# DRAWING LESSONS FOR NUCLEAR EXPORT CONTROLS AND SAFEGUARDS FROM STUDYING SUPPLY CHAINS AND COVERT PROCUREMENTS OF MILITARY DUAL-USE ITEMS USED IN THE UKRAINE WAR

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## ABSTRACT

The analysis of covert procurements of military equipment and dual-use items for the deployment of unmanned aerial vehicles (UAVs) against Ukraine reveals lessons relevant to export controls and safeguards. A key overlap between nuclear-related trade controls and safeguards is oversight over manufacturing and supply capabilities of nuclear and dual-use items, necessary to control exports of items listed on a control list, regulate non-listed items restricted or prohibited to certain end-uses, and report relevant activities and exports to the International Atomic Energy Agency (IAEA). However, large-scale deployment of combat and reconnaissance drones in the Ukraine war reveals that components for UAVs were successfully procured on the international market. This paper presents examples of foreign-made dual-use items identified as used in large-scale production and deployment of UAVs. The examples highlight the increasing difficulty of understanding global supply chains for sensitive products and capabilities and countries' difficulties in overseeing domestic manufacturing and supply potential of dual-use items. In many cases, the items sought by procuring countries are readily available for purchase on the open market, demonstrating a stringent need for enhanced end-user verification and catch-all mechanisms. Secondary and resale markets pose an even more complicated challenge. The examples further highlight the rising difficulties of focusing on narrowly-defined items listed on a control list. They provide a stark warning that proliferating countries adapt and work to undermine control lists, and highlight the need to counter this activity to undermine proliferating countries' abilities to conduct covert, undeclared nuclear activities in violation of safeguards obligations. The identified challenges not only reduce the effectiveness of national export control systems but also the effectiveness of IAEA member state reporting based on activities and items listed in the Model Additional Protocol Annexes. They further reduce countries' abilities to identify and voluntarily share other relevant procurement data with the IAEA. Updating the AP Annexes periodically is one important step that can be taken to help address these challenges, but more are needed. If unaddressed, these challenges may reduce the IAEA's ability to detect the development of undeclared activities and contribute to the undermining of global non-proliferation goals more broadly.

## INTRODUCTION

Since the beginning of the invasion of Ukraine in February 2022, Russia has deployed hundreds of combat unmanned aerial vehicles (UAVs) to cause damage to Ukrainian forces and civilian infrastructure. Not only has Russia deployed hundreds of its own Orlan-10 drones, but also hundreds of drones produced by and purchased from Iran, currently under United Nations missile embargo. As Ukrainian forces succeeded in intercepting and capturing some of these drones, they have publicly shared images and information on the drones, leading to widespread public attention and expert analysis of the drone designs, and specifically their components. The analyses revealed that the designs and mass production of the drones, both Russian and foreign, relied heavily on components successfully sourced from Western and allied producers, in some cases, well-known multinational companies. As such, studying the components these programs were able to procure en masse provides rare insights into the limitations of export controls and sanctions regimes, and the current efforts by proliferators to exploit these, many of which may overlap with illicit procurement efforts that keep sanctioned or unsafeguarded nuclear programs afloat.

## COMPONENTS IN IRANIAN DRONES SOLD TO RUSSIA

As of April 2023, Iran has supplied hundreds of drones to Russian forces, with a focus on the following three types: The Shahed-136 (Russian designation: Geran-2/Germanium-2), its smaller version, the Shahed-131 (Russian designation: Geran-1/Germanium-1), and the Mohajer-6. Other types of drones may have been supplied, such as the Shahed-129, but reportedly in smaller quantities. In addition, according to media reports, Russia and Iran intend to build a drone manufacturing facility in Russia for the production of 6,000 "advanced" types of the Shahed-136.[1]

The Iranian drones identified as used against Ukraine have various capabilities and combat roles. The Shahed-136 and Shahed-131 serve as loitering long-range munitions that attack targets in a kamikaze style and explode on impact. These loitering munitions have a range of several hundred to several thousand kilometers. The Mohajer-6 serves a reconnaissance, surveillance, and in some cases, a combat role. It carries surveillance cameras and has the ability to launch multiple air to ground rockets.

Open-source information, including videos of captured or downed Iranian drones, reveals foreign commodities as the key components in the Shahed-136, Shahed-131, and Mohajer-6.[2] Many of the commodities are non-listed civilian aircraft or civilian drone parts from Western companies; other parts are common items readily available. Many items are produced by known multinational companies headquartered in a Western or allied country, yet other parts are Chinese or Iranian copies or redesigns based on Western technology. The expiration of the UN arms embargo on Iran in 2020 complicates the question of whether all shipments or technology transfers related to the UAVs to Iran were illegal, however, Iran remains subject to a UN missile embargo, which covers drones of a maximum range of 300 kilometers or more, and much of its drone program remains subject to multilateral sanctions imposed by Western countries and their allies. Several countries have concluded, based on the drone's range, that the Shahed and the Mohajer drones are covered by the embargo, thus, knowingly providing components or technology to Iran used for the production of the drones is inconsistent with the relevant UN Security Council resolution. Below, key parts and their origin are highlighted.

### <u>Shahed-136</u>

Images of downed Shahed-136 drones show that it contains an MD550 engine that appears to be based on a model aircraft engine, the Limbach L550e, designed by Limbach Flugmotoren GmbH & Co.KG, a German aircraft company. The MD550 is produced by a Chinese company, Beijing MicroPilot Flight Control Systems, based in Beijing. The MD550 is identical in design to the engine produced by Limbach. The MD550 is estimated to generate 50 horsepower and is powered by gasoline. The engine is commonly used by civil aviation enthusiasts.

Iran has a long history of illicitly procuring Limbach engines for its drone programs, in violation of United Nations embargos and German national law. In 2012, Limbach opened a subsidiary in China, Xiamen Limbach Aircraft Engine Co., Ltd., to produce the L550 series and other engines. It is unclear how Beijing MicroPilot Flight Control Systems obtained the design for the L550 series engine, or if Limbach or its agent sold the design to the company under a license. A recent report suggests that Iran obtained the technology as well and is also capable of producing the engine.[3] Overall, it is possible that increased scrutiny on the engines in Germany, following reports that German aircraft engines ended up in drones used by Houthis in Yemen, led Iran to seek an alternative supplier in a country with less stringent export controls, and ultimately to seek domestic production.

The electronic receiver recovered in the Shahed-136 was assessed to be a fairly inexpensive component originating in the United States. Similar components from comparable brands can be purchased from several electronics distributors on the internet. The fuel pump found in wreckage is reportedly an in-line high-efficiency fuel pump produced by the American company TI Automotive; not specifically for aviation or drone purposes, but for high performance engines in general. Again, the product is commonly used by hobbyists and is fairly inexpensive. Many similar products of different brands can be found on the internet.

Shahed-131

The Shahed-131 drone is also a loitering munition, less advanced and smaller than the Shahed-136. The drone contains an Iranian redesigned engine, the Sorat-1/Sorat-2, that appears to be based on a Chinese design, the MDR-208, which in turn is based on a British aircraft engine design, the AR731, produced by UAV Engines LTD. On their website, UAV Engines LTD states that this engine has been “specifically designed and developed to be the ultimate engine for small target drones and short-life UAV’s.”[4] The Sorat-1/Sorat-2 has been displayed at aviation expos in Iran and is listed as a product produced by MADO Company, an Iranian UAV component manufacturer. The engine has less horsepower output than the engine used in the Shahed-136, giving it less range and payload capacity.

Mohajer-6

Images from media reports indicate that the engine used in the Mohajer-6 is a Rotax brand 912 IS Sport aircraft engine produced by the Austrian company, BRP-Rotax GmbH & Co KG. The engine has an output of 100 horsepower and is powered by gasoline. The engine is popular in civil small frame aviation.


**Figure 1. Left: A screenshot of Shahed-136 drones. Source: https://www.youtube.com/watch?v=y7v-VfBGg Right: A screenshot of a Mohajer-6 Iranian UAV drone. Source: https://www.youtube.com/watch?v=jkS-qSLVk7w**

## COMPONENTS IN THE RUSSIAN-MADE ORLAN-10

Russia's Orlan-10 is a mid-range, gasoline-engine, propellor-driven reconnaissance UAV widely used by Russian military forces to pinpoint Ukrainian civilian and military targets for artillery strikes. The Orlan-10 is a relatively low-tech UAV, launched from a catapult and recovered by parachute. Its modular design enables its on-the-ground assembly just prior to launch by its operating crew. The UAV is flown remotely with a handheld controller, typically from a command-and-control vehicle. Its range of 150 kilometers provides Russian combat forces in Ukraine with reconnaissance information, enabling these forces to fire its artillery more accurately at Ukrainian positions. This UAV can also provide laser guidance for guided munitions. Another variant of this UAV is also suspected to be deployed with signal jamming capabilities.

Open-source information, including videos of captured or downed Orlan-10 UAV, revealed foreign commodities as the key components in the Orlan-10.[5]

<u>Western and Allied Components Identified</u>

The Orlan-10 contains hardware originating in the U.S. or allied countries, such as a Japanese-made gasoline engine, and a U.S. starter generator. The Japanese-made engine, the Saito FG-40 is a civilian aircraft engine, available on the open market and popular among hobbyists. Being an engine, at several hundred dollars it is more expensive than other components. The starter generator series, on the other hand, is designed for a variety of applications, including "general-purpose, industrial controls, HVAC systems, test and measurement, medical instrumentation, AC/DC adapters, vehicles, marine, and avionics."[6]

The Orlan-10 also contains Western or allied-origin navigation components, such as a positioning module designed to be compatible not only with the U.S.-based Global Positioning System but also the Russian alternative satellite system, GLONASS.[7] Similarly to other electronics identified, such as the compass sensor and the tracker, it is advertised to have a wide range of automotive and industrial applications. The microcontroller at the basis for the flight controller is popular among drone enthusiasts due to its compatibility with flight controller software. Lastly, the Orlan-10 also contains imaging capabilities, which include a thermal imager, and a photocamera. While the former was difficult to identify, the latter was identified as a common Japanese camera for professionals and hobbyists, with remote shooting listed as one of its key features.

## AVAILABILITY AND APPLICATION OF THE PROCURED ITEMS

The table below lists the components identified above, as well as their country of origin and their apparent primary application. While none of these components are specifically designed for military drones and many are components of consumer electronics or have a wide range of industrial applications, some have a primary use in aviation. The list is not exhaustive, and others have created more comprehensive lists,[8] but it is meant to sample the range of components in terms of sophistication, costliness, and availability. Further, while some of these components' designs originated in countries with stringent export controls, some were indigenized or copied by others.

| Drone | Part and Details | Country of Origin | Apparent Primary Application |
|---|---|---|---|
| **Shahed-136** | Engine<br>MD550 (Based on: German L550) | Germany / China / Iran | Civil aviation |
| | Electronic Signal Receiver<br>TMS320F28335 | United States | No specific application |
| | Fuel Pump<br>In-Line High-Efficiency Fuel Pump | United States / Poland | High-performance engines in general |
| **Shahed-131** | Engine<br>Serat-01/Serat-02 (Based on: Chinese MDR-208: which is based on: British AR731) | United Kingdom / China / Iran | Target UAV's |
| **Mohajer-6** | Engine<br>912 IS SPORT | Austria | Civil aviation |
| **Orlan-10** | Engine<br>FG-40 gasoline engine | Japan | Civil aviation |
| | Navigator with LEA-6N chip | Switzerland | No specific application |
| | Tracker with chips marked HC4060 2H7A201 and STC 12LE5A32S2 35i | China; ? | No specific application |
| | Compass sensor<br>HMC6352 | United States | No specific application |
| | Starter-generator<br>PTN78020 | United States | No specific application |
| | Flight controller with<br>STM32F103 LQFP chip | France / Italy | No specific application |
| | Telemetry transmission module with ATxmega256A3 microcontroller; High-frequency amplifier RF3110; Receiver DP1205-C915 | United States; Germany | No specific application |
| | Flight servo actuator<br>Atlas servo CACA05k | Hong Kong, made in South Korea | No specific application; aviation is one of the advertised applications |
| | Camera, presumably a Canon EOS 750D | Japan | Professional and hobby photography |

**Table 1. The Western or allied designed or made aircraft parts identified as components in select drones used by Russia against Ukraine.**

## TRENDS UNDERMINING EXPORT CONTROLS

The extent of foreign components used for the design and mass production of the drones involved in direct military operations in Ukraine, particularly kamikaze-type drones, was surprising, especially because many of the components originate in countries with developed export control systems, meaning those with comprehensive national control lists of dual-use items and experience in controlling non-listed items based on end-use, i.e., catch-all controls, or non-listed items based on prohibited end-users, i.e. sanctions listings.

In evaluating the drone supply chains, it becomes clear that the difficulties to prevent the sales stem from a combination of the commonality of the parts and increased efforts to circumvent and undercut existing export controls and sanctions. One such effort is the increased misuse of widely available goods for military purposes; items that are produced, stocked, sold, and re-sold by many. These items are too ubiquitous to add to a national control list. Another effort to circumvent controls in countries with stringent list-based export controls is the procurement of items that fulfill the same function as a listed item but do not quite meet the technical parameters listed. In other words, the country procures items that are "good enough," accepting items that are not hardened or specifically designed for the end-use, and thus accepting a higher breakage rate or decreased reliability and capability. Yet another effort that becomes clear is the indigenization or semi-indigenization of components originating in a country with stringent export control and facing increased scrutiny; the procuring country may however still need to acquire sub-components. Similarly, the drone procurements show that third-party countries with less stringent export controls but access to the needed technology, whether legally acquired or by theft, and with the required industrial capabilities, enter the supply chain and provide needed components.

## LIMITATIONS AND OPPORTUNITIES FOR EXPORT CONTROLS

The in-depth analyses of the military drone procurements reveal challenges but also opportunities for export controls. The fact that it was widely unknown what components certain countries are procuring for their military drone programs, and where these components are produced and distributed, shows the increasing difficulty to understand global supply chains for sensitive products and capabilities. This makes it difficult for export control regulators to gauge the supply potential of their national industry and identify affected companies for outreach and awareness raising. Additionally, most of the items procured for the drone programs were not listed on national control lists. Thus, a list-based licensing approach to export controls is not sufficient in this case, and catch-all controls are needed. However, catch-all controls are difficult to implement; either the exporter has to be aware that the end-use is a restricted or prohibited one, or the government needs to have intelligence pertaining to the supply chain of a specific good, namely what item is procured from where, and for what restricted end-use. Only then can a government invoke a licensing requirement and communicate that to the affected company. Lastly, not all countries with export control laws in place have a catch-all clause that allows for this type of ad-hoc licensing requirement.

Once the supply chains are better understood, opportunities arise for export limitations. Outreach to companies can be tailored, license requirements for non-listed items can be established, and new entities can be added to the sanctions lists. One by one, past shipments can be analyzed, identifying procurement networks and leading to their disruption. When sanctions laws do not apply, involved entities can be added to internal "grey lists" by companies or governments. Similarly, governments can create "watch lists" of frequently sought components or combinations of components. In some instances, when items are especially critical to a sensitive program and not widely available on the open market, they should be added to the national control lists of the affected countries. In the case of the military drones, for example, at least one country added ultralight aircraft engines to its national control list and established a licensing requirement for the export to certain countries. The same country also added "technology" related to the production of controlled unmanned aerial vehicles that was not otherwise covered by the multinational control list it had adopted. However, a more coordinated effort with other countries would be desirable, especially if there are like-minded countries with possibly similar supply potential. For example, efforts to make additions to the relevant multinational regime control list should follow suit. Further, even in the event where countries with less developed export control systems enter the supply chain for sensitive commodities, a coordinated effort may reveal other sub-components or items still being produced in countries with developed export controls.

## UNDERMINING EXPORT CONTROLS IN NUCLEAR PROLIFERATION

While the components of the discussed military drones differ from those needed for unsafeguarded or sanctioned nuclear programs, such as an unsafeguarded centrifuge uranium enrichment program, the efforts taken to undercut other countries' export controls and sanctions are similar. Examples and case studies of these efforts exist, with the sought-after items for a centrifuge enrichment program, for example, generally understood, and many known cases dating back years including detailed shopping lists. Overall, however, the information that does exist on frequently sought items by sanctioned nuclear programs is less consolidated in the public domain and does not appear to receive the same widespread public attention as the procurements for the military drones.

Yet, many sanctioned nuclear facilities do rely on recurrent imports of foreign components for their operation and maintenance, and thus must rely on undercutting and evading export controls and sanctions to avoid widespread shutdowns. One example is North Korea's sanctioned plutonium production and uranium enrichment programs at Yongbyon. The known centrifuge enrichment facility appears to be active, as far as can be assessed by satellite imagery, and while North Korea's plutonium-producing 5 MWe nuclear reactor appeared to have been shut down for a few years, it appears to have been restarted. In addition, there were signs of activity at the reprocessing plant indicative of a reprocessing campaign as recently as July 2021, and North Korea's larger Experimental Light Water Reactor (ELWR) at Yongbyon, while years behind, appears largely finished, with multiple tests of its cooling system reported in 2022.[9],[10]

Given that ELWR's operation may be approaching, a timely example to consider is the items North Korea needs for light water reactor fuel production. Information available to the Institute reveals that around 2013 to 2014, the North Korean government created a purchase list for a small fuel pellet production line that included a sintering furnace, pelleting equipment, inspection equipment, and ultrasonic cleaning equipment.[11] According to available information, North Korea successfully obtained the goods mostly from a range of suppliers in China. Other than learning that the ultrasonic equipment came from a Western ally, which was unlikely to know the true purpose of this sale, the Institute did not learn of the specific origin of the equipment. While equipment specifically designed or prepared for nuclear fuel production is covered by the NSG Trigger List, the Institute learned that the equipment sought by North Korea was not typically found on national control lists. North Korea used the same method to acquire goods for the renovation of the 5 megawatt-electric reactor. Catch-all controls and UN Security Council sanctions would have prohibited the sale of these goods to North Korea, but without information on the true end-use(r), the initial sale to an intermediary would have received little scrutiny.

Since the depth of detail on sought-after items for the military drones used against Ukraine is not generally available for sensitive programs, and especially not for sanctioned or unsafeguarded nuclear programs, many of the above listed challenges for export controls remain. To overcome these challenges, regulators should work to improve their understanding of sanctioned and unsafeguarded nuclear programs, analyze domestic manufacturing and supply potential, assess national risks, communicate with companies to draw upon the knowledge companies have on their products, their product's applications, and their customers, and share relevant information with international partners and organizations.

## CHALLENGES AND OPPORTUNITIES FOR SAFEGUARDS

The analysis of procurements for military drone programs unveils several trends and efforts to undermine export controls and escape scrutiny that have been used by nuclear proliferators as well. Since export controls and safeguards are two important pillars of nuclear non-proliferation, operating in largely different spaces but with overlapping goals and a certain degree of reliance on one another, it is important for regulators and implementers in both safeguards and export controls to remain aware of challenges and limitations the other is facing. The challenges for export controls are listed above. However, there are also lessons relevant to safeguards.

The role of items that are not on national control lists is very prominent in military drone production, and while less visible, is increasingly important for nuclear programs. This complicates the IAEA's use of lists; most importantly, Additional Protocol (AP) Annex I and II help verify the absence of undeclared nuclear activities. Safeguards implementation would benefit from receiving information on manufacturing activities and trade of items beyond those listed in the Annexes. At a minimum, it highlights the need to keep AP Annex I and II lists up to date in line with updates made to the NSG Part 1 list; ideally the lists should be expanded by incorporating more items from Part 2.

In safeguards as in export controls, the development of "watch lists" can supplement the use of control lists. The Institute has developed lists of goods involving specific technologies, such as gas centrifuges, where many items are not on national control lists. They are called "watch lists" or "chokepoint lists;" there are other names. If an item on a watch list is not on a NSG control list, it is on the watch list typically because it was sought as part of secret procurement efforts for nuclear purposes. These lists serve as a guide to the most important goods, typically dual-use goods, to monitor for exports with the goal of preventing sales, identifying covert procurement, and learning more about covert or sensitive nuclear programs. In safeguards, the use of a watch list allows for a broader search for secret procurements and undeclared nuclear or nuclear-related activities. It is likely that the IAEA has its own lists of nuclear-related items relevant to covert procurement efforts, and additional sources would undoubtedly be appreciated. This is closely tied to the analysis of supply chains and export control regulators' efforts to understand national supply potential. Thus, there are many entities collecting information related to the development and application of these types of watch lists. More sharing with the IAEA should be encouraged.

Further, there are several ways to supplement the data the IAEA is currently receiving from its member states, including those implementing the Additional Protocol. First, on a voluntary basis, countries with developed export control systems should share licensing decisions and enforcement actions relevant to nuclear proliferation with the IAEA. This includes information on invoking catch-all legislation to prevent a sale suspected for a nuclear end-use. Second, IAEA member states should encourage their national companies to communicate directly with the IAEA and share relevant information on suspicious enquiries and unfulfilled orders with nuclear relevance; companies with developed internal compliance programs operating in the nuclear dual-use industry should be encouraged to do so on a regular basis. Several companies have been willing to share their data with the IAEA on a confidential basis, since 2005 under a voluntary cooperation mechanism called the IAEA Procurement Outreach Program. Finally, the IAEA should continue to promote the global implementation of export controls by providing member states with the underlying rationale for export controls and providing concrete guidance on export controls to member states that have adopted the Additional Protocol, as it pertains to their ability to report relevant manufacturing capabilities and import and export data to the IAEA.

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