unmanned and under attack: defending UAVs from cyber attacks', *IHS Jane's International Defence Review,* vol. 15 (Feb. 2017), p. 29.

[28] See Knights, M. and Mello, A., 'Defeat by annihilation: mobility and attrition in the Islamic State's defense of Mosul', *CTC Sentinal*, vol. 10, no. 4 (Apr. 2017), pp. 1-7.

[29] Binnie, J., 'Iraqi forces now using weaponised commercial drones', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 20.

[30] Anonymous, 'Technology Quarterly, civilian drones', *Economist*, vol. 423, no. 9044 (10 June 2017), p. 4.

[31] Anonymous, 'Technology Quarterly, civilian drones', *Economist*, vol. 423, no. 9044 (10 June 2017), p. 4.

[32] Anonymous, 'Militant web watch: monitoring militant activity online', *IHS Jane's Intelligence Review*, vol. 29, no. 3 (Mar. 2017), p. 16. One type of munition has the appearance of an elongated tennis feather ball (commonly referred to as 'shuttlecock' design). Iraqi government forces attacking Mosul have the support of surveillance and jamming equipment to mitigate IS UAV threats.

[33] Anonymous, 'Militant web watch: monitoring militant activity online', *IHS Jane's Intelligence Review*, vol. 29, no. 3 (Mar. 2017), p. 16.

[34] Binnie, J., 'Iraqi forces now using weaponised commercial drones', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 20.

[35] Binnie, J., 'Iraqi forces now using weaponised commercial drones', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 20.

[36] Westcott, T., 'UAV deconfliction a growing problem over Mosul', *Jane's Defence Weekly*, vol. 54 no. 14 (5 Apr. 2017), p. 17.

[37] Westcott, T., 'UAV deconfliction a growing problem over Mosul', *Jane's Defence Weekly*, vol. 54 no. 14 (5 Apr. 2017), p. 17.

out of Manbij, Syria.[38] For the period May-August 2016 USAF UAVs flew 11000 hours of 'persistent attack and reconnaissance in direct support of [US] partnered forces [Syrian Democratic Forces, SDF] on the ground'.[39] The UAVs fired more than 300 Lockheed Martin AGM-114 Hellfire air-to-surface missiles which, in turn, comprised 40 per cent of the total 'kinetic strikes' carried out by coalition aircraft during the campaign.[40] On 8 June 2017 the United States shot down a pro-Syrian government UAV of similar dimensions to a US MQ-1 Predator that had fired on US-supported coalition forces in southern Syria.[41] This drone was probably a Shahed-129.[42] On 20 June the US shot down a second Shahed-129 also operating northeast of al-Tanf, Syria.[43]

The airspace over and near Raqqa is more contested as compared to that of the Mosul Campaign. IS fighers have displayed greater proficiency in tactics and execution and are reportedly timing the launch of drones with those of opposition forces. They have thus achieved some success in disrupting US spotters.[44] Finally, the role of UAVs can be further considered according to cities and towns in Iraq and Syria.[45]

In 2017 the United States used a MIM-104 Patriot surface-to-air missile (SAM) to down a quadcopter in a practice exercise.[46] General David Perkins speaking before the Association of the United States Army's Global Force symposium in Alabama stated:

[38] Jennings, G., 'USAF details role of Predator and Reaper UAVs in countering Islamic State in Syria', *Jane's Defence Weekly*, vol. 54, no. 16 (19 Apr. 2017), p. 6.

[39] Jennings, G., 'USAF details role of Predator and Reaper UAVs in countering Islamic State in Syria', *Jane's Defence Weekly*, vol. 54, no. 16 (19 Apr. 2017), p. 6.

[40] Jennings, G., 'USAF details role of Predator and Reaper UAVs in countering Islamic State in Syria', *Jane's Defence Weekly*, vol. 54, no. 16 (19 Apr. 2017), p. 6.

[41] Combined Joint Task Force Operation Inherent Resolve, 'Coalition statement on At Tanf', Press Release no. 20170608-02, 8 June 2017.

[42] Gibbons-Neff, T., 'ISIS drones are attacking US troops and disrupting airstrikes in Raqqa, officials say', *Washington Post*, 14 June 2017, <https://www.washingtonpost.com/news/checkpoint/wp/2017/06/14/isis-drones-are-attacking-u-s-troops-and-disrupting-airstrikes-in-raqqa-officials-say/?utm_term=.6393c4152452>.

[43] US Central Command (DOD), 'Coalition shoots down armed UAV in Syria', Press Release no. 17-233, 20 June 2017, <http://www.centcom.mil/MEDIA/PRESS-RELEASES/Press-Release-View/Article/1219863/coalition-shoots-down-armed-uav-in-syria/>; and Borger, J., 'US shoots down second Iran-made armed drone over Syria in 12 days', *Guardian*, 20 June 2017, <https://www.theguardian.com/us-news/2017/jun/20/us-iran-drone-shot-down-syria>.

[44] Gibbons-Neff, T., 'ISIS drones are attacking US troops and disrupting airstrikes in Raqqa, officials say', *Washington Post*, 14 June 2017, <https://www.washingtonpost.com/news/checkpoint/wp/2017/06/14/isis-drones-are-attacking-u-s-troops-and-disrupting-airstrikes-in-raqqa-officials-say/?utm_term=.6393c4152452>.

[45] E.g., the CTC is collecting data according to cities/towns 'post-liberation'. These include: Al-Sa 'diyyah (Iraq), Baiji (Iraq), Falluja (Iraq), Hit (Iraq), Jalawla (Iraq), Jurf al-Sakhar (Iraq), Mosul (left side) (Iraq), Ramadi (Iraq), Rutba (Iraq), Sinjar (Iraq), Tikrit (Iraq), 'Azaz (Syria), Jarabulus (Syria), Manbij (Syria), Palmyra (Syria), and Shadadi (Syria). Milton, D. and al-'Ubaydi, M., *The Fight Goes On: the Islamic State's Continuing Military Efforts in Liberated Cities* (CTC: West Point, June 2017), p. 4.

[46] Baraniuk, C., 'Small drones "shot with Patriot missile"', *BBC News*, 15 Mar. 2017, <http://www.bbc.com/news/technology-39277940>.

'I'm not sure that's a good economic exchange ratio…In fact, if I'm the enemy, I'm thinking, "Hey, I'm just going to get on eBay and buy as many of these $300 quadcopters as I can and expend all the Patriot missiles out there"'.[47]

Also in 2017 the United States deployed the MQ-1C Gray Eagle UAS to Kunsan Air Base (South Korea).[48] In June 2017 a North Korean drone was recovered that had taken at least 10 photos of US terminal high altitude area defense (THAAD) missile launchers and a radar system located in Seongju.[49] According to South Korean sources, the drone had components from seven countries: 7.5l engine (Czech Republic), computer control system (Canada), GPS (Switzerland), GPS antennae (USA), 400g camera (Japan), and battery (China).[50]

Indian authorities prohibited the flying of drones, gliders and micro-light aircraft in Mumbai for the period 31 March-29 April 2017 out of safety and security concerns which, in turn, are exacerbated by underdeveloped regulations and associated enforcement capacity.[51] Authorities implemented a similar ban in 2016.[52]

In January 2017 the United Arab Emirates (UAE) air force reportedly destroyed an Iranian military drone near Yemen's port of Al-Mukha.[53]

1.4. Definitions

The understanding and application of standards and regulatory best practices and norms are informed by definitions and associated phrasing which, in turn, are evolving and may overlap. Distinctions arising from language and national standards may also occur.

Unmanned aerial systems (UAS) may be understood to be equivalent to UAVs. The term drones is avoided in some of the definitional literature and

47 Baraniuk, C., 'Small drones "shot with Patriot missile"', *BBC News*, 15 Mar. 2017, <http://www.bbc.com/news/technology-39277940>; and Fein, G., 'US ally shoots down small UAV with Patriot missile', *Jane's Defence Weekly*, vol. 54, no. (22 Mar. 2017), p. 12.

48 Pearson, J., 'US deploys attack drones to South Korea amid tensions with North', *Reuters*, 13 Mar. 2017, <http://www.reuters.com/article/us-southkorea-usa-drones-idUSKBN16K0VB>; and Dominguez, G., 'US Army begins deploying company of Gray Eagle UASs to South Korea', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 5.

49 From Associated Press, 'Suspected North Korean drone photographed US THAAD missile site before crash', *South China Morning Post*, 13 June 2017, <http://www.scmp.com/news/asia/east-asia/article/2098094/suspected-north-korean-drone-photographed-us-thaad-missile-site?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB%2006.13.2017&utm_term=Editorial%20-%20Military%20-%20Early%20Bird%20Brief>.

50 Petersson, T., 'Spiondrönare från Nordkorea byggd av delar från sju länder', *Dagens Nyheter,* 22 June 2017, <http://www.dn.se/nyheter/varlden/spiondronare-fran-nordkorea-byggd-av-delar-fran-sju-lander/>.

51 Anonymous, 'Police fears aerial terror attacks in Mumbai, bans drones, glider from 31 March', Financial Express, 29 Mar. 2017, <http://www.financialexpress.com/india-news/police-fears-aerial-terror-attacks-in-mumbai-bans-drones-gliders-from-31-march/607415/>.

52 Anonymous, 'Mumbai: police extend ban on drones, paragliders by another month', *Indian Express*, 7 Apr. 2017, <http://indianexpress.com/article/cities/mumbai/mumbai-police-extend-ban-on-drones-paragliders-by-another-month/>.

53 Binnie, J., UAE airstrike reportedly destroyed Iranian UAV in Yemen', *Jane's Defence Weekly*, vol. 54, no. 6 (8 Feb. 2017), p. 18.

tends to be used in a military operational context. UAS/UAV may be classified inter alia by endurance, range or size; or mission, size and altitude (see tables 1-4).[54]

Table 1. UAS/UAV classification according to US DOD.

Category	Size	MGTW (lbs)	NOA (ft)	Airspeed (knots)
Group 1	Small	0-20	<1200 AGL	<100
Group 2	Medium	21-55	<3500	<250
Group 3	Large	<1320	<18000 MSL	<250
Group 4	Larger	>1320	<18000 MSL	any airspeed
Group 5	Largest	>1320	>18000	any airspeed

Source: PennState University, '1.4 Classification of unmanned aerial systems', <https://www.e-education.psu.edu/geog892/node/5>.

Table 2. UAS/UAV classification by range.

Range	Range/endurance/altitude	Examples
Very low cost close range	5km, 20-45 mins.	Dragon Eye, Raven
Close range	50km, 1-6 hrs.	
Short range	150km, 8-12 hrs.	
Mid-range	650km [high speed]	
Endurance	300km, 30000 ft	

Source: PennState University, '1.4 Classification of unmanned aerial systems', <https://www.e-education.psu.edu/geog892/node/5>.

Table 3. UAS/UAV classification by size.

Size	Examples
Very small (micro, nano, mini)	CyberQuad Mini, Mosquito, Skate
Small	Bayraktar, RQ-7 Shadow, RQ-11 Raven
Medium	Fire Scout, Eagle Eye, Hunter, Pioneer, Skyeye, Watchkeeper
Large	Global Hawk, Harfang, Predator A

Source: PennState University, '1.4 Classification of unmanned aerial systems', <https://www.e-education.psu.edu/geog892/node/5>.

[54] PennState University, '1.4 Classification of unmanned aerial systems', <https://www.e-education.psu.edu/geog892/node/5>.

Table 4. UAS/UAVs by mission, size and altitude.

Type	System
High-altitude HALE	Global Hawk, BAMS, Zephyr
UCAV	Taranis, Neuron
Medium-altitude MALE	Heron, Predator MQ-1, MQ-9 Reaper
MUAV	RQ-11 Raven, Skylark, Wasp III
TUAV	RQ-7 Shadow 200, Hermes 450, ScanEagle
VTOL UAV	Fire Scout, Camcopter S-100, A-160 Hummingbird

Source: Based on *The Global Unmanned Aerial Vehicle Market 2011-2021*, ref. code DF0003SR (ICD Research: July 2011) (free downloadable extract).

1.5. Regulatory and normative frameworks

Some consideration of the regulatory and normative frameworks for UAVs has occurred in the context of lethal autonomous weapons (LAWs) discussions. It should be emphasized that the LAWS (or lethal autonomous robot, LAR) discussions are distinct from those concerning UAVs in those cases where the latter are remotely-controlled. Some take the view that automation of any decision to kill an opponent should be illegal.[55] A 2012 US DOD directive 3000.09 (revised May 2017) supports the principle of ‘meaningful human control’ and specifies the modalities by which humans control specified (‘certain’) autonomous or semi-autonomous weapon systems (see Annexe 3).[56] The Administration of US President Barack Obama institutionalized a system by which targeted individuals were represented by legal counsel in a classified legal review process prior to the President taking the final decision to authorize an attack.

Some autonomous and/or semi-autonomous platform systems also fall under the purview of Missile Technology Control Regime (MTCR) guidelines. In 1992 the participating states extended the guidelines to cover UAVs.[57] These guidelines are implemented on a ‘presumption of denial’ for the transfer of Category 1 UAVs (i.e., UAVs that have a range of more than 300 km and which possess a payload of more than 500 kg).[58]

The MTCR defines a ‘payload’ as: ‘the total mass that can be carried or delivered by the specified rocket system or unmanned aerial vehicle (UAV)

[55] van Kralingen, M., ‘Use of weapons: should we ban the development of autonomous weapon systems?’, *International Journal of Intelligence, Security and Public Affairs*, vol. 18, no. 2 (2016), pp. 132-156; and Klincewicz, M., ‘Autonomous weapons systems, the frame problem and computer security’, *Journal of Military Ethics*, vol.14 , no. 2 (2015), pp. 162-176. See also ‘Campaign to Stop Killer Robots’, <http://www.stopkillerrobots.org/>.

[56] DOD, ‘Directive: autonomy in weapon systems’, no. 3000.09, 21 Nov. 2012 (rev. 8 May 2017).

[57] Morely, J., ‘Drone proliferation tests arms control’, *Arms Control Today*, vol. 44, no. 3 (Apr. 2014), p. 30.

[58] Morely, J., ‘Drone proliferation tests arms control’, *Arms Control Today*, vol. 44, no. 3 (Apr. 2014), p. 30.

system that is not used to maintain flight'.[59] The MTCR also considers 'payloads' for 'Other UAVs' to include:

'a. Munitions of any type (e.g. explosive or non-explosive);

b. Mechanisms and devices for safing, arming, fuzing or firing;

c. Countermeasures equipment (e.g. decoys, jammers or chaff dispensers) that can be removed without violating the structure integrity of the vehicle;

d. Signature alteration equipment that can be removed without violating the structural integrity of the vehicle;

e. Equipment required for a mission such as data gathering, recording or transmitting devices for mission-specific data and supporting structures that can be removed without violating the structural integrity of the vehicle;

f. Recovery equipment (e.g. parachutes) that can be removed without violating the structural integrity of the vehicle. [sic]

g. Munitions supporting structures and deployment mechanisms that can be removed without violating the structural integrity of the vehicle'.[60]

At the national level, hobbyists, researchers, professional associations and government agencies have sought to bring clarity to best practices and guidelines for the use of autonomous and/or semi-autonomous platforms. The US Center for Robot-Assisted Search and Rescue (CRASAR) has developed useful principles and guidelines that are independent of some of the legal or political 'baggage' that LAWs or defence sector guidance might be understood to carry.

FAA guidelines and regulations have been developed by inter alia: (*a*) Unmanned Aircraft Program Office (UAPO), (*b*) Production and Airworthiness Division, (*c*) Flight Technologies and Procedures Division, and (*d*) Office of System Operations and Safety. As of 2015 the FAA has operated UAS research and test sites at: (*a*) the University of Alaska, (*b*) the University of Nevada, (*c*) Griffiss International Airport (New York), (*d*) a facility operated the Department of Commerce (North Dakota), (*e*) Texas A&M University at Corpus Christi, (*f*) Virginia Polytechnic Institute, and (*g*) the State University (Virginia Tech).[61]

FAA principles of 'know before you fly' are:

1.) Do not fly above 400 feet
2.) Maintain unmanned aircraft within sight,
3.) Do not operate near individuals or crowds,

59 MTCR/TEM/2016/Annex, dated 10 Oct. 2016, <http://mtcr.info/wordpress/wp-content/uploads/2016/10/MTCR-TEM-Technical_Annex_2016-10-20.pdf>.

60 MTCR/TEM/2016/Annex, dated 10 Oct. 2016, pp. 12-13, <http://mtcr.info/wordpress/wp-content/uploads/2016/10/MTCR-TEM-Technical_Annex_2016-10-20.pdf>.

61 Anonymous, 'How the FAA boss is keeping the skies safe', *Hispanic Engineer and Information Technology*, vol. 30, no. 2 (fall 2015), p. 10.

4.) Do not fly an unmanned aircraft within 5 miles of an airport without prior notification of FAA Air Traffic Control or the airport operator.
5.) Fly unmanned aircraft for hobby or recreational purposes only (i.e., not for financial gain or for business purposes without prior FAA authorization),
6. Respect personal privacy of others (e.g, do not take photos when not expected).
7.) Join a model aircraft club to learn the safe operation of aircraft.[62]

The ‘know before you fly’ website summarizes US rules for 3 categories of UAV users: recreational, business and the public.[63] The FAA has also supported a UAS Center of Excellence in order to inter alia promote technological development within designated ‘innovation zones’.[64]

Operators must currently register and pass an operations test. UAVs may not be operated above 400 feet. UAVs should/must also be operated within line-of-sight. Drones must be registered prior to their first flight. The initial registration requirement is with the drone user, not manufacturers or retailers. However, the FAA is working towards the implementation of a broader registration and tracking system. As of March 2017 more than 770 000 drone users had registered with the FAA.[65] It should be noted, however, that a 19 May 2017 District of Columbia Circuit court decision casts doubt on the registration rule as it pertains to ‘model aircraft hobbyists’.[66]

The United States is currently drafting legislation to permit the tracking, hacking and destruction of UAVs.[67] In May 2017 DJI stated that it will severely restrict the functionality of its drones until their owners have registered the unit.[68] DJI is introducing a new activation process for non-US customers that to ensure users possess the ‘correct set of geospatial

62 Based on Anonymous, ‘How the FAA boss is keeping the skies safe’, *Hispanic Engineer and Information Technology*, vol. 30, no. 2 (fall 2015), p. 10.

63 <knowbeforeyoufly.org>.

64 Based on Anonymous, ‘How the FAA boss is keeping the skies safe’, *Hispanic Engineer and Information Technology*, vol. 30, no. 2 (fall 2015), p. 10.

65 Yurieff, K., ‘Future tense: US drone registrations skyrocket to 770,000’, CNN, 28 Mar. 2017, <http://money.cnn.com/2017/03/28/technology/us-drone-registrations/?iid=EL>.

66 John A. Taylor v. Michael P. Huerta (FAA), ‘On petitions for review of orders of the Federal Aviation Administration’, case no. 15-1495. Decided 19 May 2017 by US Court of Appeals for the District of Columbia Circuit. Available at: <https://www.cadc.uscourts.gov/internet/opinions.nsf/FA6F27FFAA83E20585258125004FBC13/$file/15-1495-1675918.pdf>.

67 Humphries, M., ‘Trump wants power to track, hack, and destroy drones’, PCMag UK, 25 May 2017, <http://uk.pcmag.com/news/89485/trump-wants-power-to-track-hack-and-destroy-drones>. A summary of the legislation has been made available by the *New York Times* at <https://www.documentcloud.org/documents/3728796-Government-Drone-Hacking-Destruction-Proposal.html>, accessed May 2017.

68 Humphries, M., ‘Trump wants power to track, hack, and destroy drones’, PCMag UK, 25 May 2017, <http://uk.pcmag.com/news/89485/trump-wants-power-to-track-hack-and-destroy-drones>; and DJI, ‘DJI updates process for activating software and firmware updates: new procedure requires login after update; password reset available’, Press Release, 20 May 2017, <http://www.dji.com/newsroom/news/dji-updates-process-for-activating-software-and-firmware-updates>.

information and flight functions…as determined…[by the user's] geographic location and user profile'.[69] Users who do not register or connect to the internet using smart phones, tablets or similar to verify their account information in order to activate the updated software or firmware will find that their drones cannot access the 'correct geospatial information and flight functions for that region, and [their] operations will be restricted'.[70] In particular, live camera streaming will be disabled, and flight will be limited to a 50m (164ft) radius to 30m (98ft) high.[71]

Finally, 3-D printing guidelines and rules, including registration of sales, may become increasingly relevant to international and national autonomous/semi-autonomous platform technology regulatory frameworks.

[69] DJI, 'DJI updates process for activating software and firmware updates: new procedure requires login after update; password reset available', Press Release, 20 May 2017, <http://www.dji.com/newsroom/news/dji-updates-process-for-activating-software-and-firmware-updates>.

[70] DJI, 'DJI updates process for activating software and firmware updates: new procedure requires login after update; password reset available', Press Release, 20 May 2017, <http://www.dji.com/newsroom/news/dji-updates-process-for-activating-software-and-firmware-updates>.

[71] DJI, 'DJI updates process for activating software and firmware updates: new procedure requires login after update; password reset available', Press Release, 20 May 2017, <http://www.dji.com/newsroom/news/dji-updates-process-for-activating-software-and-firmware-updates>.

2.0 Select systems and development projects

DARPA's Offensive Swarm Enabled Tactics (OFFSET) project comprises two technology characteristics: (*a*) an evaluation of swarm using technologies currently available but not yet 'employed in a swarm tactic-centric' manner (e.g., to support simultaneous top-down/bottom-up multi-story building clearance operations), and (*b*) the development of new swarm using techniques using inter alia game-based environment simulation systems, including for the possible identification of new missions.[72] OFFSET utilizes unmanned air and ground platforms (i.e., some 250 robotic systems).[73] The Coyote is the US Office of Naval Research's (ONR) principal platform for implementing a Low-Cost UAV Swarming Technology (LOCUST).[74] In late 2016 three US F/A-18 Hornets released 103 Perdix micro-UAVs at the Naval Air Weapons Station (NAWS) China Lake, located in California, in order to evaluate 'advanced swarm behaviours such as collective decision-making, adaptive formation flying, and self-healing'.[75] The US Department of Defense's (DOD) Strategic Capabilities Office (SCO) runs this project.[76]

The Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) is another autonomous platform mission under development by the US Navy in cooperation with DARPA.[77] The United States aims to deploy this platform worldwide from US territory with endurance of weeks or months.[78] It has been observed that the 'track and trail' mission is resource intensive and typically involves the use of warships.[79] Since August 2012 the US Navy has contracted Leidos to construct and test a full-scale ACTUV prototype.[80] The initial prototype was launched in January 2016. ONR will gradually assume responsibility, while DARPA involvement is wound down.[81]

72 Fein, G., 'DARPA to explore swarming operations', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 28.

73 Fein, G., 'DARPA to explore swarming operations', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 28.

74 Fein, G., 'Coyote earmarked for ISR and offensive roles', *IHS Jane's International Defence Review*, vol. 15 (Feb. 2017), p. 25.

75 Jennings, G., 'US demonstrates "one of the world's largest" mico-UAV swarms', *IHS Jane's Defence Weekly*, vol. 54, no. 3 (18 Jan. 2017), p. 12.

76 Jennings, G., 'US demonstrates "one of the world's largest" mico-UAV swarms', *IHS Jane's Defence Weekly*, vol. 54, no. 3 (18 Jan. 2017), p. 12.

77 Anonymous, 'Unmanned: drones at sea? DARPA demos the potential', *Defense News*, 3 Apr. 2017, p. 14.

78 Anonymous, 'Unmanned: drones at sea? DARPA demos the potential', *Defense News*, 3 Apr. 2017, p. 14.

79 Anonymous, 'Unmanned: drones at sea? DARPA demos the potential', *Defense News*, 3 Apr. 2017, p. 14.

80 Anonymous, 'Unmanned: drones at sea? DARPA demos the potential', *Defense News*, 3 Apr. 2017, p. 14.

81 Anonymous, 'Unmanned: drones at sea? DARPA demos the potential', *Defense News*, 3 Apr. 2017, p. 14.

The US Army has, since 2013, pursued a Manned-Unmanned Team (MUM-T) concept with respect to unmanned platforms.[82]

The sensor array of the RQ-4 Global Hawk is to be upgraded with the MS-177 (a 7-band multispectral sensor constructed by UTC Aerospace Systems).[83] Pending US Congressional approval, the USAF intends to replace the U2 with the RQ-4 Global Hawk.[84] The USAF will continue to operate U2s until at least 2019.[85]

DARPA and ONR are currently testing SideArm within the framework of the Tactically Exploited Reconnaissance Node (TERN) programme for the retrieval of drones flying at high-speed.[86]

Starting in 2010 the US Navy began planning missions for an Unmanned Carrier Launched Airborne Surveillance and Strike (UCLASS) system that originally had two objectives: air strikes and ISR.[87] Starting in 2017 the UCLASS mission focus was shifted to air-to-air refueling (AAR).[88] US Navy plans to incorporate high performance UAS into carrier wings will occur in the mid-2020s at the earliest.[89]

Global Positioning System (GPS) tracking may not be available in all circumstances, such as search and rescue (SAR) missions. NASA's Jet Propulsion Laboratory (JPL) has developed, with funding from the US Department of Homeland Security (DHS), an alternate tracking system that can be used instead of GPS called POINTER.[90] POINTER uses quasistatic electromagnetic fields which have a range of several hundred meters.[91]

Electronics-based capabilities requirements for UAVs may be structured according to inter alia: electro-optical/infrared (EO/IR) sensors, short-wave infrared (SWIR) spectrum capabilities, radio frequency electronic support measures (ESM), and communications intelligence (COMINT) sensors. Seven states currently share access the Wideband Global SATCOM (WGS) system for secure communications.[92] Orollo—a positioning, navigation and timing (PNT) technology provider—has entered into a partnership with Satellites Inc.

[82] Stevenson, B., 'To man or not to man?, *Jane's Defence Weekly*, vol. 54, no. 10 (8 Mar. 2017), pp. 30-33.

[83] Fein, G., 'MS-177 sensor trialled on Global Hawk', *Jane's International Defence Review*, vol. 50 (Apr. 2017), p. 26.

[84] Insinna, V., 'Drones: Northrup beefs up sensor for Global Hawk', *Defense News*, 3 Apr. 2017, p. 34.

[85] Insinna, V., 'Drones: Northrup beefs up sensor for Global Hawk', *Defense News*, 3 Apr. 2017, p. 34.

[86] Keddie, I., 'SideArm undergoes successful testing', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 29. See also DARPA, 'SideArm prototype catches full-size unmanned aerial system flying at full speed', Press Release, 6 Feb. 2017, <http://www.darpa.mil/news-events/2017-02-06>.

[87] Scott, R. and Stevenson, B., 'Unmanned ambitions', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 26.

[88] Scott, R. and Stevenson, B., 'Unmanned ambitions', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), pp. 26-27.

[89] Scott, R. and Stevenson, B., 'Unmanned ambitions', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 26.

[90] *Search and Rescue: New Technology Making a Difference* (Defence IQ: 2017), p. 2 (unclassified).

[91] *Search and Rescue: New Technology Making a Difference* (Defence IQ: 2017), p. 3 (unclassified).

[92] Fein, G., 'USA, Boeing launch ninth WGS satellite', *Jane's Defence Weekly*, vol. 54, no. 13 (29 Mar. 2017), p. 23.

to bring to market the latter's satellite time and location (STL) signal technology which, in turn, is advertised as being immune to interference vulnerabilities associated with GPS.[93] Finally, the COSPAS-SARSAT international signals network is separate from the GPS system.

Marduk Technologies—an Estonian startup—is developing a Shark System that employs laser effectors to temporarily or permanently blind swarming UAV optical systems.[94]

A UK defence consortium comprising Blighter Surveillance Systems, Chess Dynamics and Enterprise Control Systems (ECS) has developed an Anti-UAV defence system (AUDS) that has achieved technology readiness level (TRL)-9 and units have been sold to the United States.[95]

According to Defense Group Incorporated (DGI), China's UAV manufacturers are 'at or near international standards for industrial, commercial, and recreational consumer drone systems'.[96] DGI cites a 2014 market analysis that estimates that China's demand for UAVs will grow 15 per cent annually between 2013-2022 reaching a total value of 2 billion USD by 2022.[97] In accordance with China's 13th Five Year Plan (2016-2020), the China Aerospace Science and Technology Corporation (CASIC, also known as CASC) is reportedly developing long endurance armed stealth UAVs and near-space drones that can fly between 20-100km.[98] Some estimate that China will be able to manufacture up to 41800 UAVs worth circa 10.5 billion USD for land and sea operations by 2023.[99] China has established a UAV industrial park in Beijing's southern Daxing District which will reportedly generate more than CNY100 billion by 2025.[100] China has reportedly exported UAVs to

[93] *Search and Rescue: New Technology Making a Difference* (Defence IQ: 2017), p. 3 (unclassified).

[94] Williams, H., 'Baltic innovation: Estonia pursues agile technology development plan', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), pp. 40-41. The company's website does not yet describe its products. See <http://marduk.ee/>.

[95] Williams, H., 'AUDS achieves TRL 9, deploys with US forces', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 31. See also Williams, H., 'Unmanned and unguarded: operators and industry look to close a defence gap', *Jane's International Defence Review*, vol. 50 (May 2017), p. 52.

[96] Ray, J., et al., *China's Industrial and Military Robotics Development* (Defense Group Incorporated: Vienna, Virginia, Oct. 2016). p. 10, <https://www.uscc.gov/sites/default/files/Research/DGI_China%27s%20Industrial%20and%20Military%20Robotics%20Development.pdf>. Report prepared on behalf of the US-China Economic and Security Review Commission.

[97] Ray, J., et al., *China's Industrial and Military Robotics Development* (Defense Group Incorporated: Vienna, Virginia, Oct. 2016). p. 10, <https://www.uscc.gov/sites/default/files/Research/DGI_China%27s%20Industrial%20and%20Military%20Robotics%20Development.pdf>. Report prepared on behalf of the US-China Economic and Security Review Commission. For a review of China's institutions planning priorities for UAVs in the defence sector, see also Easton, I. M. and Hsiao, L. C. R., *The Chinese People's Liberation Army's Unmanned Aerial Vehicle Project: Organizational Capacities and Operational Capabilities* (Project 2049 Institute: 11 Mar. 2013, Arlington, Virginia), <https://project2049.net/documents/uav_easton_hsiao.pdf>.

[98] Dominguez, G., 'CASIC reportedly developing stealth UAVs', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 8.

[99] Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 52.

[100] Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 57.

approximately 10 states, including Iran, Iraq, Kazakhstan and Saudi Arabia.[101] On 16 March 2017 the China Aerospace Science and Technology Corporation (CASC) and the King Abdulaziz City for Science and Technology (KACST) signed a partnership agreement that allows for the construction of UAVs from the CH family in Saudi Arabia.[102] The Saudi-manufactured UAVs will have civilian and military applications and will be marketed to other states in the region.[103] On 11 May 2017 the KACST unveiled its Saqr 1 UAV.[104] It has reportedly been fitted with the FT-9 guided bomb and M-4/M-3 missile.[105] The FT-9 was developed by CASC for its CH-series UAVs that are in RSAF service.[106] In 2016 Aero-Starloop High-tec Co. Ltd. unveiled its BH-series VTOL UAV systems.[107] In February 2017 Ehang flew more than 1000 drones in the Lantern Festival at Guangzhou.[108] In June 2017 the China Electronics Technology Group Corporation stated that it had flown 119 fixed wing UAVs in formation, reportedly the largest such formation to date.[109] Finally, it should be noted that the Chengdu Aircraft Industry Company (CAC) is a subsidiary of the Aviation Industry Corporation of China (AVIC).[110]

France will purchase up to 210 mUAVs (SpyRangers) for reconnaissance from Thales starting in 2018.[111]

Under its Stratobus airship project, Thales Alenia Space (Thales Group) is currently conducting studies on the possible creation of an unmanned platform that is between a UAV and a satellite. This autonomous stratospheric airship

[101] Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 57.

[102] Binnie, J., 'Saudi Arabia to build Chinese UAVs', *Jane's Defence Weekly*, vol. 54, no. 13 (29 Mar. 2017), p. 18; and Binnie, J., 'Saudi Arabia to build Chinese UAVs', *IHS Jane's Defence Weekly*, 23 Mar. 2017, <http://www.janes.com/article/68975/saudi-arabia-to-build-chinese-uavs>. Open web version.

[103] Binnie, J., 'Saudi Arabia to build Chinese UAVs', *IHS Jane's Defence Weekly*, 23 Mar. 2017, <http://www.janes.com/article/68975/saudi-arabia-to-build-chinese-uavs>. Open web version.

[104] Binnie, J., 'Saudi Arabia unveils Saqr 1 armed UAV', *Jane's Defence Weekly*, vol. 54, no. 20 (17 May 2017), p. 16.

[105] Binnie, J., 'Saudi Arabia unveils Saqr 1 armed UAV', *Jane's Defence Weekly*, vol. 54, no. 20 (17 May 2017), p. 16.

[106] Binnie, J., 'Saudi Arabia unveils Saqr 1 armed UAV', *Jane's Defence Weekly*, vol. 54, no. 20 (17 May 2017), p. 16.

[107] Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 54.

[108] Yan, A., '1,000 drones dominate southern China's night sky in record-breaking display for Lantern Festival', *South China Morning Post*, 14 Feb. 2017, <http://www.scmp.com/news/china/society/article/2070715/record-breaking-drone-display-staged-southern-china>.

[109] Chen, S., 'Chinese defence firm claims drone formation world record', *South China Morning Post*, 11 June 2017, <http://www.scmp.com/news/china/society/article/2097835/chinese-defence-firm-claims-drone-formation-world-record?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB%2006.12.2017&utm_term=Editorial%20-%20Military%20-%20Early%20Bird%20Brief>.

[110] Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), p. 53.

[111] Stone, A., 'Mini drones: a growing interest as a US military capability', C4ISRNET, 25 May 2017, <http://www.c4isrnet.com/articles/new-mini-drone-weighs-just-5-ounces>.

possesses the following characteristics: 20km ceiling, 200km surveillance range, 100m long, 33m diameter, 250kg payload.[112]

In March 2017 it was reported that Iran is deploying a recently developed jamming system against UAVs which, once it locks on target one can take over control of the operational signal.[113]

On 29 March 2017 the Korea Institute for National Unification (KINU) issued a report that estimates that DPRK has approximately 1000 drones.[114]

Abu Dhabi Autonomous Systems Investments (ADASI) is responsible for unmanned air systems development in the UAE.[115] ADASI is a subsidiary of Emirates Defence Industry Company (EDIC).[116]

In the civil sector, UAVs are used to study vulcanos, including plume trajectories and compositions (ash velocity, content and type; temperature, SO_2 profiles determining a given volcano's unique chemical signature/fingerprint).[117] For example, volcanologists operate RQ-14 Dragon Eyes (AeroVironment) and other UAVs to study plume composition of the Turrialba Volcano in Costa Rica. [118] Drone-equipped defibrillators have been tested as they can be sent to the scene of an accident faster than ambulances.[119]

The autonomous/semi-autonomous delivery of packages is considered to be an area ready for market. The California-based company Natilus' business model is to reduce air freight costs by half through the use of large autonomous drones.[120] The company plans to begin FAA-approved tests of a 30ft prototype in mid-2017 with a view towards testing larger prototypes carrying 700lbs between Los Angeles and Hawaii.[121] Amazon Prime Air is a 30-minute package delivery programme.[122] HorseFly™ is a truck-based package delivery system currently being tested by the United Parcel Service

[112] Cowan, G., 'Stratobus demonstrator set for 2018 launch', *Jane's International Defence Review*, vol. 50 (Apr. 2017), p. 28.

[113] Scarborough, R., 'Iran deploys jamming device to counter drones', *Washington Times*, 12 Mar. 2017, <http://m.washingtontimes.com/news/2017/mar/12/iran-counter-drone-weapon-jamming-device-takes-war/>.

[114] According to a 2016 report by the Korea Institute for Defence Analysis, DPRK probably possesses 25 warfare agents, including six organophosphorus nerve agents, as well as 13 biological warfare agents, including the causative agents for anthrax and clostridium botulinum. Anonymous, 'NK estimated to have some 1,000 drones: report', *Yonhap*, 29 Mar. <http://english.yonhapnews.co.kr/news/2017/03/29/0200000000AEN20170329002100315.html>.

[115] Forrester, C., 'EDIC focuses on integration as UAE MoD's approach to prcurement shifts', *Jane's Defence Weekly,* vol. 54, no. 9 (1 Mar. 2017), p. 18.

[116] Forrester, C., 'EDIC focuses on integration as UAE MoD's approach to prcurement shifts', *Jane's Defence Weekly,* vol. 54, no. 9 (1 Mar. 2017), p. 18.

[117] Everts, S. and Davenport, M., Drones detect threats such as chemical weapons, volcanic eruptions', *Chemical & Engineering News*, vol. 94, no. 9 (22 Feb. 2016), pp. 36-37

[118] Everts, S. and Davenport, M., Drones detect threats such as chemical weapons, volcanic eruptions', *Chemical & Engineering News*, vol. 94, no. 9 (22 Feb. 2016), pp. 36-37

[119] Claesson, A., Bäckman, A. and Ringh, M., 'Time to delivery of an automated external defibrillator using a drone for simulated out-of-hospital cardiac arrests vs[.] emergency medical services', *Journal of the American Medical Association*, (13 June 2017), pp. 2232-2334.

[120] Natilus, <http://www.natilus.co/#main>.

[121] Terdiman, D., 'A startup's plan to cut air freight costs in half with 777-size drones', fastcompany.com, 27 Mar. 2017, <https://www.fastcompany.com/3069053/a-startups-plan-to-halve-cargo-shipping-costs-with-777-size-drones>.

[122] Amazon Prime Air, <https://www.amazon.com/Amazon-Prime-Air/b?node=8037720011>.

(UPS) in cooperation with Workhorse.[123] Japan plans to finalize a regulatory framework on 9 June 2017 that will allow for UAV delivery of packages starting in 2020 and the commercialization of self-driving trucks by 2022.[124]

Zipline's business model is the UAV delivery of medical equipment and/or supplies. It currently delivers blood supplies to 21 hospitals in Rwanda.[125]

UAV applications for wildlife surveillance, including countering poaching.[126] The Bat Hawk—an IR sensor, camera, telemetry-equipped fixed wing bespoke system by UAV & Drone Solutions with an 8 hour duration—has been employed for anti-poacher surveillance in Malawi since 2015. The project is supported by funding from the World Wildlife Fund (WWF), including 5 million USD from Google.[127] Efforts have also been made to develop single-winged rotorcraft that, for example, can mimic the maple seed's (samara fruit) spiral fall behaviour.[128]

2.1. Counter-UAV developments

One market survey concluded that the 13 leading C-UAV companies are: Boeing Company, Airbus Group SE, Saab AB, Thales Group, Lockheed Martin Corporation, Israel Aerospace Industries Ltd., Selex ES S.p.A., Blighter Surveillance Systems Ltd., DroneShield LLC, Raytheon Company, Northrup Grumman Corporation, Rafael Advanced Defense Systems Ltd., and Rheinmetall AG.[129]

C-UAVs are being developed that can net target UAVs which, in turn, may have conventional explosive or chemical and/or biological weapon (CBW) payloads. An advantage of the netting approach is that the target UAV will not kill people or contaminate the environment (which can occur if the target were kinetically disabled). The target drone is also more amenable to forensics analysis.

Currently, low flying UAVs may be disabled through various means including through the use of SkyNet Mi-5 shotgun shells (manufactured by AMTEC Less Lethal Systems, ALS).[130] The shells deploy 5ft wide capture

[123] Workhorse, <http://workhorse.com/aerospace>.

[124] Anonymous, 'Japan to finalize strategy for drones, self-driving trucks on June 9: government sources', *Reuters*, 29 May 2017, <http://www.reuters.com/article/us-japan-economy-drones-idUSKBN18P0LP>.

[125] Zipline, <http://flyzipline.com/now-serving/index.html>, accessed 19 June 2017.

[126] Flodell, A. and Christenssson, C., *Wildlife Surveillance Using a UAV and Thermal Imagery* (Linköping University (Dept. of Electrical Engineering): Linköping, Sweden, 2016), Master of Science in Electrical Engineering thesis.

[127] Nuwer, R., 'High above, drones keep watchful eyes on wildlife in Africa', *New York Times*, 13 Mar. 2017, <https://www.nytimes.com/2017/03/13/science/drones-africa-poachers-wildlife.html?_r=0>.

[128] Anonymous, 'Aerial surveillance technology', *The Science Teacher*, vol. 76, no. 9 (Dec. 2009), pp. 17-18.

[129] Summary of *Counter-UAV Market Forecast 2017-2027* (Visiongain: May 2017), <https://www.asdreports.com/market-research-report-374315/counter-uav-market-forecast?utm_source=ASDEvents&utm_medium=affiliate&utm_campaign=ASDEvents_bottom&utm_content=Tekstlink&guid=F60B7AEC-55D2-477F-8E40-F56F26923B14>.

[130] Humphries, M., 'US Air Force orders anti-drone net-filled shotgun shells', *PCMag.com*, 14 Mar. 2017, <http://www.pcmag.com/news/352360/us-air-force-orders-anti-drone-net-filled-shotgun-shells>.

nets that are fired from Remington Model 870 shotguns specially equipped with ‘choke tubes’.[131] The shells are capable of bringing down Category 1 and Category 2 UAVs (i.e., UAVs that weigh up to 55lbs and have a flight ceiling of 3500 feet).[132] Russia’s NPO [Research and Industrial Association] Pribor (which is affiliated with Tekhmash) is developing 30mm and 57mm shrapnel ammunition to be used against drones.[133] Airspace Systems is also developing a UAV netting technology.[134]

In 2017 the KB Radar Design Bureau unveiled a C-UAV called the Groza-R Counter-Multicopter Radio Electronic Rifle (mounted on a Cyma CM0011 rifle).[135] Other C-UAV systems include: Airfence (Sensofusion Oy), DroneDefender™ (Battelle) (electromagnetic/radio control disrupter rifle), Drone Dome UAV (Rafael) (detection system incorporated with own UAV jammers), Excipio Anti Drone Systems (Theiss UAV Solutions) (net system), MESMER® (Department 13) (software-based approach for taking over target UAV control signal), Skywall 100 (Open Works Engineering) (net system), and trained birds-of-prey that grasp drones with their talons.[136]

On 7-19 May 2017 the DoD organized the 2017 Black Dart counter-drone exercise at Elgin Air Force Base (Florida).[137] The previous year Northrup Grumman displayed a mobile application for small, low-flying drones identification using an acoustic sensor that operates on Android cellphones.[138]

OSCE-operated camcopters operating in Ukraine have reportedly been subjected to ‘military-grade GPS jamming’.[139] With technology support from QinetiQ, NovAtel and Schiebel cooperated to support the OSCE by introducing an anti-GPS jamming system developed by NovAtel called GPS Anti-Jam Technology (GAJT) for S-100 aircraft.[140] [based on null-forming algorithm technology]

[131] Humphries, M., ‘US Air Force orders anti-drone net-filled shotgun shells’, *PCMag.com*, 14 Mar. 2017, <http://www.pcmag.com/news/352360/us-air-force-orders-anti-drone-net-filled-shotgun-shells>.

[132] Humphries, M., ‘US Air Force orders anti-drone net-filled shotgun shells’, *PCMag.com*, 14 Mar. 2017, <http://www.pcmag.com/news/352360/us-air-force-orders-anti-drone-net-filled-shotgun-shells>.

[133] Anonymous, ‘Russia to develop anti-drone shrapnel ammunition’, TASS, 18 Apr. 2017 (?), <http://tass.com/defense/941885>.

[134] <http://airspace.co/>.

[135] Williams, H., ‘Groza-R enters C-UAV fray’, *Jane’s International Defence Review*, vol. 50 (Apr. 2017), p. 26.

[136] O’Dryer, G., ‘Finland counter-drone firm gains foothold in US’, *Defense News*, 15 May 2016, p. 22.

[137] Stone, A., ‘Counter-drone tech requires constant improvement, former DoD official says’, *C4ISRNET*, 5 May 2017, <http://www.c4isrnet.com/articles/counter-drone-tech-requires-constant-improvement-former-dod-official-says?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB%2005.08.2017&utm_term=Editorial%20-%20Military%20-%20Early%20Bird%20Brief>.

[138] Stone, A., ‘Counter-drone tech requires constant improvement, former DoD official says’, *C4ISRNET*, 5 May 2017, <http://www.c4isrnet.com/articles/counter-drone-tech-requires-constant-improvement-former-dod-official-says?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB%2005.08.2017&utm_term=Editorial%20-%20Military%20-%20Early%20Bird%20Brief>.

[139] Williams, H., ‘Unmanned and unguarded: operators and industry look to close a defence gap’, *Jane’s International Defence Review*, vol. 50 (May 2017), p. 52.

[140] Williams, H., ‘Unmanned and unguarded: operators and industry look to close a defence gap’, *Jane’s International Defence Review*, vol. 50 (May 2017), pp. 52-53.

On 19-20 September 2017 a Countering Drones LIVEdemo forum will be convened in Geneva.[141]

2.2. Development trends

UAV operating parameters include weight, altitude, speed, and sensor configuration. UAVs have to be able to operate or communicate with each other in semi-isolation from the controllers because of inter alia short lines-of-sight and GPS signal blockages (or blocking) in urban areas.

A quadrotor UAV sensor suite typically comprises: (*a*) a 3-axis gyroscope, (*b*) a 3-axis accelerometer, (*c*) a 3-axis magnetomer, (*d*) pressure sensors, (*e*) sonar sensor, (*d*) GPS unit, and (*e*) payload.[142] Guidance, navigation, and control (GNC) algorithms provide the necessary degree of UAV autonomy and data fusion.[143]

The behaviour of UAVs must be evaluated by means of model checking. Since UAVs are reactive systems (i.e., 'systems that maintain constant interaction with the environment in which they operate'), programmes have been developed to model such systems, including 'concurrent programmes', and 'embedded' and 'process control' programmes.[144] Input-output behaviour models are not applicable. This is because such models do not capture the changes between one state ('an instantaneous description of the system that captures the variables at a particular instant of time') as it transitions to another state.[145] Thus, for example, Kripke structure (or Kripke modeling) is a type of state transition graph that can be used to reflect the behaviour of reactive systems in an autonomous/semi-autonomous platform system context.[146]

A key focus is improving the integration of sensor software with UAV navigation systems. With respect to autonomy, in 2016 a Swiss research team tested a prototype Search and Rescue (SAR) UAV system that is equipped with 'deep learning' neural network software to map hiking trails in the

[141] ASDEvents, 'Countering drones LIVE demo forum', <https://www.asdevents.com/event.asp?id=16092&utm_source=ASDNews&utm_medium=affiliate&utm_campaign=ASDNews_Mainblock&utm_content=logo&guid=3CD76B21-D118-4B10-9FD8-C9DF416376F0&hash=>.

[142] Chua, C. N., *Integration of Multiple UAVs for Collaborative ISR Missions in an Urban Environment* (Naval Postgraduate School: Monterey, Sep. 2012) (unclassified), p. 13.

[143] Chua, C. N., *Integration of Multiple UAVs for Collaborative ISR Missions in an Urban Environment* (Naval Postgraduate School: Monterey, Sep. 2012) (unclassified), pp. 13-14.

[144] Sirigineedi, G., 'Modeling and verification of multiple UAV mission using SMV', *Formal Methods for Aerospace* (2009), p. 3.

[145] Sirigineedi, G., 'Modeling and verification of multiple UAV mission using SMV', *Formal Methods for Aerospace* (2009), p. 3.

[146] Sirigineedi, G., 'Modeling and verification of multiple UAV mission using SMV', *Formal Methods for Aerospace* (2009), p. 3.

Alps.[147] The trials yielded approximately 20 000 images which were used to identify the hiking trails with 85 per cent accuracy.[148]

Power consumption requirements (especially battery life and weight of power plants) comprise another constraint. Most batteries are currently alkaline or lead acid-based. Lithium ion battery applications for unmanned platforms has yet to achieve widespread use due to a tendency for them to catch fire.[149] That said, Japan intends to equip its diesel-electric submarines with lithium-ion batteries (the first country to do so).[150] In addition, Open Water Power (OWP) has developed an aluminum-based battery that is less prone to catching fire and which could extend UUV ranges tenfold.[151]

Controlling platforms through virtual reality gloves is another possible UAV technology development focus. In this regard, recent published results of a lab on a glove concept funded by the Defense Threat Reduction Agency (DTRA) may be relevant.[152]

UAVs have also been adapted for counter-improvised explosive device (C-IED) missions (albeit ground reconnaissance for prior identification may be required initially).[153] Finally, unmanned surface vehicles (USVs) can serve as off-shore missile platforms.[154]

[147] *Search and Rescue: New Technology Making a Difference* (Defence IQ: 2017), p. 2 (unclassified). The Swiss group is not named.

[148] *Search and Rescue: New Technology Making a Difference* (Defence IQ: 2017), p. 2 (unclassified). The Swiss group is not named.

[149] Anonymous, Unmanned underwater vehicles: a clever solution', *Economist*, vol. 422, no. 9031 (11-17 Mar. 2017), pp. 75-76. For corrections to the print article, see <http://www.economist.com/news/science-and-technology/21718492-armed-forces-are-among-those-interest-aluminium-batteries-could-let>.

[150] Takahashi, K., 'Japan to equip future Soryu-class submarines with lithium-ion batteries', *Jane's Defence Weekly*, vol. 54, no. 10 (8 Mar. 2017), p. 16. On 13 March the Japan Maritime Self-Defense Force (JMSDF) took delivery of its eighth Soryu-class submarine from Kawasaki Heavy Industries (KHI). Rahmat, R., 'Japan receives eighth Soryu-class sub', *Jane's Defence Weekly*, vol. 54, no. 12 (22 Mar. 2017), p. 16.

[151] Anonymous, Unmanned underwater vehicles: a clever solution', *Economist*, vol. 422, no. 9031 (11-17 Mar. 2017), pp. 75-76. For corrections to the print article, see <http://www.economist.com/news/science-and-technology/21718492-armed-forces-are-among-those-interest-aluminium-batteries-could-let>.

[152] 'The new wearable, flexible glove biosensor carries out the sampling and electrochemical biosensing steps on different fingers, with the thumb finger used for collecting the nerve-agent residues and an enzyme immobilized on the index finger. The researchers created stretchable inks to print the collection and sensing elements on these fingers. Detection of the collected residues is performed when the thumb touches the printed enzyme-based organophosphate biosensor on the glove index finger. So, a user would swipe the thumb of the glove on a surface for testing, then touch the thumb and index fingers together for the electrochemical analysis. For real-time results, the voltammetric data are sent via a reusable Bluetooth device on the back of the glove to a user's mobile device. Testing showed that the glove could detect organophosphate pesticides methyl parathion and methyl paraoxon on various surfaces—including glass, wood and plastic—and on produce. The researchers say the sensor could be used in both security and food safety settings'. Rupesh, K. M., et al., 'Wearable flexible and stretchable glove biosensor for on-site detection of organophosphorus chemical threats', *ACS Sensors* (3 Mar. 2017), <http://pubs.acs.org/doi/pdfplus/10.1021/acssensors.7b00051>; and Anonymous, '"Lab-On-A-Glove" could bring nerve-agent detection to your fingertips', CBRNEcentral.com, 22 Mar. 2017, <https://cbrnecentral.com/lab-glove-bring-nerve-agent-detection-fingertips/10635/>.

[153] Bechtel, W., et al., *Roving UAV IED Interdiction System* (Naval Postgraduate School: Monterey, California, 1 Mar. 2011), unclassified.

[154] E.g., Williams, H., 'Rafael launches Spike missiles from Protector USV', *Jane's International Defence Review*, vol. 50 (Apr. 2017), p. 28.

Proof-of-concept research has also been carried out to solve the problem of UAVs to follow a person or group while maintaining a fixed distance based on visual camera inputs.[155]

Looking ahead, the use of drones—especially small ones—entails ensuring they remain within defined air spaces (including within urban environments. There are sharp changes in of weather (updrafts and downdrafts). The drive to use many drones means a drive in mapping and understanding micro-weather patterns.

Human-machine interface applications could be further considered by contrasting them against brain imaging techniques.[156] Satellite communications systems and technology developments in the civil and defence sectors are intertwined and continue to evolve.[157] Due to weight and power requirements, most work on detect and avoid (DAA) systems has traditionally focused on larger, higher-flying UAVs.[158] However, this is changing partly to take into account low-altitude package deliveries, potential automated taxi services and, perhaps, the employment of mUAV swarms (e.g., for persistent environmental monitoring or to support law enforcement operations).

Work will also continue on measures to enhance UAV survivability in contested environments. This includes adapting measures from manned systems such as chaff and flare dispensers, incorporating radar warning receivers, employment of radio frequency (RF) decoys and the use of directed infrared (IR) systems.[159] However such measures have SWaP constraints.[160]

Another UAV development priority is to improve connectivity of wireless networks, and the speed and carrying capacity of wireless networks. Currently there are 4G networks. By about 2020 many of these networks will be

155 Gottleben, E., *Vision based Control of an Autonomous UAV* (Linköping University (Dept. Of Electrical Engineering, Division of Automatic Control): Linköping, Sweden, 2015), Master of Science thesis in control technology.

156 E.g., computational axial tomography, cranial ultrasound, diffuse optical imaging, event-related optical signal, magnetic resonance imaging, functional magnetic imaging, magnetoencephalatography, positron emission tomography, single photon emission computed tomography. Hart, J., ‘Autonomous/semi-autonomous platform technologies in an arms control and security and defence context’, slide 29. Presented at *Workshop on HF & Autonomous Systems*; Netherlands Aerospace Centre; 7 June 2017; Amsterdam. See Neuralink’s 2017 profile: (*a*) microfabrication engineer (MEMS & sensors), (*b*) mechatronics engineer, (*c*) polymer scientist, (*d*) medical device engineer, (*e*) electrochemist, (*f*) analogue and mixed signal engineer, (*g*) software engineer (embedded systems and firmware), (*h*) software engineer (infrastructure and tooling), (*i*) biomedical engineer, (*j*) harware systems integration engineer, (*k*) in-vitro electrophysiologist, (*l*) in-vivo electrophysiologist, (*m*) microelectronics packaging engineer, (*n*) principal scientist (advanced interfaces), (*o*) senior scientist (brain-machine interfacing), (*p*) senior scientist (neuroscience), (*q*) senior technician for immunohistochemisry, and (*r*) software engineer (medical imaging). See also Le Bihan, D., *Loooking Inside the Brain: the Power of Neuroimaging* (Princeton University Press, 2015). Transl. by T. Fagan.

157 Donaldson, P., ‘SATCOM capability and next-generation systems’, *Military Technology*, vol. 61, no. 6 (2017), pp. 92-93.

158 Warwick, G., ‘Avoidance for all: compact sense-and-avoid system scaled for drones, electric vertical-takeoff-and-landing uses’, *Aviation Week & Space Technology*, vol. 179, no. 18 (26 June-9 July 2017), p. 47.

159 Williams, H., ‘Unmanned and unguarded: operators and industry look to close a defence gap’, *Jane’s International Defence Review*, vol. 50 (May 2017), p. 51.

160 Williams, H., ‘Unmanned and unguarded: operators and industry look to close a defence gap’, *Jane’s International Defence Review*, vol. 50 (May 2017), p. 51.

replaced by 5G networks that, by some accounts, will be between 10 and 100x faster than current 4G networks.

3.0 Unmanned platform operating environment

[under development]

4.0 Unmanned platforms in a chemical weapons verification context

DTRA and US Army specialists have experimented with placing chemical weapons detectors and sample collectors on UAVs since at least 1998 (e.g., with an ion mobility spectrometry [IMS] detector systems).[161]

Various defence planners have considered the concept of placing Mission-Adaptable Chemical Sensor (MACS) onto a UAV.[162] One MACS project sought, in part, to develop a system that can assay air samples at circa 1 bar [c. 1 atmosphere] using a sub-millimeter wave precision spectrometer-based sensor to within 7 minutes.[163]

Singapore's Defence Research Organisation (DSO) National Laboratories have developed a tool that incorporates weather data for informing decisions to evacuate potentially chemical weapons contaminated public areas.[164] This system is called the Hazardous Material (HAZMAT) Decision Support Tool.[165] It collects data from inter alia environmental sensors, and weather stations and gives estimates of the nature and direction of toxic plumes.[166] The defence establishment has also developed a portable Scentmate Kit that has a throughput of screening capacity of up to 96 people for organophosphorus nerve agent exposure per hour.[167] The defence establishment seeks to commercialize these two tools within three years.[168]

Rheinmetall has developed an all-terrain, amphibious-capable unmanned ground vehicle (UGV) whose projected missions include: casualty removal,

[161] Everts, S. and Davenport, M., 'Drones detect threats such as chemical weapons, volcanic eruptions', *Chemical & Engineering News*, vol. 94, no. 9 (22 Feb. 2016), pp. 36-37

[162] Reiss, K. [Patten, F.], *Mission-Adaptable Chemical Sensor (MACS)* (US Army Research Office: Research Triangle Park, North Carolina, 27 Mar. 2009). Contract performed by Smart Transitions, LLC (Oakton, Virginia) for US Defense Advanced Programs Agency (Strategic Technologies Office), unclassified. Keith Reiss is identified as the author, except on the cover page which lists Frank Patten as the author.

[163] Reiss, K. [Patten, F.], *Mission-Adaptable Chemical Sensor (MACS)* (US Army Research Office: Research Triangle Park, North Carolina, 27 Mar. 2009), pp. 6 & 10.

[164] Ying, L. L., 'Singapore develops quick diagnostic tools to deal with chemical attacks', *Channel News Asia*, 21 Mar. 2017, <http://www.channelnewsasia.com/news/singapore/singapore-develops-quick-diagnostic-tools-to-combat-chemical/3613038.html>.

[165] Ying, L. L., 'Singapore develops quick diagnostic tools to deal with chemical attacks', *Channel News Asia*, 21 Mar. 2017, <http://www.channelnewsasia.com/news/singapore/singapore-develops-quick-diagnostic-tools-to-combat-chemical/3613038.html>.

[166] Ying, L. L., 'Singapore develops quick diagnostic tools to deal with chemical attacks', *Channel News Asia*, 21 Mar. 2017, <http://www.channelnewsasia.com/news/singapore/singapore-develops-quick-diagnostic-tools-to-combat-chemical/3613038.html>.

[167] Ying, L. L., 'Singapore develops quick diagnostic tools to deal with chemical attacks', *Channel News Asia*, 21 Mar. 2017, <http://www.channelnewsasia.com/news/singapore/singapore-develops-quick-diagnostic-tools-to-combat-chemical/3613038.html>.

[168] Ying, L. L., 'Singapore develops quick diagnostic tools to deal with chemical attacks', *Channel News Asia*, 21 Mar. 2017, <http://www.channelnewsasia.com/news/singapore/singapore-develops-quick-diagnostic-tools-to-combat-chemical/3613038.html>.

CBRN reconnaissance, communications relay, logistics, surveillance, weapons platform.[169]

Many defence contractors have developed integrated sensor systems and software packages to provide near real-time field contamination profiles.

In 2014 Médecins Sans Frontières (MSF) tested, with the permission of Papua New Guinea (PNG) authorities, the UAV transport of sputum turberculosis samples in the country which took 1 hour (as compared to 4hrs by vehicle).[170] Chikwanha and Pujo identify the following factors for further consideration: possible legal questions, health concerns associated with biological sample transportation, ethical questions and the use of UAVs in armed conflict zones.[171]

[169] Williams, H., 'Rheinmetall develops multipurpose UGV', *Jane's International Defence Review*, vol. 50 (Apr. 2017), p. 25.

[170] Chikwanha, I. and Pujo, E., 'New technology for an old disease: unmanned aerial vehicles for tuberculosis sample transport in Papua New Guinea', <https://www.msf.org.uk/sites/uk/files/1._2_chikwanha_new_operational_models_ocp_sv_final_0.pdf>.

[171] Chikwanha, I. and Pujo, E., 'New technology for an old disease: unmanned aerial vehicles for tuberculosis sample transport in Papua New Guinea', <https://www.msf.org.uk/sites/uk/files/1._2_chikwanha_new_operational_models_ocp_sv_final_0.pdf>.

5.0 Unmanned platforms in a nuclear weapons verification context

Seismic technology is the principal means by which states have detected and characterized nuclear explosions.[172] The 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT) is the international legal basis against nuclear warfare.

Multilateral nuclear weapons disarmament and arms control treaty regimes embody managed access provisions whereby inspectors are to be afforded sufficient access by the host party to permit the inspectors to fulfill their mandates.

Autonomous and semi-autonomous platform technologies are considered within the framework of the CTBT. The CTBTO PrepCom operates a verification network (International Monitoring System, IMS) of 337 monitoring facilities that employ four technologies: seismic, hydroacoustic, infrasound and radionuclide.

[172] Ford, S. R., et al., *Trends in Nuclear Explosion Monitoring Research & Development: a Physics Perspective*, rpt. no. LA-UR-17-21274 (Dept. of Commerce: Alexandria, Virginia, June 2017), unclassified. For historical perspectives of nuclear weapons programme monitoring, see George Washington University, ‘Electronic briefing books, nuclear history’, <http://nsarchive.gwu.edu/NSAEBB/index.html>.

6.0 Chemical Weapons Convention context[173]

As with other multilateral disarmament and arms control regimes, CWC verification provisions provide for 'managed access' principles whereby inspectors are to be afforded access by the inspected party that is sufficient for the team members to fulfill their inspection mandates.

The default position of the CWC Member States is to limit the cost, scope and level of intrusiveness of the routine declaration and verification regime to that deemed to be sufficient. Some OPCW verification is devoted to confirm the non-production of chemical weapons by the chemical industry, while other verification is devoted to chemical weapon-related facilities (e.g., any facility that has produced chemical weapons at any time since 1 January 1946 and chemical weapon storage and destruction facilities).

OPCW approved analytical techniques comprise gas chromatography (GC), infrared (IR), mass spectrometry (MS) and nuclear magnetic resonance (NMR). The OPCW Central Analytical Database (OCAD) contains c. 5000 CWC-listed chemicals—mainly GC/MS mass spectrometry and retention indices. Blinding software that gives a 'yes' or 'no' response may be employed by the OPCW's field deployable GC/MS equipment. The OPCW has developed procedures to employ—subject to authorization by the inspected State Party—supplemental (including commercial) databases. Such procedures have to be balanced against requirements of protecting sensitive proprietary chemical industry information.

Conceptually the OPCW approved inspection equipment is informed by: List of Approved Inspection Equipment Annex 2: General Operational Requirements and Common Criteria for All Inspection Equipment.[174] Key documents concerning inspection equipment include:

-Understanding with respect to the adoption of the list of approved equipment (C-I/DEC.71),

-Procedures for the inspection of equipment (C-I/DEC.7),

-Decision on the use of approved equipment during on-site inspections (C-I/DEC.50),

-Decision on measures in relation to approved equipment following completion of inspection activities (C-I/DEC.51),

-Procedures for updating the list of approved equipment (C-7/DEC.20), and

-Procedures for revising the technical specifications for approved equipment (EC-31/DEC.8).

[173] Operational linkages in a CWC context will, in principle, be elaborated in a later iteration of this working paper.

[174] 'Decision, list of approved inspection equipment with operational requirements and technical specifications', OPCW document C-I/DEC.71, 30 Nov. 2010; and 'Decision, list of approved equipment with operational requirements and technical specifications, corrigendum', OPCW document C-I/DEC.71/Corr.1, 23 May 1997.

A key document concerning sampling and analysis during IAU, is the Understanding on sampling and analysis during investigations of alleged use (C-I/DEC.47).

The OPCW affords National Authorities (NAs) the opportunity to familiarize themselves with current approved inspection equipment.[175]

The OPCW identified four key CWC provisions in its 2010 decision concerning approved inspection equipment specifying operational requirements and technical specifications.[176]

[175] For the 2016 list of approved inspection equipment, see 'Note by the Technical Secretariat, information for familiarisation purposes for National Authorities of States Parties on approved inspection equipment', OPCW document S/1375/2016, 18 Apr. 2016.

[176] 'Decision, list of approved inspection equipment with operational requirements and technical specifications', OPCW document C-1/DEC.71, 30 Nov. 2010, p. 3.

7.0 Recommendations

Institutionally it may be useful to examine how the Organization for Security and Co-operation in Europe (OSCE) has integrated UAVs into its work.[177]

7.1. Policy

-Review overarching primary and secondary policy issues as they pertain to UAVs in general and a CWC context in particular (i.e., a broad mapping exercise).

-Principles of autonomy (in general, in CWC context).

-Understandings and definitions of 'sensitive' applications (technology, and platform-specific), including in a CWC-relevant context (e.g., for possible inclusion on approved inspection equipment list, observing the principle of equitable geographic distribution, potential relevance of NTM and NTM-related processes).

-Potential relevance of existing OPCW standard operating procedures SOPs and WIs.

-Relevance and potential applicability of strategic trade controls.

-Relevance and potential applicability of national security regulations.

-Relevance and potential applicability of human health and safety regulations and best practices.

-Relevance and potential applicability of environment safety regulations.

-Relevance and potential applicability of national, regional and international governance structures (e.g., 'bottom- up' self regulation).

-Relevance and potential applicability of work streams by OPCW organs and subsidiary bodies.

-Relevance and potential applicability of bodies (e.g, working groups) on UAV-relevant topics that OPCW currently interacts with.

-Review rules and handling procedures for information derived from operation of autonomous/semi-autonomous platforms (e.g., to support or to inform the work of non-OPCW bodies, including the UN, and relationship with OPCW Confidentiality Policy).

[177] See Request for Proposals, Supply and delivery of two (2) small mid-range UAVs for the OSCE Special Monitoring Mission to Ukraine (SMM), <http://www.dgmarket.com/tenders/np-notice.do?noticeId=14842263>.

7.2. Operational or technical

-Review systems engineering models processes for possible unmanned autonomous/semi-autonomous platform CWC-relevant applications.

-Implementation of the principles of autonomy.

-Review status and potential relevance of COTS and related factors (e.g., supply chain management and outsourcing trends and practices).

-State-of-the-art control systems and their modeling.

-Review the status and potential applicability of STL signal technology.

-Review the status and potential applicability of PNT technologies and delivery packages.

-Review the status and potential applicability of crowd sourcing techniques and associated technologies.

-Review the status and potential applicability of machine learning techniques and associated technologies.

-Review potential effects of SAR autonomous/semi-autonomous platform operations in context of inter alia OPCW field deployments/operations.

-Review potential relevance of NATO Standardization Agreement 4586 and similar (i.e., standard interfaces of UCS for NATO interoperability requirements.

-Review role of USVs to support maritime removal operations.

8.0 Conclusions

Autonomous and/or semi-autonomous platform-based technologies may profoundly affect the nature and understanding of biological chemical, and nuclear disarmament and arms control.

In the chemical sector, such platforms may provide near real time information on dispersions of toxic chemicals and principal (key) degradation products, as well as authoritative data on wind, moisture, and particulates/contaminants.[178] Such platforms could also be used for transporting samples and for ensuring more secure communications. Such platforms could serve as a type of tamper-resistant 'inspector seal' to ensure that items remain undisturbed in the absence of inspection team members, particularly in armed conflict zones.

It may become feasible to adapt ground penetrating radar (GPR) technologies (or similar) into networked, low-cost, COTS quadcopters for persistent monitoring, including checking whether a vehicle has passed into a facility (e.g., by detecting compacting of soil). Such platforms could also be employed to support individuals in the field (e.g., for inspector safety and security, including through the use of facial recognition software).[179] Civil society may have the capacity to independently deploy networked UAV platforms to conduct parallel verification monitoring.

Networked UAVs may become ubiquitous, with implications for how inspection site perimeters are agreed (e.g., through the employment of UAV survey data which, in turn, may not match other data), as well as for ensuring authorized inspector movement remains unimpeded during inspections and longer term monitoring work. Highly capable autonomous systems may become adaptable within months or days.[180]

In short, the CWC Member States could, out of an abundance of caution, give further structured consideration to S&T developments (evolving or disruptive) so as to better anticipate possible fundamental shifts in CWC implementation practice.

[178] E.g., Technologies for scattering patterns and images from single laser-trapped airborne aerosol particles could be mounted on autonomous/semi-autonomous platforms. See Fu, R., et al., 'Elastic back-scattering patterns via particle surface roughness and orientation from single trapped airborne aerosol particles', *Journal of Quantitative Spectroscopy & Radiative Transfer*, vol. 187 (2017), pp. 224-231.

[179] As of May 2017 the OPCW had verified the destruction of 24 of the 27 chemical weapon production facilities (CWPFs) declared by Syria. The remaining three, consisting of one aircraft hangar and two above-ground stationary facilities, remain outside Syrian government control. Nakamitsu, I., 'Briefing to [the] Security Council on the implementation of Security Council resolution 2118 (2013) on the elimination of the chemical weapons programme of the Syrian Arab Republic and update on the activities of the OPCW-UN Joint Investigative Mechanism (JIM)', 23 May 2017, New York.

[180] The DSB has observed the following timeframes: (*a*) platforms (20-50+ years), (*b*) infrastructure (10-25+ years), (*c*) mobile weapons (5-20+ years), (*d*) electronics (1-5 years), and (*e*) IEDs and software (days to months). US DOD, *Seven Defense Priorities for the New Administration: Report of the Defense Science Board (*DOD: Washington, DC, Dec. 2016), p. 64.

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Annexe 1. Select autonomous and semi-autonomous platforms

Unit	Description
Aaryon Scout	Manufactured by Aeryon Labs Inc.
Ababil II	Iran Aircraft Manufacturing Industries.[zz]
Ababil-5	Iran Aircraft Manufacturing Industries.[zz]
Ababil-B	Iran Aircraft Manufacturing Industries.[zz]
Ababil-T	Iran Aircraft Manufacturing Industries. UCAV.[zz]
Aerolight, Aerosky, Aerostar	Aeronautics Defence Systems (Israel).[zz]
Aerosonde®	SUAS manufactured by Textron Systems. 14 hr endurance, 9.1kg payload, 140km range. ISR, aerial survey/geospatial mapping, border monitoring, critical infrastructure monitoring.[bb]
Air Wasp	UVision Air Ltd. (Israel).[zz]
Aist [Stork]	Institute Kulohu NII OAO. [zz]
Albatross	Yakovlev (Russia). Ship-based short-range V/STOL UAV.[zz]
Altius	Sokol and Tranzas (Russia). UAV and UCAV.[zz]
Altius-M	Strategic UAV planned for entry into service in 2019 (Russia). [bbb]
Alitius Mk II	Man. by Aurora Integrated Systems Ltd. (India?).[zz]
Amazon Prime Air	30 min. package delivery programme.[cc]
ANDROS WOLVERINE	UGV for underground combat.
Anjian (Dark Sword)	Man. by Shenyang Aircraft Corporation. Stealth UAV/UCAV.[zz]
Anka (Phoenix)	Turkish UAV man. by Turkish Aerospace Industries Inc. Anka +A [UCAV] . Anka-TP (UCAV/longrange UAV). [zz] 10 Anka-S ordered for delivery in Oct. 2013 are expected to be delivered by 2018. Equipped with Roketsan MAM-L PGBs, Cirit guided rockets and UMTAS long-range anti-tank missiles.[ww]
AP3 System	AWES tethered aircraft that converts wind into electricity. Developed by ampyxpower (NL).
Aqua/Terra Puma	Manufactured by AV AeroVironment.[gg]
Aquila	Solar powered unmanned plane by Facebook. First tested in June 2016. Business model is to link the planes at 60000ft for wireless network coverage.
AR4 Evolution	Manufactured by Tekever (Portugal). EO/IR, laser illuminator, chem/bio sensors. 20 km range. 2 hr. endurance. [l] ArrowliteManufactured by Stark Aerospace (USA). EO/IR, laser illuminator. 15 km range. 2.75 hr. endurance. [l]
ARI-1T	Aselsan Inc. (Turkey). VTOL ISR UAV.[zz]
ASN-15	Man. by Xian ASN Technical Group (China). [zz]
ASN-104/105B	Man. by Xian ASN Technical Group (China. ISR. [zz]

ASN-206	Man. by Xian ASN Technical Group (China).[zz]
ASN-207	Man. by Xian ASN Technical Group (China).[zz]
ASN-209	Man. by Xian ASN Technical Group (China).[zz]
ASN-211	Man. by Xian ASN Technical Group (China).[zz]
ASN-213	Man. by Xian ASN Technical Group (China).[zz]
ASN-216	Man. by Xian ASN Technical Group (China).[zz]
ASN-217	Man. by Xian ASN Technical Group (China).[zz]
ASN-229A	Man. by Xian ASN Technical Group. MALE UAV/UCAV.[zz]
Aura	Defence Research and Development Organisation (India). Attack stealth UCAV.[zz]
AV500W	Man. by AVIC. Armed VTOL under development at CHRDI. Weaponized model of AV500.[hh]
AW series	Beijing Wisewell Avionics Science and Technology Company.[zz]
BA-5	Shenyang Aircraft Corporation (China).[zz]
Banghyun	Class of DPRK drones. 162km/hr. 20-25kg payload.[v]
BatHawk	IR sensor, camera, telemetry-equipped fixed wing bespoke system by UAV & Drone Solutions. Anti-poacher surveillance in Malawi since 2015. Supported by funding from WWF, including $5 (US) million from Google. 8hr. duration.[m]
Baykus	Turkish Aerospace Industries Inc.[zz]
Bayraktar-B	Turkish manufacture (Baykar).[zz] 5kg weight. 20km range.
Berta	ENICS JSC (Russia).[zz]
Bird Eye 100	IAI manufacture. mUAV.[zz]
Bird Eye 400	IAI manufacture. Surveillance mUAV.[zz]
Black Eagle 50 (STD-5 Helivision)	Steadicopter (Israel).[zz]
Black Hornet	Nano UAS by Flir Systems.
BlueBird ThunderB	UAV (Israel).
Blueye	BlueBird Aero Systems Ltd. (Israel).[zz]
Bluefin 21	Underwater unmanned system. 21 inch diameter.[i]
Blue Horizon/Sting	EMIT Aviation Consulting (Israel).[zz]
Boeing Echo Voyager	Underwater unmanned system. 11 foot diameter.[i]
Boomerang	BlueBird Aero Systems Ltd. (Israel).[zz]
Bora (Gust)	Vestel Defence Industry AS (Turkey).[zz]
Breeze	Yuneec man.
Buster	mUAV man. by Mission Technologies, Inc. 1.4kg payload.[ii]
BZK-005	Beijing University of Aeronautics and Astronautics. HALE UAV.[zz]
CAIG Wing Loong	Loong 1 developed and manufactured by CADI.[q]
Cai Hong 4 (Rainbow 4/CH-4)	CASC manufacture. CH-4 is armed variant. In service with Saudi armed forces.
Cai Hong 5 (Rainbow 5/CH-5)	CASC manufacture. MALE, MTOW of 3300kg, 1200kg payload, 250-2000km range, has design similarities to MQ-9 Predator B/Reaper UAV.[x]
Caldiran	Turkish Aerospace Industries Inc.[zz]
Canard	Spanish Company. UAV-based application for

	checking PAPI system inspection at airports; and UAV sensor platform configurations for industrial facility inspections (lighting, corrosion, air quality, etc.).
Casper 200/250	Top I Vision (Israel).[zz]
Casper 350	Top I Vision (Israel).[zz]
CH-3/3A (Rainbow)	Man. by China Aerospace Science and Industry Corporation. Armed tactical MALE UAV.[zz]
CH-4	Man. by China Aerospace Science and Industry Corporation.[zz]
CH-91	Aerospace Long-March International Trade Company Ltd. [zz]
CH-92	Aerospace Long-March International Trade Company Ltd. ISR and strike UAV/UCAV.[zz]
CH-901	Man. by Aerospace Long-March International Trade Company Ltd.[zz]
Cloud Shadow	China manufacture. Developed by AVIC CAC.[o]
Camcopter S-100	Autonomous surveillance helicopter man. by Schiebel.
CANTAS A (Advanced)	Developed by Krill Design and New Space Technologies (Czech Republic). Vertical takeoff.[z]
CANTAS E (Endurance)	Developed by Krill Design and New Space Technologies (Czech Republic). Vertical takeoff.[z]
Cendence	DJI manufacture.
CL-289	Canadair (Turkey?).[zz]
Coyote[a]	C-UAS/ISR/hurricane measurement. Platform manufactured by Raytheon. To be used by US Army by end of 2017. NOAA has used since early 2016.
Crystolsky	DJI manufacture.
Delilah-GL	IMI (Israel).[zz]
Disco FPV	Man. by Parrot.
DJI Matrice 100	Quadcopter.
DJI Phantom	Quadcopter.
DOGO Robot	Tracked UGV man. by General Robotics Ltd. (Israel) for surveillance and/or secure weapon delivery (e.g., a Glock 26 9mm pistol).
Dominator II	Aeronautics Defence Systems (Israel).[zz]
DOZOR 50 [former DOZOR 2]	Trans Avia (Russia). Surveillance UAV.[zz]
DOZOR-600 [former DOZOR 3]	Tranzas-manufactured MALE (Russian Federation).
Dragonfly 2000	EMIT Aviation Consult (Israel).[zz]
Dragon[dragan] Eye	1m wingspan. 500 g payload. Vulcanology.[s]
Dragan Flyer X6	Launched 2008.[jj]
EBEE	Man. by senseFly (owned by Parrot Company).
Echo Voyager	Boeing manufactured USV.
EHang 184[b]	Human transport. 1-person/passenger quadcopter approved in principle for service in UAE starting in late 2017. Chinese manufacture. 100 km/hr @ 300m. 30 min. travel range. 120 min. recharge time.

EHang Falcon B[c]	Commercial drone (various). China manufacture (EHang).
Eleron-3 (T-23)	ENICS JSC (Russia). Tactical mUAV.[zz]
Eleron-10 (T-10)	ENICS JSC (Russia).[zz]
Erasmus	MKU Private Ltd. (India).[zz]
ETOP	IAI Ltd. (Malat UAV Division) (Israel). Tethered unmanned platform.[zz]
EELUME	Remotely- controlled underwater inspection and repair vessel. Man. by Konigsberg Maritime.
EyeBall	Throwable UGV for underground combat developed by Mistral Group's ODF Optronics.
EyeDrive	UGV for underground combat.
Expert	Yakovlev (Russia). Ship-based short-range V/STOL UAV.[zz]
Falco	Used by Pakistan.[aa] MALE UAV man. by Italian sensors developer Selex Galileo; co-produced starting in 2009 by Pakistan Aeronautical Complex (PAC) located at Kamra facility (Punjab province). Can carry two missiles with payload of up to 25kg.[kk] Involvement of Leonardo.
Falcon 600/Firebee	Ryan Aeronautical Company.[zz]
FireBee	Kadet Defence Systems (India?)[zz]
FK-11/12	Huahang Airship Development Group (China).[zz]
Fly Eye	Manufactured by WB Electronics (Poland). EO/IR, laser pointer (Safran configuration). 30 km range. 3 hr. endurance.[l]
Flying Sea Glider	Combination UAV/UUV under development by NRL.
Forpost	Tactical and strategic UAV, entered service 2013 (Russia).[bbb] Battlefield support. Russian-manufactured version of Israel's IAI Searcher 2.[j] Deployed during 2016 battle for Aleppo.
Fury	UAV manufactured by Lockheed Martin.
Ghost	UAV developed by Israel's IAI Malat. 600 g. payload.[t]
Ghostdrone 2.0[c]	AAV. Mobile phone app-controlled. China manufacture (EHang).
Gnat 750/I-GNAT ER	General Automics. MALE UAV.
Gongji-1 (Attack-1)	China manufacture.
Gonshchik	Tactical and strategic UAV planned for entry into service in (or after) 2020 (Russia).[bbb]
Gray Eagle	UAS. US-deployed to ROK.
Gremlins	DARPA swarming, recoverable UAS development programme.
Griff 300	A 'megadrone' system launched in Dec. 2016 by Griff Aviation which is said to possess a qualitatively higher lift capacity (i.e., 300kg) and 45 min. endurance and eight propellers. The Griff 800 [ie, 800 kg payload] is under development.[w]
Gözcü	Turkish Aerospace Industries Inc.
H520	Yuneec man.
H920 Plus	Yuneec man.

Harfang	MALE UAS. Max. speed 110 knots, max. altitude 25000ft. Man. by Airbus.
Harop	SEAD. Israel Aerospace Industries man.[zz] Loitering munition.
Harpy	Developed by IAI. Loitering (anti-radar) attack UAV/UCAV.[zz]
Harrier Hawk	AVIC Defence Company (China).[zz]
Hermes 90	Elbit Systems.[zz]
Hermes 180	Elbit Systems short-range tactical UAV.[zz]
Hermes 450	Elbit Systems tactical UAV.
Hermes 900	Elbit Systems.
Hermes 1500	Elbit Systems MALE UAV.[zz]
Hornet	AD&D (Israel).[zz]
Heron 1 (Machatz 1)	UAV manufactured by IAI. Supplied to Saudi Arabia.[p] Powered by inter alia Rotax 914 engine [designed and constructed by BRP-Powertrain (Austria)].
Heron TP (Eitan)	UAV manufactured by IAI. HALE UAV/UCAV.[zz]
HorseFly™	Truck-based package delivery system tested by UPS and developed by Workhorse.[tt]
Hoverbike P2	Man. by Malloy Aeronautics.
Hudhud 1	Yemeni opposition forces-publicly displayed as indigenous UAV. Possible copy of AeroVironment RQ-20 Puma.[r]
Hunter	IAI.[zz]
Igla	ENICS JSC (Russia).[zz]
Imperial Eagle	Aeronautical Development Establishment (Indian MOD). Close-range mUAV.[zz]
Inokhodets	Sokol and Tranzas (Russia). UAV and UCAV.[zz]
Inspire 1	DJI manufacture.
Inspire 2	DJI manufacture.
Intel® Falcon™ 8+	Drone.
Irkut-1A	Scientific Production Corporation and Irkut JSC (Russia). Tethered aerostat surveillance system.[zz]
Irkut-2F/2T	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-2M	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-3	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-10	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-20	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-60	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-200	Scientific Production Corporation and Irkut JSC (Russia).[zz]
Irkut-850	Scientific Production Corporation and Irkut JSC (Russia).[zz]
I-See	IAI (Malat UAV Division) (Israel).[zz]
Iskatel' (Searcher)	Popov Omsk Radio Factory (Russia).[zz]

I-View (Eye View)	IAI.[zz]
I-Z	Nanjing Research Institute on Simulation Technique (China).[zz]
JTARV[e]	Tactical re-supply platform. Quadrotor concept developed by US ARL and awaiting approval from OSD to be designated as JCTD. Design targets to be met at end of 3 yrs. Resupply of troops in 25-50 km range within 30 min. 455 kg payload. 3-D printable (in principle) flat airframe. Delivery in urban environment.
Jump 20	Platform. Manufactured by Arcturus.
Kapothaka	Aeronautical Development Establishment (Indian MOD).[zz]
Karayel	Vestel Defence Industry AS (Turkey). Fixed wing ISR UAV.[zz]
Karma	Karma personal drone part of GoPro product line.[ll]
Karrar	Iran Aircraft Manufacturing Industries. UCAV.[zz]
Keklik	Turkish Aerospace Industries Inc.[zz]
Klest	Yakovlev (Russia). Recon. UAV.[zz]
Knifefish	General Dynamics Mission Systems manufacture. Detection of bottom and buried mines. Deployment platform: General Dynamics Bluefin Robotics Bluefin-21.[y]
LA-17R	Strela (Lavochkin) (Russia).[zz]
Lakshya	Defence Research and Development Organisation (India).[zz]
Lancaster 5	Man. by PRECISIONHAWK.
LDUUV	Underwater unmanned system. 54 inches per side.[i]
Lijian (Sharp Sword)	China manufacture. Hongdu-Shenyang Aircraft Corporation. ISR and strike UAV/UCAV.[zz]
Little Bird H-6U[f]	Resupply, comms, surveil. Unmanned/manned helicopter. 6 hr. endurance. C2 STANAG 4586-compliant. 544-635 kg payload.
Liquid Robotics Wave Glider	Surface-submersible system.[i]
Loong Eye (Dragon Eye)	China manufacture. Chengdu Aircraft Industry Group Company. Surveillance MALE UAV/UCAV.[zz]
LN60F	Liaoning General Aviation Research Institute (China).[zz]
LT-series	China Aerospace Science and Industry Corporation. mUAVs.[zz]
Luna	German manufacture all weather ISR UAV employed in Afghanistan and Balkans.[mm] Operated by Pakistan.[aa]
M-22	Beijing University of Aeronautics and Astronautics. Small remotely-piloted helicopters.[zz]
Malazgirt	Baykar (Turkey). mVTOL helicopter.[zz]
Makani	Energy kites (based on wind turbine electricity generation principles). Acquired by Google in 2013.

Marti (Seagull)	Turkish Aerospace Industries Inc.[zz]
Matrice 100	DJI manufacture.
Matrice 200	DJI manufacture.
Matrice 600 Pro	DJI manufacture.
Mavic	DJI manufacture. Reacts to hand gestures.
MBVK-137 (KA-137)	Kamarov (Russia). Helicopter UAV.[zz]
Mi-34BP1/2	Mil Helicopters (Russia).[zz]
Micro B	BlueBird Aero Systems Ltd. (Israel).[zz]
MicroFalcon I	IMI (Israel).[zz]
Micro-UUV	Manufactured by Riptide Autonomous Solutions. 3 individually actuated control fins. GPS, WIFI-equipped. 200 m depth. 30 hr. endurance. 1-8 knot speed.[n]
Mini-Falcon I	IMI (Israel).[zz]
Mini-Falcon II	IMI (Israel).[zz]
Mini Panther	IAI.[zz]
Mini-V	Elbit Systems Ltd. (Israel).[zz]
Mohadjer 2	Qods Aviation Industries.[zz]
Mohadjer 3 (Dorna/Bluebird)	Qods Aviation Industries.[zz]
Mohadjer 4 (Hodhod)	Qods Aviation Industries.[zz]
Mosquito 1	mUAS manufactured by IAI for ISR missions, in use since 2003.[nn]
MQ-4C Triton	Man. by Northrup Grumman.
MQ-5A/5B/5C Hunter	Originally based on IAI Hunter. One of the oldest and most heavily used platforms.
MQ-8B Fire Scout	Manufactured by Northrup Grumman.
MQ-9 Reaper/Predator B	Manufactured by General Atomics Aeronautical Systems Inc. 1360kg load carry capacity.[uu]
MQ-25A Stingray	Product of US Navy UCLASS programme. Production contract expected to be awarded in 2018 with first delivery in 2021. Current applicants include Boeing, General Atomics, Lockheed, and Northrup Grumman.[oo]
MUAS-1/2	Aselsan Inc. (Turkey).
Mysterious Bee	VTOL Man. by China Electronics Technology Corporation. 180 km/hr max. speed, 36-50 km/hr speed in helicopter mode. Advertised for surveillance, target tracking and designation missions.[o]
Nazir (Harbinger)	Farnas Aerospace Company. Recon. UAV and strike UCAV.[zz]
Night Eagle	AVIC Defence Company (China). [zz]
Nishant (Dawn)	Aeronautical Development Establishment (Indian MOD).[zz]
NRUAV	IAI Ltd. (Malat UAV Division) (Israel).[zz]
Okhotnik-B/U	Medium weight UCAV planned for entry into service in (or after) 2025 (Russia).[bbb]
Optimus	1kg payload. 30 min. [1hr.] endurance. CAAI certified. Manufactured by Airbotics. First UAV granted authorization to fly fully automated without pilot/controller in Mar. 2017.[u]
Orbiter I	Aeronautics Defence Systems (Israel).[zz]
Orbiter 1K	Loitering munition UAS.

Orbiter III	Aeronautics Defence Systems (Israel). [zz]
Orbiter 4	Small tactical UAS.
Orion/Inokhodets	Tactical and strategic UAV under development with planned entry into service in 2018 (Russia).[bbb]
Orlan-10	Russian recon. UAV developed by Special Technological Centre. 1.8m monoplane, nose-mounted engine, 5km ceiling, 16hr endurance, 2.5kg payload. Deployed by Kazakhstan.[xx]
Orlan-10	Tactical UAV, entered service 2013 (Russia).[bbb]
Orlan-10E	Demonstrated at HeliRussia-2017 exhibition.
Panther	IAI.[zz]
Parrot Mambo	Man. by Parrot.
Patroller	Man. by Safran Electronics & Defence. In use by French Army. Some units fitted with Euroflir 410 optronics.
Pchela-1K	Tactical UAV, entered service 2009 (Russia).[bbb]
Pchela-1/1T [Yak-61 Shmel]	Yakovlev (Russia).[zz]
PD-100 Black Hornet	Nano rotary-wing UAV by FLIR's Prox Dynamics.[vv]
Pegasus 120	Tactical VTOL UAS. Man. by Aeronautics Group.
Pelikan (IHA-X2)	Turkish Aerospace Industries Inc.
Perdix[g]	Micro-UAV swarm. Under evaluation by SCO (US DOD).
Phantom 3	DJI manufacture.
Phantom 4	DJI manufacture.
Phantom 4 Advanced	DJI manufacture.
Phantom 4 Pro	DJI manufacture.
Picador	Aeronautics Defence Systems (Israel).[zz]
Predator	Manufactured by General Atomics Aeronautical Systems Inc. Models include: Predator A, Predator XP, Predator C Avenger. Powered by, inter alia, Rotax 914 engine [designed and constructed by BRP-Powertrain (Austria)].
Proryv-R	Yakovlev (Russia).[zz]
Proryv-U	Yakovlev (Russia). UCAV.[zz]
Puma AE	Manufactured by AeroVironment (USA). EO/IR, IR illuminator. 15 km range. 3 hr. endurance. [l]
PW-1/2	Nanjing Research Institute on Simulation Technique (China). Surveillance UAVs. [zz]
Qasef 1	Yemeni opposition forces-developed and publicly displayed as indigenous UAV. Possible copy of Iran's Ababil 2. 250cm wingspan, 120min. endurance, 150km range. Capable of carrying 30kg payload.[r]
[Quadcopter][d]	Pollination. Under development by National Institute of Advanced Industrial Science and Technology (Tsukuba, Japan). 42mm diameter.
QUBE	Quadcopter manufactured by AeroVironment Inc. Used by Swedish armed forces and police.[pp]
R-90	ENICS JSC (Russia).[zz]

R-300 (R-IHA)	Turkish Aerospace Industries Inc.
Ra'ad (Thunder)	Farnas Aerospace Company. Recon. UAV and strike UCAV.[zz]
Raqeep	Yemeni opposition forces-publicly displayed as indigenous UAV. Possibly a reassembled AeroVironment RQ-11 Raven that had previously crashed in Yemen.[r]
Rased	Yemeni opposition forces-publicly displayed as indigenous UAV. Possible copy of Skywalker hobby drone.[r]
Raven B DDL®	Military/ISR version of RQ-11B Raven®
Reaper	Operated by France in support of *Operation Barkhane* in Sahel region of Niger (2017).[g]
Reis-D	Tupolev PSC (Russia). MALE UAV recon. and BDA.[zz]
Remus 100	Underwater unmanned system. 7.5 inch diameter.[i]
Remus 600	Underwater unmanned system. 12.75 inch diameter.[i]
Riptide	Underwater unmanned system. 4.875 inch diameter.[i]
RQ-2 Pioneer	US Navy tactical battlefield UAV.
RQ-4 Global Hawk	Manufactured by Northrup Grumman. 30hr endurance. In service since 2001 with more than 200.000 mission flight hours.[qq] MQ-4C is marinised adaptation of RQ-4B Global Hawk HALE.
RQ-5/IAI RQ-5 Hunter	IAI variant (based on Northrup Grumman Hunter). UAV line.
RQ-7 Shadow	Single person-operated UAV manufactured by Textron Systems.
RQ-11 Pathfinder (Raven)	Single person-operated lightweight UAV manufactured by inter alia AeroVironment.
RQ-11 Dragon Eye/Swift	Lightweight UAV.
RQ-11B Raven®	32-81km/hr, 1.9kg weight, 60-90min endurance, 6.5oz payload (dual forward and side look EO camera nose).[ee]
RQ-16A T-Hawk	Manufactured by Honeywell. Ducted-fan VTOL micro-UAV. 35-55 km/hr. 120-3000m altitude. Used for real-time video ISR support by US forces in Iraq.[t]
RQ-20B [Block 2 Puma AE]	Small UAS.
RQ-21A Blackjack	Manufactured by Insitu.
RS-16	Manufactured by American Aerospace.
Rubezh-20/Granat-4	Tactical UAV, entered service 2013 (Russia).[bbb]
Rustom-1 (Warrior)	Defence Research and Development Organisation (India).[zz]
Rustom-2 (Warrior)	Defence Research and Development Organisation (India). MALE UAV.[zz]
S1000+	DJI manufacture.
Saeghe 1/2 (Lightening)	Qods Aviation Industries.
Saqr-1	Saudi UAV produced with Chinese support.

	2500km range, 24hr endurance, 20.000ft ceiling. Can be equipped with SATCOM, FT-9 guided bomb, and M-4/M-3 missiles.[yy]
Sarir H-110	Qods Aviation Industries. Recon. UAV and strike UCAV.[zz]
ScanEagle	Manufactured by Insitu.
Scout	IAI.[zz]
Seagull	Elbit Systems Ltd. (Israel).[zz]
Searcher 1	IAI manufacture.
Searcher 2	IAI manufacture.
Seeker	Omsk Production Association (Russia).[zz]
SH-1/SH-3	China Aerospace Science and Industry Corporation. Long-range mUAVs.[zz]
Shadow M2	UAS.
Shadow V2	Manufactured by Textron Systems.
Shahed-129	Qods Aviation Industries. Recon. UAV and strike UCAV.[zz]
Shahpar	Produced by Pakistan's Global Industry and Defence Solutions (GIDS). 50kg payload, 7hr endurance, 17000ft ceiling, 250km range.[aa]
Sheddon/Mini-Sheddon	BTA Automatic Piloting Systems Ltd. (Israel).[zz]
Shen Zhou-1/2	Shanghai Aircraft Research Institute (China). Airships[zz]
Shrike	VTOL manufactured by AeroVironment, Inc.
Shahed-129	Iranian drone having similarities to Predator.
SIERRA	Military missions. Volcano measurements.[s]
Silver Fox	Catapult-launched tactical UAV manufactured by BAE Systems (originally by Advanced Ceramics Research prior to 2009 acquisition by BAE).[rr]
Simsek (Lightening)	Turkish Aerospace Industries Inc.
Sirius Pro	Man. by MAVinci.
Skat	MIG. SEAD UCAV.[zz]
Skate	Small lightweight UAV for 1km patrol surveillance and border monitoring. Manufactured by Aurora Flight Sciences.
Skimmer	Man. by Swallow Systems Ltd (India). mUAV.[zz]
Sky Dot	Aurora Integrated Systems Ltd. (India).[zz]
Skydio [company name]	A recent startup with no product line.
Skyeye	Manufactured by BAE Systems. Used for humanitarian assistance monitoring.
Skylark I	Elbit Systems [Instro Precision–UK-based subsidiary][l] Elbit Systems.[zz]
Skylark II	No longer marketed.[l] Elbit Systems.[zz]
Skylark™ 3	Manufactured by Elbit Systems Ltd. (Israel).
Skylark C	Maritime use.[l]
Skylark I-LE	EO/IR, laser designator (I-LEX). 20 km range. 3 hr. endurance.[l]
Skylark I-LEX	EO/IR, laser designator (I-LEX). 20 km range. 3 hr. endurance.[l]
Skylark Block 2	Modified for US military requirements.
SkyRanger	Canada manufacture (Aeryon) sUAS BVLOS.[ff]
Sky Saker	China manufacture.
Skywalker X7/8	

Sky Wing (Tian Yi) 6	China manufacture.
Skyzer 100	AeroTactiX Ltd. (Israel). Recon. mUAV.[zz]
Slybird	Aeronautical Development Establishment (Indian MOD).[zz]
Snipe	Personal soldier quadcopter for visual check of surroundings controlled by tablet system. 15 min. endurance, 20mph speed. Man. by Aerovironment. First 20 delivered to USG in Apr. 2017.[dd]
Soar Bird	Nanjing University of Aeronautics and Astronautics. Remotely-piloted helicopter.[zz]
Soar Dragon	China manufacture.
Sofreh Mahi (Eagle Ray)	Iran Aircraft Manufacturing Industries. Stealth UAV.[zz]
Solo	3D Robotics. Reportedly stopped making hardware.
Spark	DJI manufacture.
Sparrow-N	EMIT Aviation Consult (Israel). Tactical mUAV and UCAV.[zz]
SpyLite	BlueBird Aero Systems Ltd. (Israel).[zz]
Spy Ranger	Surveillance. Manufactured by Thales. 14.5 kg with 2.8 m wingspan. 2.5 hr. endurance.[h] EO/IR, laser illuminator. 30 km range.2.5 hr. endurance.[l]
SQ-4	Quadcopter manufactured by BCB Robotics (Wales).
Stalker	Manufactured by Lockheed Martin. 15 km range. 2.75 hr. endurance.[l]
Stratobus	THALES. Scheduled for 2018 launch.
Strekoza	Yakovlev (Russia).[zz]
SVU-200	Ewatt Technology (Fetters Aerospace US).[zz]
Sunshine	AVIC Defence Company (China).[zz]
Takhion	Russian UAV.
TACMAV	mUAV. Currently called NightHawk. Also previously known as BatCam. Developed by ARA.
Takhion	Tactical UAV, entered service 2014 (Russia).[bbb]
Talash 1/2 (Endeavour)	Qods Aviation Industries.[zz]
TALON	UGV for underground combat.
TERP	MKU Private Ltd. (India).[zz]
Thunder B	BlueBird Aero Systems Ltd. (Israel).[zz]
Tianjyl (Sky Wing)	Chengdu Aircraft Industry (Group) Company (China).[zz]
Tipchak (Nomad)	Lutch Design Bureau JSC (Russia).[zz]
Titan	Google high altitude communications relay drone [discontinued Jan. 2017].
Tolloue 4/5	Aviation Industries Organisation (Iran).[zz]
Tracker	Manufactured by Airbus Defence & Space. EO/IR. 9 km range. 1.5 hr. endurance.[l]
Trogon	Kadet Defence Systems (India).[zz]
Tu-141 Strizh	Tupolev PSC (Russia).[zz]
Tu-143/243/300	Tupolev PSC (Russia).[zz]
Turac	Helvesan Inc. and Istanbul Technical University Aeronautics Research Centre.

Turna	Turkish Aerospace Industries Inc.
Typhoon 4K	Yuneec man.
Typhoon H	Yuneec man.
U8	China National Aero-Technology Import & Export Corporation. VTOL UAV. [zz]
UAV-X1	Turkish Aerospace Industries Inc.
Urban View	Aurora Integrated Systems Ltd. (India).[zz]
UTAP-22 Mako	Developed and manufactured by Kratos Defense and Security Solutions for function as robotic wingmen to fighter pilots.
V750	Joint venture by Brantly International Inc., Qingdao Wenquan International Aviation Investment Co. Ltd., and Qingdao Brantly Investment Consultation Co. Ltd. [zz]
Volocopter VC200	AAT under testing in Abu Dhabi with RTA approval.
Voron	Yakovlev (Russia). UAV. [zz]
VSR700 VTOL UAV	Manufactured by Airbus Helicopters. Scheduled to be test flown in 2017 as per requirements of the French Navy's Système de Drones Aériens de la Marine (SDAM).[k]
W-30/W-50	Nanjing Research Institute on Simulation Technique (China). Surveillance UAVs. [zz]
Wander B	BlueBird Aero Systems Ltd. (Israel). mUAV.[zz]
Wasp III	Manufactured by AeroVironment. Wasp AE MAV is all environment version of Wasp III.
Watchkeeper	Manufactured by Thales. CS23/STANAG 4671 standard.[ss]
Whirlwind Scout	AVIC Defence Company (China). VTOL and mUAVs. [zz]
Wing Loong (Yilong)	Developed and manufactured by CADI.[q] Chengdu Aircraft Industry (Group) Company. [zz]
Wing Loong II	Developed and manufactured by CADI. Recon., strike capable. [q]
WJ-600	China Aerospace Science and Industry Corporation. [zz] Corporation. Armed recon UAV/UCAV.[zz]
WP-13 Xianglong (Soaring Dragon/Eagle)	Guizhou Aviation Industry Group Company. HALE UAVs. Similar to UAEs ADCOM Systems-produced United 40 Block 5 UAVs – with possible Russian origin. [zz]
WZ-5 (Chang Hong 1)	Beijing University of Aeronautics and Astronautics. [zz]
WZ-2000	Guizhou Aviation Industry Group Compnay. Jet-powered UCAV.[zz]
X-Star	Man. by Autel Robotics.
X-Star Premium	Man. by Autel Robotics.
XQ-222 Valkyrie	Developed and manufactured by Kratos Defense and Security Solutions for function as robotic wingmen to fighter pilots.
Xianglong (Soaring Dragon)	China manufacture.
XPV-1 Tern	1990s-era tricycle undercarriage UAV acquired by BAI Aerosystems.

XPV-2 Mako	Developed by Navmar Applied Sciences Corp. Long endurance mUAV.
Yak-133	Yakovlev (Russia).[zz]
Yilong (Pterodactyl)	China manufacture.
Z-2	Nanjing Research Institute on Simulation Technique (China). [zz]
Z-3	Nanjing Research Institute on Simulation Technique (China). [zz]
ZALA 421-01	ZALA Aero Company (Russia).[zz]
ZALA 421-02	ZALA Aero Company (Russia).[zz]
ZALA 421-03	ZALA Aero Company (Russia).[zz]
ZALA 421-04	ZALA Aero Company (Russia).[zz]
ZALA 421-06	ZALA Aero Company (Russia).[zz]
ZALA 421-08 [Grusha/Granat-1]	Tactical UAV, entered service 2010.[bbb] ZALA Aero Company (Russia).[zz]
ZALA 421-09	ZALA Aero Company (Russia).[zz]
ZALA 421-12	ZALA Aero Company (Russia).[zz]
ZALA 421-16	ZALA Aero Company (Russia).[zz]
ZALA 421-16E2	Manufactured by Kalashnikov Group.[aaa]
ZALA 421-21	ZALA Aero Company (Russia).[zz]
Zastava	Tactical UAV, entered service 2013 (Russia).[bbb]
Zephyr S	Solar-powered HAPS man. by Airbus. In service.
Zephyr T	Solar-powered HAPS man. by Airbus. Scheduled 2020 release.
Zohal (Saturn)	Farnas Aerospace Company (Iran).[zz]
Zond-1	Sukhoi (Russia). Strategic UAV with AWACS phased array radar overhead.[zz]
Zond-2	Sukhoi (Russia).[zz]
Zond-3	Sukhoi (Russia).[zz]

Source: [a]Fein, G., 'Coyote earmarked for ISR and offensive roles', *IHS Jane's International Defence Review*, vol. 15 (Feb. 2017), p. 25; [b]Anonymous, 'Dubai aims to launch hover-taxi by July', *phys.org*, 13 Feb. 2017, <https://phys.org/news/2017-02-passenger-carrying-drone-dubai.html>; [c]EHang, <http://www.ehang.com/>; [d]Anonymous, 'Pollination: where the bee sucks', *Economist*, vol. 422, no. 9027 (11-17 Feb. 2017), p. 68; [e]Fein, G., 'Express delivery: US Army targets UAS-based tactical force resupply', *IHS Jane's International Defence Review*, vol. 15 (Feb. 2017), pp. 38-40; [f]Boeing, 'Unmanned Little Bird H-6U', <http://www.boeing.com/defense/unmanned-little-bird-h-6u/#/technical-specifications>; [f]Jennings, G., 'US demonstrates "one of the world's largest" micro-UAV swarms', *IHS Jane's Defence Weekly*, vol. 54, no. 3 (18 Jan. 2017), p. 12; [g]Lert, F., 'France receives two more Reapers, deploys them to Niger', *IHS Jane's Defence Weekly*, vol. 54, no. 3 (18 Jan. 2017), p. 15; [h]Lert, F., 'France orders 105 Spy Ranger UAVs from Thales', *IHS Jane's Defence Weekly*, vol. 54, no. 3 (18 Jan. 2017), p. 15; [i]US DOD, *Seven Defense Priorities for the New Administration: Report of the Defense Science Board (*DOD: Washington, DC, Dec. 2016), p. 49; [j]Ripley, T., 'Revealing facts: OSINT helps to uncover details of Aleppo battle', *IHS Jane's Intelligence Review*, vol. 29, no. 3 (Mar. 2017), p. 56; [k]Jennings, G., 'Airbus to fly VSR700 VTOL UAV before end of year', *IHS Jane's International Defence Review*, vol. 59 (Mar. 2017), p. 29; [l]Williams, H., 'Skylark: a family affair', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), pp. 58-61; [m]Nuwer, R., 'High above, drones keep watchful eyes on wildlife in Africa', *New York Times*, 13 Mar. 2017, <https://www.nytimes.com/2017/03/13/science/drones-africa-poachers-wildlife.html?_r=0>; [n]Riptide Autonomous Solutions, 'Micro-UUV', <https://riptideas.com/micro-uuv/ >; [o]Wong, K., 'Eastern promise: China grows unmanned capabilities', *IHS Jane's International Defence Review*, vol. 50 (Mar. 2017), pp. 53, 57; [p]Jennings, G., 'IAI pitches Heron TP for Australia's Project AIR 7003', *Jane's Defence Weekly*, vol. 54, no. 10 (8 Mar. 2017), p. 6; [q]Grevatt, J., 'China secures its "biggest" export order for UAV system', *Jane's Defence Weekly*, vol. 54, no. 10 (8 Mar. 2017), p. 17; [r]Binnie, J., 'Yemeni rebels display UAVs', *Jane's Defence Weekly*, vol. 54, no. 10 (8 Mar. 2017), p. 18; [s]Everts, S. and Davenport, M., Drones detect threats such as chemical weapons, volcanic eruptions', *Chemical & Engineering News*, vol. 94, no. 9 (22 Feb. 2016), pp. 36-37; [t]Chua, C. N., *Integration of Multiple UAVs for Collaborative ISR Missions in an Urban Environment* (Naval Postgraduate School: Monterey, Sep.

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Annexe 2. Possible draft mandate for WG on platform technology implications for verification and investigations of alleged use within a CWC framework.

Cognisant of…
Convinced of…
Recalling…
Bearing in mind…
Taking note of…
Alert to…

Hereby:
1. **Establishes** xxxx
2. **Appoints** xxxx
3. **Requests** xxxx
4. **Further requests** xxxx

Terms of reference

Relevant documents may include:

-First CWC Review Conference document C-1/DEC.71, and corr.1, 23 May 1997.

-Second Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention (hereinafter "the Second Review Conference"), para. 9.147 (RC-2/24, 18 April 20018).

-SAB advice provided to OPCW at inter alia its 13th and 14th sessions.

-TS note (EC-61/S/1, 29 Mar. 2010).

-TS corr. (EC-61/S/Corr.1, 17 Sep. 2010).

-EC document (EC-62/DEC.2, 6 Oct. 2010).

Annexe 3. US DOD guidelines for review of certain autonomous or semi-autonomous weapons systems

'1. Autonomous or semi-autonomous weapon systems intended to be used in a manner that falls outside the policies in subparagraphs 4.c (1) through 4.c.(3) above the signature of this Directive must be approved by the USD(P), USD(AT&L), and the CJCS before formal development and again before fielding.

a. Before a decision to enter into formal development, the USDP(P), USD(AT&L), and CJCS shall ensure:

(1) The system design incorporates the necessary capabilities to allow commanders and operators to exercise appropriate levels of human judgment in the use of force.

(2) The system is designed to complete engagements in a timeframe consistent with commander and operator intentions and, if unable to do so, to terminate engagements or seek additional human operator input before continuing the engagement.

(3) The system design, including safeties, anti-tamper mechanisms, and information assurance in accordance with Reference (a), addresses and minimizes the probability or consequences of failures that could lead to unintended engagements or to loss of control of the system.

(4) Plans are in place for V&V and T&E to establish system reliability, effectiveness and suitability under realistic conditions, including possible adversary actions, to a sufficient standard consistent with the potential consequences of an unintended engagement or loss of control of the system.

(5) A preliminary legal review of the weapon system has been completed, in coordination with the General Counsel of the Department of Defense (GC, DoD) and in accordance with References (b) and (c), DoD Directive 2311.01E (Reference f), and, where applicable, Reference (d).

b. Before fielding, the USD(P), USD(AT&L), and CJCS shall ensure:

(1) System capabilities, human-machine interfaces, doctrine, TTPs, and training have demonstrated the capability to allow commanders and operators to exercise appropriate levels of human judgment in the use of force and to employ systems with appropriate care and in accordance with the law of war, applicable treaties, weapon system safety rules, and applicable ROE.

(2) Sufficient safeties, anti-tamper mechanisms, and information assurance in accordance with Reference (a) have been implemented to minimize the probability or consequences of failures that could lead to unintended engagements or to loss of control of the system.

(3) V&V and T&E assess system performance, capability, reliability, effectiveness, and suitability under realistic conditions, including possible adversary actions, consistent with the potential consequences of an unintended engagement or loss of control of the system.

(4) Adequate training, TTPs, and doctrine are available, periodically reviewed, and used by system operators and commanders to understand the functioning, capabilities, and limitations of the system's autonomy in realistic operational conditions.

(5) System design and human-machine interfaces are readily understandable to trained operators, provide traceable feedback on system status, and provide clear procedures for trained operators to activate and deactivate system functions.

(6) A legal review of the weapon system has been completed, in coordination with the GC, DoD, and in accordance with References (b), (c) and (f), and, where applicable, Reference (d).

2. The USD(P), USD(AT&L), and CJCS may request a Deputy Secretary of Defense waiver for the requirements outlined in section 1 of this enclosure, with the exception of the requirement for a legal review, in cases of urgent military operational need'.

Source: DOD, 'Directive: autonomy in weapon systems', no. 3000.09, 21 Nov. 2012 (rev. 8 May 2017), pp. 7-8.

Annexe 4. Glossary of terms and select systems

Accelerometer. Used as tilt sensors of mobile phones. Perhaps fine control of UAVs (e.g., quadcopters).

Geo-fencing.

Global Information Grid.

International Traffic in Arms Regulations.

Microcontroller.

Multi-Function Active Sensor.

National Imagery Interpretability Rating Scale. Four major imagery types are ranked according to 10-levels for visible, radar, IR and multispectral.

Radar Warning Receiver.

-END-