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Title: Recent UAS and Counter-UAS Industry Technology Trends and Developments

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Abstract:
Use of unmanned aircraft systems (UAS) is one of the fastest growing technology spaces in the global commercial market. This rapid growth makes it increasingly difficult to maintain a current knowledge base on recent technology advancements in the UAS and counter-UAS industry. This paper will catalogue recent trends and developments from open sources including media and news reports, industry outlets and company product announcements. This paper will cover recent developments in the following topics: platform development, payloads and sensors, cyber resilience, autonomy, police and response use of UAS/CUAS, and state-sponsored developments. This information will help nuclear regulators and site operators understand where commercially available unmanned and counter unmanned technologies are headed, and to consider the possible impacts of these technologies on their security planning.

1. INTRODUCTION

Uses of and improvements to unmanned aircraft systems (UAS) are one of the fastest growing technology spaces in the global commercial market. This rapid growth makes it increasingly difficult to keep current with recent advancements in the UAS and counter-UAS (CUAS) industry. Organizations are seeking ways to evaluate the possibility of integrating UAS or CUAS technologies into their physical security system, and there is a need for easily digestible analysis of current capabilities and recent developments. The information included in this paper describes the first stage of an ongoing effort to catalogue recent trends and developments aggregated from a variety of open sources that include industry news websites, blogs, company press releases, academic research papers, and observations from UAS industry conference events. Subject matter experts were consulted to identify emerging technologies and trends that affect the UAS/CUAS industries. Recent UAS and CUAS developments will be sorted according to: platform, payloads and sensors, cyber resilience, autonomy, pro-force/blue-force use, and state-sponsored.

End Product: Shareable Information

The main goal of this research is to collect information on current UAS and CUAS technology trends and developments and present the data in a format that will assist in purchase decisions as well as inform the reader the current direction of UAS and CUAS. The information provided will be shareable and in a format that allows for simple identification of technologies or topics of interest.

Disclaimer

All content was passively researched through open sources and does not represent an exhaustive list of advancements or developments. The U.S. National Nuclear Security Administration's International Nuclear Security Program has not confirmed any of the capabilities or events that are presented herein or advertised in the reference links provided.

2. TOPICAL CATEGORIES

Platform Development

Platform technology developments include novel advancements in UAS and CUAS platforms, including but not limited to airframe, propulsion, and unique operating capability. Prominent trends in platform development include UAS that are smaller, operate using hybrid power, and perform longer duration flights. Some notable advancements in this area, followed by a representative list of additional advancements are:

- Small, agile UAS: Researchers at MIT introduced a new generation of tiny, bug like, agile UAS. This technology could allow tiny UAS to operate in cramped spaces and withstand collisions. [1]
- Autonomous solar-powered UAS: Skydweller Aero has performed a successful flight demonstration of the initial aircraft control, actuation, and sensor technology systems of their autonomous solar-powered UAS. The demonstration included testing autonomous software while measuring and evaluating multiple open-loop system identification inputs to collect data on the UASs static and dynamic characteristics at various altitudes. [2]

Table 1. ***Other Notable Platform Developments***

Company/Agency	*Name*	*Description*
Lockheed Martin	MORFIUS	UAS Mounted High Power Microwave CUAS [3]
Fixar	007	Hybrid Technology VTOL [4]
Anavia	HT-100	Long Range VTOL Helicopter [5]
Seaplane	Twin Otter	Human Transporting UAS [6]
Jetoptera	J-2000	Bladeless UAS Propulsion System [7]
Vanilla	Vanilla Unmanned	Very High Endurance UAS [8]
MIT	CSAIL	3D Printed UAS [9]

Payloads and Sensors

Payload and sensor technology developments include novel advancements in UAS/CUAS payload and sensor capabilities, including but not limited to cameras, radars, unique payload/sensor capabilities, and environmental monitoring. Payload and sensor trends include: low-cost advanced cameras and imagers, package delivery systems, and specialized sensor integration. Key advancements in this area, followed by a representative list of additional advancements are:

- Radar: IMSAR has developed a radar called NSP-3 that is specifically for UAS applications. Its Ku-band frequency synthetic aperture radar weighs only 7 pounds, which makes it suitable for use on a variety of small UAS including fixed and rotary wing aircraft. [10]

- Radiation detection: Kromek has developed the Autonomous Airborne Radiation Monitoring System, which is a UAS equipped with a lightweight CZT payload for radiological detection and surveying. [11]

Table 2. ***Other Notable Payload and Sensor Developments***

Company/Agency	*Name*	*Description*
Georgia Tech	Modular Delivery	Smart Package Delivery System [12]
PreVision	WAMI	Low-Cost Mapping Sensor [13]
FLIR	Thermal Imager	Low-Cost Thermal Imaging Camera [14]
Micasense, Sentera	Multi-spectral Imager	Multi-Spectral Imagers [15]
Arxiv	SARDO	UAS Search and Rescue [16]
NYU	PCMCP	Autonomous Payload Control [17]
SPH Engineering	Bathymetry	Water Depth Measurement [18]

Company/Agency	*Name*	*Description*
Soarability	Sniffer4D	Environmental Monitoring System [19]
Honeywell	SATCOM	UAS Satellite Communications [20]
IAEA	Radiation Detecting UAS	IAEA Radiation Detection Drone [21]
Wingcopter	Wingcopter 198	High Endurance, Long Range Delivery UAS [22]

Cyber Resilience

Cyber resilience technology developments include novel advancements in cyber protection capabilities, including but not limited to hardened critical components, supply chain reliability, and blockchain security. Cyber resilience is trending towards, resiliency to UAS cyber threats, protecting/limiting risk of UAS data compromise and RF signal spoofing for delivery applications and other important missions. Key advancements in this area, followed by a representative list of additional advancements are:

- Privacy and Security: IBM filed a blockchain patent to tackle privacy and security concerns. The patent aims to use blockchain as a method of privacy preserving and securing drone data and communications. The blockchain ledger would store data from a UAS flight where a security risk is suspected. This will help eliminate future attempts to "steal" UAS communications, this will be especially useful for delivery drones, to keep package thief's from obtaining information about where the UAS is delivering a package.[23]
- Supply Chain Integrity: The U.S. Government has input an executive order that encourages federal agencies to divest from unmanned aerial systems manufactured by DJI products due to cyber concerns. Currently, companies and governments are looking more closely at supply chain to ensure reliability.[24]

Table 3. ***Other Notable Cyber Resilience Developments***

Company/Agency	*Name*	*Description*
SETO	Solar Cyber Security	Solar Farm Cyber Resiliency Against UAS [25]
Regulus	Pyramid GNSS	GPS Time Spoofing Protection [26]
Raytheon	Electronic Armor	Mission Critical Cyber Resiliency [27]
NASA	Urban Canyon GPS Testing	Urban Canyon GPS Signal Effectiveness [28]
seL4 OS	seL4 kernal	UAS Cyber Resilience [29]
US DOT Volpe	Blockchain for UAS	UAS Blockchain [30]

Autonomy
Autonomy technology developments include novel advancements in UAS autonomy capabilities, including but not limited to fully autonomous flights, improved structural characterization and inspection, and recording/filming. Autonomy is advancing rapidly in the world of UAS, trends in autonomy include: object avoidance, drone in a box for security, swarms, and inspection and repair. Key advancements in this area, followed by a representative list of additional advancements are:

- The United States Federal Aviation Administration (FAA) has approved the first-ever fully automated commercial drone flights within the US. Other countries have performed fully autonomous flights as well. The US aviation regulator has permitted American Robotics to fly its Scout quadcopter beyond the line-of-sight of human operators. In approval documents recently posted on the FAA website, the agency said the exemption only applies to rural areas, daylight visibility, and altitudes below 400 feet. [31]
- Obstacle Avoidance and Autonomy: The Skydio 2 (S2) is a human tracking autonomous UAS. The Skydio 2 utilizes an AI-powered flight autonomy engine with a lightweight platform. It uses real-time 360° obstacle avoidance and motion prediction capabilities that almost eliminates crashes and allows individuals with limited operator skill the ability to operate the UAS. [32]

Table 4: ***Other Notable Autonomy Developments***

Company/Agency	*Name*	*Description*
Sunflower Labs	Sunflower Home Awareness System	Drone in a Box Using Motion Sensors [33]
Nightingale	Blackbird	Drone in a Box [34]
DARPA	OFFSET	Autonomous Swarm [35]
DARPA	Gremlins	Launching UAS from UAS [36]
ORCA Hub	Monitoring UAS	UAS Inspection and Repair [37]
Silvus	Swarm	UAS Self-Forming Networks for Swarming [38]

Pro-Force/Blue Force Use of UAS and CUAS
Pro-Force/Blue Force use of UAS and CUAS technology developments include novel advancements in UAS and CUAS capabilities used for law enforcement or response, including but not limited to communications, surveillance and monitoring, and RF protection. Trends include: utilizing UAS for communication, tethered UAS for detection and surveillance, and handheld RF devices for mitigation of UAS. Key advancements in this area, followed by a representative list of additional advancements are:

- Two-Way Communication: Dotterel Technologies in New Zealand has developed a two-way aerial audio which provides the capability to have a two-way conversation between the UAS operator and a person. Dotterel has found a way to put its unique, highly directional microphone array and processor on drones so that it can capture audio while rejecting drone propeller noise and other loud environmental noise. [39]

- The Wyoming Department of Transportation and Wyoming Highway Patrol have received $100,000 through a federal grant that will help launch a statewide program that would use drones to assist with investigations by providing a bird's eye view of an unfolding event. [40]

Table 5. ***Other Notable Pro-Force/Blue Force Use of UAS and CUAS Developments***

Company/Agency	*Name*	*Description*
Hoverfly	Sentry	Tethered UAS Hoverfly [41]
Blue Vigil	RS-1000	Tethered UAS Blue Vigil [42]
Elistair	ORION 2	Tethered UAS Elistair [43]
Flexforce	Dronebuster Block 3B	Handheld RF Jammer DroneBuster [44]
DroneGun	MKIII	Handheld RF Jammer DroneGun [45]
Hikrobots	MR-D12JAI	Handheld RF Jammer Hikrobots [46]
Modal AI	Voxl-m500	Cellular Operated UAS Pre-Configured [47]
Nanjing University	Quantum Communication	UAS Quantum Communications [48]

State Sponsored Developments

State Sponsored technology developments include any novel advancements in UAS and CUAS capabilities made from a state entity, including but not limited to, swarms, microdrones, and laser protection. State sponsored developments are focused in procuring advanced technology UAS and CUAS, swarms, and long duration and high payload UAS flights. Key advancements in this area, followed by a representative list of additional advancements are:

- Israel Multi-Intercept CUAS: Israel's RAFAEL's Drone Dome C-UAS system performed interceptions of multiple drones, including maneuvering targets, using its hard-kill laser director. The system achieved 100% success in all test scenarios. [49]
- India Kamikaze Attack Swarm: The Indian military showed off a swarm of 75 drones destroying a variety of simulated targets in explosive kamikaze attacks. The swarm is capable of autonomous operation. Three types of drones were used in this swarm: a quadcopter, a six-rotor drone, and smaller quadcopters with explosives meant to be destroyed in an attack. [50]

Table 6. ***Other Notable State Sponsored Developments***

Company/Agency	*Name*	*Description*
Elbit	Hermes 900 StarLiner	Canada Cold Weather Rated UAS Procurement [51]
Parrot	Micro Drones	French Military Micro Drone Procurement [52]
Turkey	Akinci	Turkey Unmanned Combat Aircraft System [53]
Defsys	Smartshooter	India Smart Gun Procurement [54]
NASA	Ingenuity	First UAS Flight on Mars [55]
AFRL	Valkyrie	US AFRL UAS Deploying UAS [56]
Swoop Aero	Swoop Aero	DRC Implementing Delivery Drones [57]
Nigeria/China	Wing Loong II	Nigeria Obtaining Military Drone from China [58]
Royal Air Force	LANCA	Royal Air Force Drone Swarm [59]
UK Ministry of Defense	Mosquito	UK Fighter Jet Assistant UAS [60]
Iran	Kaman-22	Iran Military Drone [61]
Greece/Israel	Heron	Greece Leasing UAS from Israel [62]
Edge/Israel Aerospace Industries	CUAS Development	Emirati and Israel Collaboration on Counter Measures [63]
China	GJ11 Stealth	China Drone and Drone Prototypes [64]
India	Rustom 2	India Medium Altitude Long Endurance UAS [65]
AFRL	Ultra LEAP	US AFRL Two-Day Flight Duration [66]
Croatia	CAMCOPTER S-100	Croatia Coast Guard Drone [67]
United States	Swarm	US Army Swarm [68]

Future Direction and Potential Impact to Security

An analysis of these recent technological advancements and refinements allows one to track and predict the future direction of UAS and CUAS platforms. UAS development will likely move toward fully autonomous flights and UAS that are lighter, faster, have increased payload and endurance capacity, and operate using a hybrid power approach. The future direction of CUAS will likely include advanced handheld UAS mitigation devices, new regulation/policy to allow fully autonomous CUAS operation, CUAS that engage multiple targets simultaneously, and CUAS that utilize uncommon mitigation techniques such as high energy lasers, which are currently being developed in the military space.

The rapid improvements in UAS and CUAS technologies have the potential to significantly impact the security at critical infrastructure, such as nuclear facilities. As stated above, the UAS industry and uses of UAS are among the fastest growing sectors worldwide. Given this growth, it is difficult to know how effective a solution to the threat today will work for future threats. High endurance, high payload capability, autonomous, UAS swarms will become increasingly difficult to protect against and will require advanced CUAS technology to counter. Security will need to shift their focus from solely ground based threats to both ground and airborne threats, and this requires new physical security methods and technologies to ensure the protection of nuclear facilities or material in transit.

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