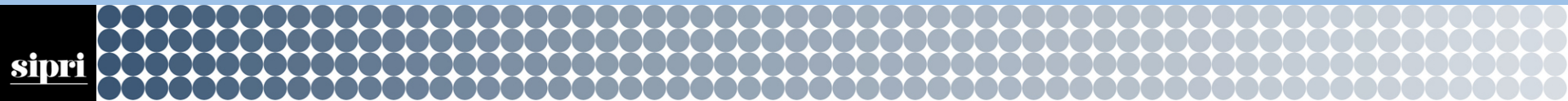# Possible role of autonomous/semi-autonomous platforms for OPCW verification and investigations of alleged use

25th ISODARCO summer course on: International Security in a Rapidly Evolving Political and Technological Environment

Eastern Mediterranean University

Famagusta, Cyprus

10-15 July 2017

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1. Purpose

- Review autonomous/semi-autonomous platform technology developments.
- Consider disarmament and arms control verification implications.

- Please see end presentation slides for acronyms list.

2. Outline

- 'The Market'
- Capabilities
- Categorization, definition, purpose
- Recent developments
- Counter-UAV approaches
- Ethical considerations
- Registration and regulatory developments
- Good operator practices
- Capability and design factors
- Artificial intelligence (AI)
- Guidance, control, navigation (GNC)
- Human-machine interface (HMI)
- Chemical weapons verification context
- Nuclear weapons verification context
- Further discussion
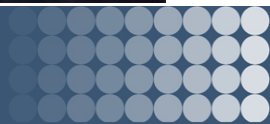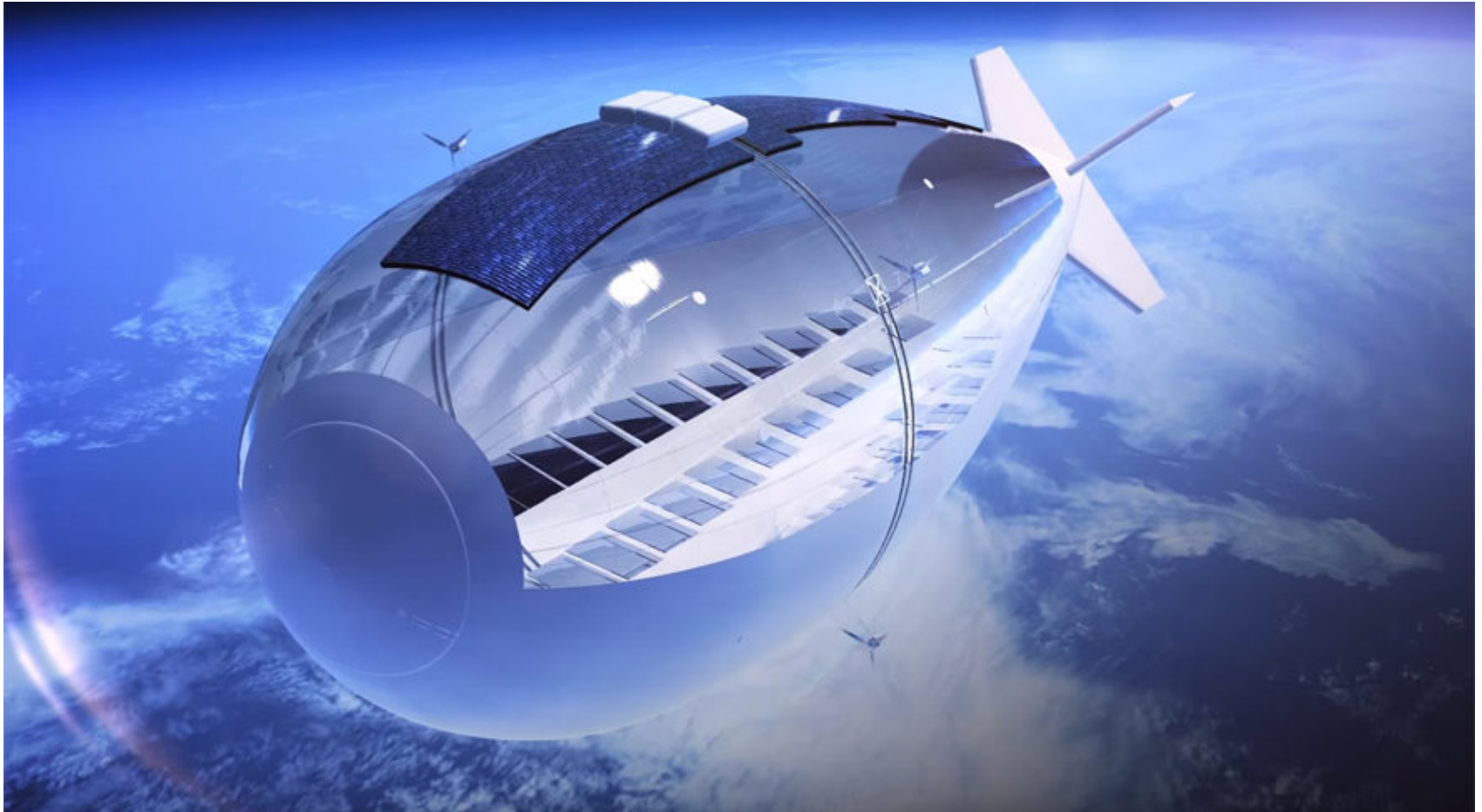- Conclusions + acronyms
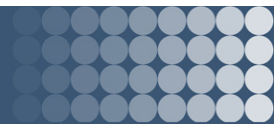
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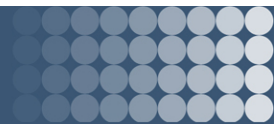
3. 'The Market'

- Over 100 billion (USD) on civil and military drone/ UAV market in 2016-2020
  - Construction: 112 billion (USD)
  - Agriculture: 5.9 billion (USD)
  - Insurance: 1.4 billion (USD)
  - Infrastructure inspection: 1.1 billion (USD) ('Technology Quarterly, civilian drones', *Economist*, 10 June 2017).
- 90% of all spending for military systems ('Technology Quarterly, civilian drones', *Economist*, 10 June 2017).
- 110000 UAVs sold worldwide in 2016 ('Technology Quarterly, civilian drones', *Economist*, 10 June 2017).
- 174000 UAVs may be sold worldwide in 2017 ('Technology Quarterly, civilian drones', *Economist*, 10 June 2017).
- China's DJI worth 8 billion (USD), has c. 70% of civilian market, controls civilian platform standard ('Technology Quarterly, civilian drones', *Economist*, 10 June 2017).
- Top c-UAV companies (*Counter-UAV Market Forecast 2017-2027* ,Visiongain).
  - Boeing Company, Airbus Group SE, Saab AB, Thales Group, Lockheed Martin Corp., Israel Aerospace Industries Ltd, DroneShield LLC, Raytheon Company, Northrup Grumman Corp., Rafael Advanced Defense Systems Ltd, Rheinmetall AG.

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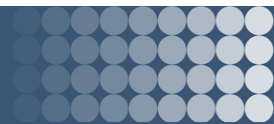
4. Stratobus (Thales Alenia Space, https://www.thalesgroup.com/en/worldwide/space/news/whats-stratobus)

5. Zephyr HAPS

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6. Perdix micro-drone swarm
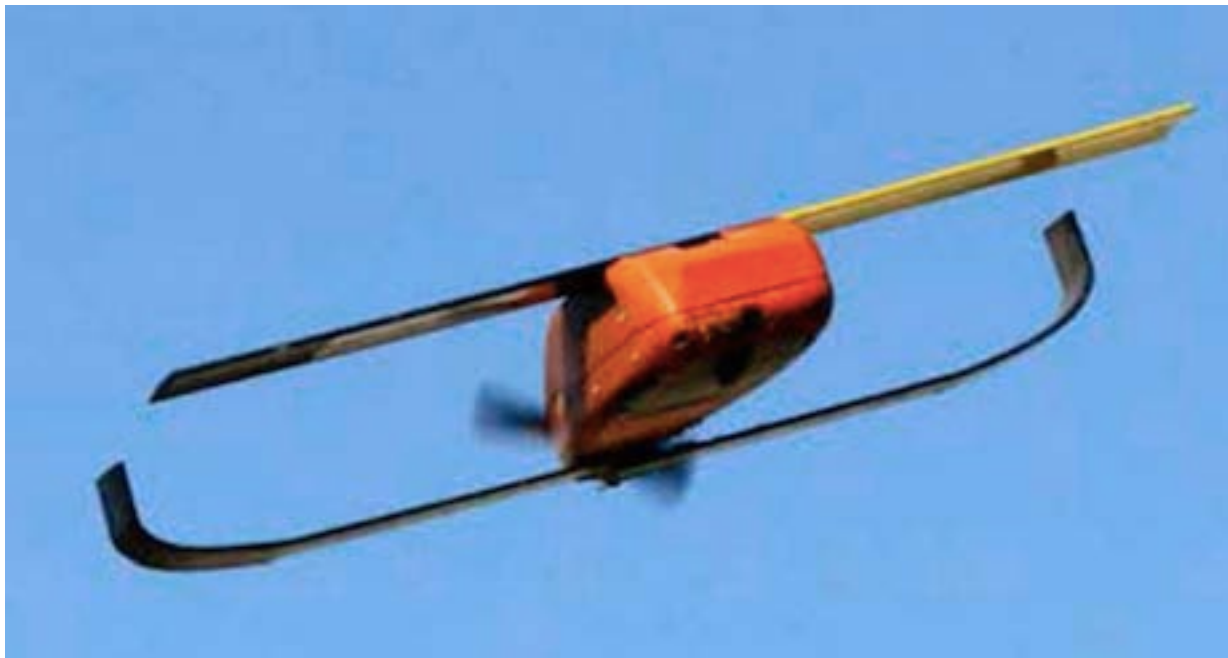
(https://www.stripes.com/news/pentagon-unveils-perdix-micro-drone-swarm-1.448124)

7. MINUSMA

The Swedish ISR task force operates the Textron Shadow 200 tactical UAV in surveillance missions around Timbuktu. The aircraft is flown from Camp Castor, the Swedish base in Timbuktu, and is not forward deployed to other locations in Mali.

8. DPRK drone surveilling THAAD

(http://www.dn.se/nyheter/varlden/spiondronare-fran-nordkorea-byggd-av-delar-fran-sju-lander/)

9. Yuneec Breeze
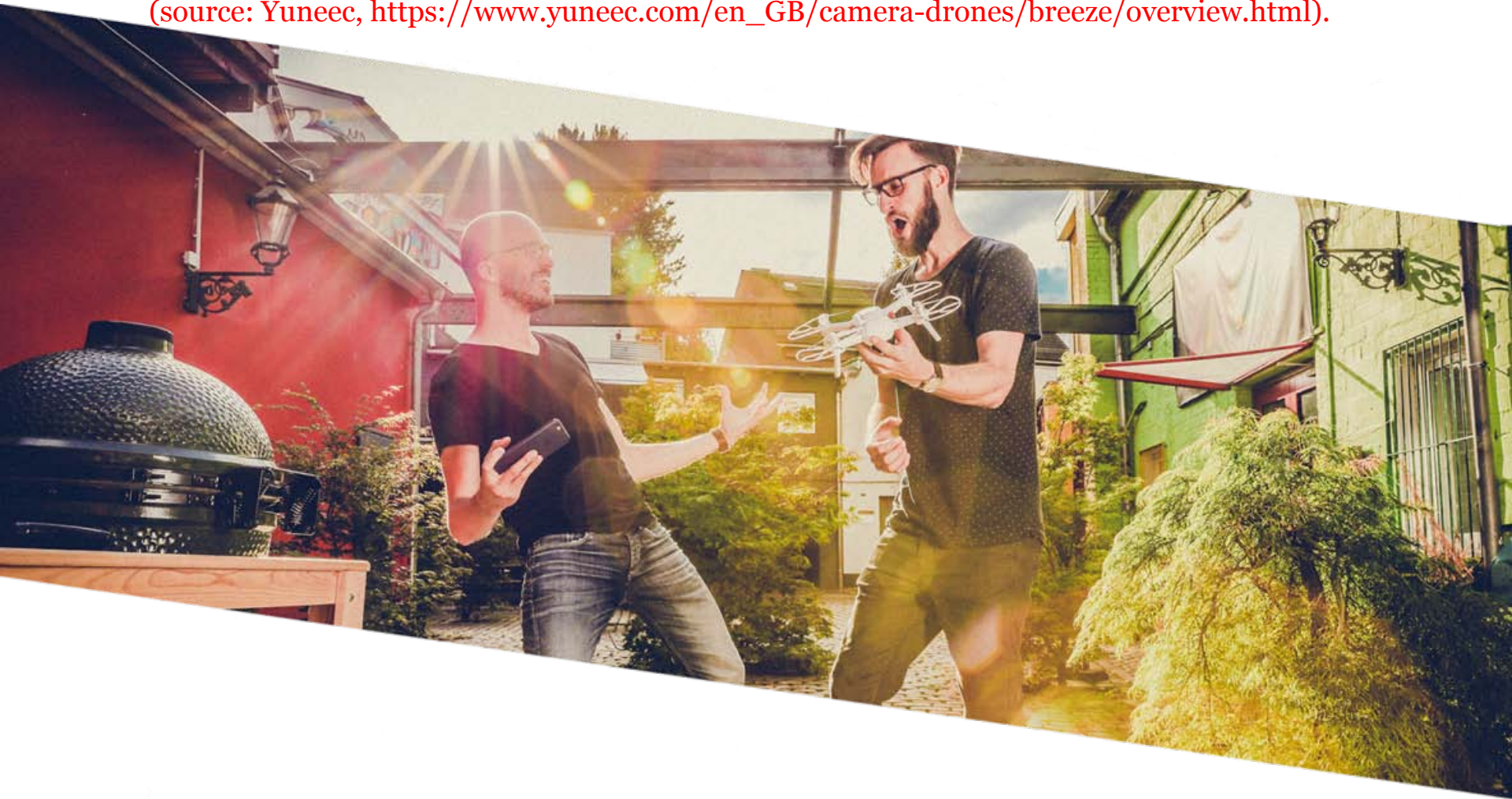
10. Quadcopter-type capabilities

- Pole balance and catch
  - https://www.youtube.com/watch?v=XxFZ-VStAp0
- Dancing lamp shades in response to hand signals
  - https://www.youtube.com/watch?v=BcbJPjPjW3on
- Playing ping pong
  - https://www.youtube.com/watch?v=YvbHXz3lccc
- Band members
  - https://www.youtube.com/watch?v=4DPlNxsh4YY

11. Categorization, definition, purpose

- Understanding and applications of standards and regulatory best practices and norms informed by range of definitions and associated phrasing (evolving with overlaps; language distinctions).

- Terms include: drones, MUAV, RPA, RPV, SUAS, TUAV, UAS, UAV, UCAV, UCLASS, UCS, UGV [see 'acronyms' slides]

- UAS/UAV may be classified <u>inter alia</u> by **endurance**, **range** or **size**; or **mission**, **size** and **altitude**.

- 'Autonomous and/or semi-autonomous platform technologies' perhaps captures range, type and applications (currently and in future).

12. MTCR UAV payload definitions

'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'.

13. Recent developments

- Uber is committed to developing e-VTOLs (Uber Elevate).
- Neuralink launched in March 2017. Business model is to link human brains to computers without a physical interface. Headed by Elon Musk (Founder, CEO and CTO of SpaceX).
- OSCE employs UAVs to support mission in Ukraine. Challenged by military-grade GPS hacks.
- In March 2017 Israel's Optimus was first UAV to be granted approval to fly fully automated commercially without a controller.

  https://www.youtube.com/watch?v=Y6fjPRwPr3c

14. Recent developments, cont'd

- In 2015 Dow Chemical obtained USG approval to operate camera-equipped UAVs at chemical plants (e.g., polypropylene plant in Freeport, Texas).
- Daesh/IS forces in Mosul have used the DJI Phantom quadcopter to drop IEDs onto Iraqi government forces (UAV is normally equipped with a GoPro-type camera).
- 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.

https://www.youtube.com/watch?v=KYInIsgJDeQ

https://www.youtube.com/watch?v=18qp-8oP4Cc

15. Recent developments, cont'd

- The USAF employed MQ-1[B] Predator and MQ-9 Reapers [Predator B] for CAS and ISR in the 2016 campaign to force IS out of Manbij, Syria.
- 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.
- UAE air force reportedly destroyed an Iranian military drone near Yemen's port of Al-Mukha.
- USAF destroyed 2 Iranian Shahed-129s in Syria in 2017.

16. Recent developments, cont'd

- DARPA implementing High-Assurance Cyber Military Systems (HACMS) project to evaluate software resiliency ('tools for developing software mathematically proven to be free of large classes of cyber vulnerabilities').

- DARPA's Offensive Swarm Enabled Tactics (OFFSET) project comprises inter alia evaluation of 'a swarm tactic-centric' tactics (e.g., to support simultaneous top-down/bottom-up multi-story building clearance operations).

- In 2016 US F/A-18 Hornets released 103 Perdix mUAVs to evaluate 'advanced swarm behaviours such as collective decision-making, adaptive formation flying, and self-healing'.

https://www.youtube.com/watch?v=ndFKUKHfuMo

17. Counter-UAV approaches

- Electro-magnetic control disrupters
  - E.g., Groza-R Counter-Multicopter Radio electronic Rifle; MESMER® by Department 13.
- Kinetic
  - E.g., firearms; SAMs; modified sponge-grenades (?).
- Nets (firearm-launched; counter-drone-deployed)
  - E.g., SkyNet Mi5 Remington model 870 shotgun-compatible shells; Skywall 100 by Open Works Engineering.
- Laser effectors
  - E.g., Shark System by Marduk Technologies.
- Birds of prey (e.g., NL project).
- https://www.youtube.com/watch?v=X27-2WDIZR0

18. Ethical considerations

- Reconciling the employment of UAVs to kill vis-à-vis the ability or right of an opponent to surrender.

- If the platform's autonomous functionality yields desired/approved outcomes in 99 per of cases, is such an outcome legally, ethically and/or politically acceptable? What are the ethical and legal implications of the autonomy-linked failures?

- International Humanitarian Law (IHL)

  - Discrimination, military necessity, proportionality

  - Martens clause

19. Registration and regulatory developments

- As of March 2017 more than 770 000 US drone users registered with FAA.
- In May 2017 DJI stated it will severely restrict functionality of unregistered drones (e.g., in view of use of DJI Phantoms and Matrice 100s in 2016-2017 Mosul Campaign)
  - New activation process for non-US customers to ensure users possess the 'correct set of geospatial information and flight functions…as determined…[by the user's] geographic location and user profile'.
  - Otherwise live camera streaming to be disabled, and flight limited to 50m radius and 30m ceiling.
  - Growth of online controller hacking support?

20. Registration and regulatory developments, cont'd

- Draft USG legislation to permit legislation to permit the **tracking**, **hacking** and **destruction** of UAVs [summary of legislation is available via the *New York Times* at <https://www.documentcloud.org/documents/3728796-Government-Drone-Hacking-Destruction-Proposal.html>].

- Revised US DOD guidelines for review of certain autonomous or semi-autonomous weapons systems [DOD, 'Directive: autonomy in weapon systems', no. 3000.09, 21 Nov. 2012 (rev. 8 May 2017)].

- Trade controls & international guidelines/practice
  - EC reg. 1334/2000, rev.
  - Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies re: RAN, RNC and BSC (?).

21. Good operator practices

- Select principles (FAA 'know before you fly')
  1.) Do not fly above 400 feet.
  2.) Maintain unmanned aircraft within sight.
  3.) Do not operate near individuals or crowds.
  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.

22. Good operator practices, cont'd

- Frameworks/projects
  - Association for Unmanned Vehicle Systems International (AUVS).
  - Center for Robot-Assisted Search and Rescue (CRASAR).
  - RTCA Drone Committee.
- Select priorities
  - Integrated, comprehensive mapping of national, regional, international best practices and oversight mechanisms in civil and defence sectors.
  - 'Bottom-up' voluntary approaches vs. 'top-down' regulatory requirements.
  - Implementation practice within the broader societal and international 'realities'.
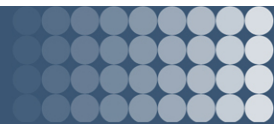
23. Capability and design factors

(*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),
(*d*) Battery storage and weight specifications (e.g.,
lithium ion batteries).
(*e*) Quadrotor UAV sensor suite typically comprises:
1.) a 3-axis gyroscope, 2.) a 3-axis accelerometer,
3.) a 3-axis magnetomer, 4.) pressure sensors, 5.)
sonar sensor, 6.) GPS unit, and 7.) payload.

24. Artificial intelligence (AI)

- Open-source vs. closed architecture/environment approaches.
- Civil focus on *financial sector* and *robotics*.
- Security and defence sector projects
  - DIUx: DOD technology incubator integrating software and robotics [informed by JIDA/JIEDDO technology development and acquisition model?]
- Google
  - Strong financial commitment + information/analytics baseline.
  - *Open-source software library for machine intelligence –* TensorFlow™
    (https://www.tensorflow.org/).
- Apple
  - Closed architecture/environment approach (?)
  - Focused on self-driving vehicles.

25. Guidance, navigation and control (GNC)

- Select principles
  - *Monitor* and *control* platform
- Frameworks/projects
  - Signal networks
    - COSPAS-SARSAT emergency beacon/signals treaty-based network
    - POINTER [JPL-project for SAR tasks and border control]
    - Wideband Global SATCOM (WGS) system [military comms currently limited to 7 states]
- Select priorities
  - Wireless carrier capacity and security.
  - System of systems validation projects (cf. JASON Defense Advisory Panel).

26. GNC, cont'd

- Select principles
  - Platform *autonomy* and *more secure data fusion*
- Frameworks/projects
  - UCLASS Unmanned Control System (UMCS)
- Select priorities
  - Clarify implications of government efforts to ensure ability to hack or disable civil sector platforms (e.g., draft May 2017 USG legislation).
  - Model checking for next generation dynamic/ reactive autonomous/semi-autonomous platforms.
  - Implications of sensor/sensor system improvements.

27. Human-machine interface (HMI)

- Select observations
  - Linking *brain imaging techniques* with *platforms* against *listed applications*.
    General background: Le Bihan, D., *Looking Inside the Brain: the Power of Neuroimaging* (Princeton, 2015). Transl. T. Fagan.
- Possible priorities
  - Review status of deception/'lie detector' projects based on brain imaging.
  - Neuralink interface concepts & strategies (cf. business model, TRLs – to market, regulatory effects on technology development and sales).
  - Oculus (or similar) in hybrid gaming-UAV applications.

28. Chemical weapons verification context

- 'Managed access'(cost, scope,level of intrusiveness)
  - Routine (chemical industry, CW-related)
  - Non-routine (CI; consultations, cooperation and fact-finding prov. of art. IX; Syria DAT, FFM, JIM; UN SecGen CBW investigative mechanism).
- List of Approved Inspection Equipment (C-I/DEC. 71 and corr.1; S/1375/2016).
- General Operational Requirements and Common Criteria for All Inspection Equipment (C-I/DEC.71 and corr.).
- Approved anal. techniques (GC; IR; MS; NMR).
- OCAD (c. 5000 CWC-listed chemicals—mainly GC/ MS mass spec and retention indices; 'blinding software'; modalities for supplemental databases).

29. Autonomous/semi-autonomous platform technologies cf. CWC

- Dispersal concern.
- Decontamination support (e.g., art. X assistance and protection provisions).
- Verification-related data acquisition and transmission
  - OPCW adaptation of SIX for remote verification of 2016 Libyan chemicals removal operation. Incorporate platform technologies in future?
- Investigation of alleged use (IAU).
  - 3D dynamic mUAV swarm-enabled particulate mapping (humidity, temp., wind data, etc.).
  - Kripke structure model checking.
  - Sample taking, stand-off detection. Mobile LIDAR platform systems feasible in future?

30. Platform technologies cf. CWC, cont'd

- OPCW inspection team safety
  - EU support for environmental clean-up at Ruwagha, Libya (contracting underway; includes OPCW, UNOPS).
  - Remote monitoring, structure pre-check (e.g., underground CWPFs outside SY gov. control)
  - Convoy safety warning (e.g., 2014 detention of OPCW team following lead vehicle disabled by shaped charge; gun fire directed towards 2013 UN SecGen team vehicles).
- Implications of 3rd party platform technologies
  - Civil society
  - ISR missions in armed conflict zones
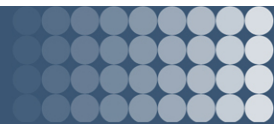 - Parallel verification/observation processes

31. Possible future considerations in a CWC context

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

-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.

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

-Integration of DAA into non-routine inspection SOPs, Wis.

32. Further considerations

- Detect and avoid (DAA) standards
- Possible synergies or lessons from multilateral disarmament and arms control treaty regimes (e.g., information sharing, technology and equipment evaluation processes).
- Autonomous and semi-autonomous platform technologies will continue to be developed and applied in ways that are difficult to predict and fully plan for.

33. Conclusions

- Arms control
  - May profoundly affect the nature and understanding of chemical disarmament and arms control (e.g., near real time information on dispersions of toxic chemicals and principal (key) degradation products).
  - 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 inspections are conducted.
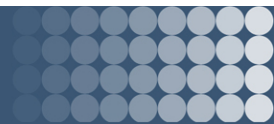
34. Conclusions, cont'd

- Security and defence acquisition
    - Integrated sensor systems and software packages to provide near real-time field contamination profiles.
    - 'Offensive' [i.e., prohibited] vs. 'defensive' [i.e., permitted] activity and programmes in chemistry and the life sciences.
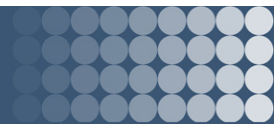
35. Acronyms

- ADS-B – Automatic Dependent Surveillance-Broadcast
- AI – Artificial Intelligence
- AUVS – Association for Unmanned Vehicle Systems International
- BSC – Base Station Controller
- CAS – Close Air Support
- CBW – Chemical and/or Biological Warfare/ Weapon
- CEO – Chief Executive Officer
- CI – Challenge Inspection
- COSPAS-SARSAT – [treaty-based emergency beacon system]
- COTS – Commercial Off-the-Shelf

36. Acronyms, cont'd

- CRASAR – Center for Robot-Assisted Search and Rescue
- CTO – Chief Technical Officer
- CWC – Chemical Weapons Convention
- CWPF – Chemical Weapons Production Facility
- DAA – Detect And Avoid
- DARPA – Defense Advanced Research Projects Agency
- DAT – Declaration Assessment Team
- DIUx – Defense Innovation Unit Experimental [DOD technology incubator]
- DJI – Da-Jing Innovations

37. Acronyms, cont'd

- DOD – Department of Defense
- EASA – European Aviation Safety Agency
- e-VTOL – electric-Vertical Take-off Aerial Vehicle
- EUROCAE – European Organisation for Civil Aviation Equipment
- FAA – Federal Aviation Administration
- FFM – Fact-Finding Mission
- GC – Gas Chromatography
- GNC – Guidance, Navigation, Control
- HACMS – High-Assurance Cyber Military Systems
- HAPS – High Altitude Pseudo-Satellite
- HMI – Human-Machine-Interface

38. Acronyms, cont'd

- IAU – Investigation of Alleged Use [of chemical weapons]
- IED – Improvised Explosive Device
- IFF – Identification Friend or Foe
- IFP – Iraqi Federal Police
- IHL – International Humanitarian Law
- IMS – International Monitoring System
- IR – Infrared Red
- IS – Islamic State
- ISR – Intelligence, Surveillance, Reconnaissance
- JIDA – Joint Improvised Threat Defeat Agency
- JIEDDO – Joint Improvised Explosive Device Defeat Organization

39. Acronyms, cont'd

- JIM – OPCW-UN Joint Investigative Mechanism in Syria
- JPL – Jet Propulsion Laboratory
- LIDAR – Light Detection And Ranging
- MINUSMA – United Nations Multidimensional Integrated Stabilization Mission in Mali
- MS – Mass Spectrometry/Member State
- MTCR – Missile Technology Control Regime
- MUAV – Mini Unmanned Aerial Vehicle
- NATO – North Atlantic Treaty Organization
- NL – Netherlands
- NMR – Nuclear Magnetic Resonance
- OCAD – OPCW Central Analytical Database
- OFFSET – Offensive Swarm Enabled Tactics
- OPCW – Organisation for the Prohibition of Chemical Weapons

40. Acronyms, cont'd

- OSCE – Organization for Security and Co-operation in Europe
- PNT – Positioning, Navigation and Timing
- POINTER – Precision Outdoor and Indoor Navigation Tracking for Emergency Responders
- RAN – Radio Access Network [equipment]
- RNC – Radio Network Controller
- RPA – Remotely Piloted Aircraft
- RPAS – Remotely-Piloted Aircraft Systems
- RPV – Remotely Piloted Vehicle
- RTCA – Radio Technical Commission for Aeronautics
- SAM – Surface-to-Air-Missile

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41. Acronyms, cont'd

- SAR – Synthetic Aperture Radar/Search And Rescue
- SATCOM – Satellite Communication
- SIX – Secure Information eXchange
- SOP – Standard Operating Procedure
- STL – Satellite, Time and Location
- SUAS – Small Unmanned Aerial System
- SY – Syria
- THAAD – Terminal High Altitude Area Defense
- TRL – Technology Readiness Level
- TUAV – Tactical Unmanned Aerial Vehicle
- UAE – United Arab Emirates
- UAS – Unmanned Aerial System
- UAV – Unmanned Aerial Vehicle

42. Acronyms, cont'd

- UCAV – Unmanned Carrier Aviation
- UCLASS – Unmanned Carrier Launched Airborne Surveillance and Strike
- UCS – UAV Control System
- UGV – Unmanned Ground Vehicle
- UNOPS – United Nations Office for Project Services
- USAF – United States Air Force
- USG – United States Government
- UMCS – UCLASS Unmanned Control System
- WGS – Wideband Global SATCOM
- WI – Work Instruction

Teşekkür ederim.
Thank you.

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*Presentation contents are personal views
and do not necessarily reflect those of SIPRI.
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