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Unmanned Aerial Vehicles (UAVs): An Emerging Technology for Logistics

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ABSTRACT: *Unmanned Aerial Vehicles (UVAs), commonly known as drones have extensively been utilized in military operations during the last decade for surveillance, monitoring enemy activities, collecting information, and even attacking military targets and terrorist hideouts. They are also increasingly finding uses in civil applications, such as policing and firefighting and nonmilitary work, such as inspection of power lines and pipelines. Furthermore, corporations utilized them in commercial applications, such as agriculture, logistics, delivering small packages to rough terrain locations, and medication to emergency locations. UAVs are often preferred for missions that are too "dull, dirty or dangerous" for manned aircraft. This paper is exploratory in nature and describes the past and current usage in logistics and military. It further explores design and development considerations of UAVs. This is an emerging technology that will change the landscape of logistics and supply chain management. This research article provides a basic foundation to academicians, researchers, and commercial companies.*

Keywords: *Unmanned Aerial Vehicles (UAVs), Emerging Technology, Unmanned Aircraft System (UAS), National Airspace System, Drones.*

I. INTRODUCTION

Unmanned Aerial Vehicles (UVAs) or Unmanned Aircraft System (UAS) are commonly known as drones and have extensively been utilized in military operations during the last decade. To distinguish UAVs from missiles, a UAV is a powered aerial vehicle, recoverable, that does not carry on board a operator, uses aerodynamic forces to provide its lift, capable of flying autonomously or piloted remotely, and capable of carrying a lethal or nonlethal payload [1]. They United States military mainly used UAVs for surveillance, monitoring enemy activities, collecting information, and even attacking military targets and terrorist hideouts. They are also increasingly finding uses in civil applications, such as policing and firefighting and nonmilitary work, such as inspection of power or pipelines [2]. Furthermore, corporations utilized them in several commercial applications, such as agriculture, delivering small packages to rough terrain locations, and medication to emergency locations. UAVs are often preferred for missions that are too "dull, dirty or dangerous" for manned aircraft [3].

Countries like France and Germany have deregulated their air space to facilitate drone operations for commercial purposes. However, the United States of America (USA) has several restrictions. For example, a license is required to operate drones. The license operator is limited to operate drones below 400 feet in the sky and only up to the range of visibility and no payload. Federal, state, and local government entities must obtain an FAA Certificate of Waiver or Authorization (COA) before flying a UAV in the National Airspace System (NAS) [4].

The evolution of camera drones has further extended its use in sports and agriculture, checking levels of pollution in the sea, and in higher education. A camera drone was used during an Alpine Skiing World Cup Downhill race in 1912 in Canada. A year later a drone was also seen hovering above the field during a National Rugby League game between Australian sides Warringah Sea Eagles and the Sydney Roosters. In September 2014, drones were used at the Pape Clement castle vineyards in Bordeaux, France to assess the maturity of grapes [5].

The commercial and the private use of drones is soaring. They are capturing news videos, assisting farmers, filming movies, delivering packages, surveying real estate, recording vacation travel logs, and providing disaster relief. The Lux Research projects the market for commercial drones will reach $1.7 billion by 2025. Each year, $6.4 billion is being spent developing the drone technology. As the Internet of Things (IoT) continues to expand, drones of all sizes are taking their place among IoT devices and feeding back torrents of data for analysis. Along with the drones come new jobs. In the US alone, 70,000 new drone-related jobs are projected

within the next three years; 100,000 new jobs are expected by 2025. In order to provide a trained workforce capable of meeting this demand, schools are already jumping in and offering drone programs and degrees.

Amazon and Google have been developing software and communication technology so that drones become autonomous, capable of delivering supplies, and providing many commercial services. The federal Aviation Administration (FAA) is working on providing license and operational regulations pertaining to UAVs.

This paper is exploratory in nature and describes the current usage in logistics and the military. It further explores future uses of UAVs, cost structure, capabilities and limitations, and drone manufacturing companies. This is an emerging technology that will change the landscape of logistics and supply chain management. The history of UAVs is described in Section and Section 3 contains a classification of drones. The military and commercial uses of drones are described in Section 4 and FAA regulations and restrictions are listed in Section 5. Defense against UAVs is stated in Section 7 and design considerations in Section7. Finally, Section 8 concludes this article.

II. HISTORY OF UAVs

Although it was not a drone, but in mid-1800s, Austria attacked Venice by sending unmanned bomb-filled balloons. The United States Department of Defense (DoD) and the United States Federal Aviation Administration (FAA) adopted the term *unmanned aircraft system* (UAS) for UAVs or drones and so did the International Civil Aviation Organization and the British Civil Aviation Authority.

The innovation of drones started in early 1900s. Its development continued during World War I, when Dayton-Wright Airplane Company produced a pilotless aerial torpedo that would drop and explode at a preset time. The earliest attempt at a powered unmanned aerial vehicle was A. M. Low's "Aerial Target" of 1916 [6]. Nikola Tesla described a fleet of unmanned aerial combat vehicles in 1915. A film star and model airplane enthusiast Reginald Denny developed a remote piloted vehicle in 1935. UAVs were used during World War II to train antiaircraft gunners and to fly attack missions. Nazi Germany produced and used various UAV aircraft during WWII. Jet engines were applied after World War II in such types as the Australian GAF Jindivik, and Teledyne Ryan Firebee I of 1951, while companies like Beechcraft also produced their Model 1001 for the U.S. Navy in 1955 [7]. Nevertheless, they were little more than remote-controlled airplanes until the Vietnam era. The Unmanned small airplanes, called “pioletless target aircraft (PTA)” have been used since WWII by military personal to target practice.

During the Vietnam War, UAVs often flew either in a straight line or in preset circles collecting video until they ran out of fuel and landed. Later, UAVs often combined remote control and computerized automation. More sophisticated versions may have built-in control or guidance systems to perform low-level human pilot duties, such as speed and flight-path stabilization, and simple scripted navigation functions, such as waypoint following.

III. UAVs CLASSIFICATION

UAVs have been used for military and commercial applications. From the application point of view, drones can be classified into the following six basic categories [9]:

- Reconnaissance – a UAV provides battlefield intelligence.
- Target and decoy – a UAV provides a target to ground and aerial gunnery, which simulates an enemy aircraft or missile.
- Combat – a UAV provides attack capability for high-risk missions.
- Research and development – A UAV is used to further develop UAV technologies to be integrated into field-deployed UAV systems.
- Civil and commercial UAVs – These are specifically designed for civil and commercial applications and include cameras and software.
- Logistics – UAVs are specifically designed for transporting payloads, cargo, and logistics operations.

Drones can also be classified in terms of range/altitude and those are enumerated below:

- Hand-held: can fly up to 600 meters(2,000 feet) altitude and about 2 kilometer range.
- Close: They can fly at 1,500 meters(5,000 feet) altitude and up to 10 kilometer range.
- NATO type: They can fly at 3,000 meters (10,000 feet) altitude and up to 50 kilometer range.
- Tactical UAVs: They can fly at 5,500 meters (18,000 feet) altitude and about 160 kilometer range.
- MALE (medium altitude, long endurance): They fly up to 9,000 meters (30,000 feet) and range over 200 kilometers.

- HALE (high altitude, long endurance): They can fly over 9,100 meters (30,000 feet) and indefinite range.
- HYPERSONIC high-speed, supersonic (Mach 1–5) or hypersonic (Mach 5+): They fly at 15,500 meters (50,000 feet) or suborbital altitude, and range over 200 kilometers.
- ORBITAL low earth orbit (Mach 25+).
- CIS Lunar Earth-Moon transfer.
- CACGS Computer Assisted Carrier Guidance System for UAVs.

The military planners use the U.S. Military UAV tier system to designate individual aircraft elements based on their roles and not on specific models.

IV. MILITARY AND COMMERCIAL APPLICATIONS

Military forces, civilian government agencies, businesses, and private individuals have used UAVs during the last decade. In the United States, for example, government agencies use UAVs to patrol the nation's borders, scout property, and locate fugitives. UAVs have been used for numerous civil aviation purposes, including aerial surveying of crops, acrobatic aerial footage in filmmaking, search and rescue operations, inspecting power lines and pipelines, counting wildlife, and delivering medical supplies to remote or otherwise inaccessible regions. Further uses include reconnaissance operations, cooperative environment monitoring, border patrol missions, convoy protection, forest fire detection, surveillance, coordinating humanitarian aid, plume tracking, search & rescue missions, detection of illegal hunting, land surveying, fire and large-accident investigation, landslide measurement, illegal landfill detection, and crowd monitoring. In the United States, Falkor Systems has targeted extreme sports photography and video for drone use, focusing on skiing and base-jumping activities Private Citizens and media organizations use UAVs for surveillance, recreation, news-gathering, or personal land assessment. Occupy Wall Street journalist, Tim Pool, used a drone, an inexpensive radio-controlled quadcopter with cameras attached and controlled by Android devices for live feed coverage of Occupy movement events. In February 2012, an animal rights group used a hexacopter to film hunters shooting pigeons in South Carolina. In 2014, a drone was used in search and rescue operations to successfully locate an elderly gentleman with dementia who went missing for 3 days. In 2012, Cavim, the state-run arms manufacturer of Venezuela, claimed to be producing its own UAV as part of a system to survey and monitor pipelines, dams, and other rural infrastructure. The UAV measuring 3 by 4 meters had a range of 100 km, a maximum altitude of 3,000 meters, and flying time of 90 minutes.

4.1 Military Uses

4.1.1 Reconnaissance

In 2013, the U.S. Navy launched a UAV from a submerged submarine, the first step to "providing mission intelligence, surveillance, and reconnaissance capabilities to the U.S. Navy's submarine force [9]." The U.S.S.R used Tu-141, a reusable operational and tactical reconnaissance drone, to a depth of hundreds of kilometers from the front line at supersonic speeds. USSR's Tu-123, a supersonic long-range drone, was used for conducting photographic and signals intelligence up to a distance 3,200 kilometers. Forty-three known Soviet drone models have been used.

4.1.2 Armed Attacks

When the United States entered the global war on terror in 2001, U.S. military officials found difficulty in fighting irregular warfare or guerilla warfare. The U.S. military turned to Harlan Ullman and James Wade's Shock and Awe doctrine, which states "the most efficient way of fighting asymmetric threats in irregular warfare is to conduct fast and destructive operations in order to incapacitate the enemy"

The U.S. military used MQ-1 PredatorUAVs armed with Hellfire missiles as platforms for hitting ground targets. Armed Predators were first used in late 2001 from bases in Pakistan and Uzbekistan, mostly aimed at assassinating high-profile individuals (terrorist leaders, etc.) inside Afghanistan]10]. Since then, many cases of such attacks have been reported taking place in Afghanistan, Pakistan, Yemen, and Somalia. The advantage of using an unmanned vehicle rather than a manned aircraft in such cases is to avoid a diplomatic embarrassment should the aircraft be shot down and the pilots captured, since the bombings take place in countries deemed friendly and without the official permission of those countries.

4.1.3 Targets for Military Training

Since 1997, the U.S. military has used more than 80 F-4 Phantoms converted into robotic planes for use as aerial targets for combat training of human pilots. The F-4s were supplemented in September 2013 with F-16s as more realistically maneuverable targets [11]. The author remembers from his personal experience while he was serving in the Indian Navy. A pilotless target airplane (PTA) was used for testing gunnery equipment and

training gunners to shoot targets. A balloon was tied to the PTA, controlled from a Leander Class Frigate, named INS Nilgiri, in 1972 off Singapore. The British Royal Navy then used to have a fleet of warships in Singapore. The Indian Navy requested the services of the PTA and its operator.

4.2 Commercial and Professional Aerial Surveillance

Low cost UAVs facilitated aerial surveillance of large areas. Surveillance applications include livestock monitoring, wildfire mapping, pipeline security, home security, road patrol, and antipiracy. The trend for the use of UAV technology in commercial aerial surveillance is expanding rapidly with increased development of automated object detection approaches.UAS technologies are used worldwide as aerial photogrammetry and LiDAR platforms.

4.2.1 Motion Picture Filmmaking and Journalism

The Motion Picture Association of America filed a petition in June 2014 with the Federation Aviation Authority (FAA) to seek approval for the use of drones in video and filmmaking. The seven filmmaking companies argued that low cost drones could be used for shots that required a helicopter or a manned aircraft, which would reduce cost of filmmaking [12]. Several countries in other parts of the world have been using drones for filmmaking and media coverage. For example, drones were used in the 2014 Winter Olympics in Sochi for filming skiing and snowboarding events. Some advantages of using unmanned aerial vehicles in sports are that they allow video to get closer to the athletes, and they are more flexible than cable-suspended camera systems.
Drones have been especially useful in covering disasters such as typhoons [13]. Journalists of the United States like some European counties are also interested in using drones for newsgathering. The Professional Society of Drone Journalists was established in 2011 and describes itself as "the first international organization dedicated to establishing the ethical, educational, and technological framework for the emerging field of drone journalism. A coalition of 11 news organizations is working with the Mid-Atlantic Aviation Partnership at Virginia Tech on how reporters could use unmanned aircraft to gather news. The College of Journalism and Mass Communications at the University of Nebraska-Lincoln has established a Drone Journalism Lab and the University of Missouri also has created the Missouri Drone Journalism Program.

4.2.2 Law Enforcement Applications

Many police departments in India have procured drones for law and order and aerial surveillance. UAVs have been used for domestic police work in Canada and the United States, and Britain. A dozen US police forces applied for UAV permits by March 2013. Drones have been used by U.S. Customs and Border Protection since 2005 and have plans to use armed drones. The FBI have been owning and using UAVs for surveillance. In 2007, British police in Liverpool used drone to capture the anti-social behavior of festive revelers during the holiday season. A report in 2014 stated that five English police forces obtained or operated unmanned aerial vehicles for observation. Merseyside Police caught a car thief with a UAV in 2010. A UAV was also used in Congo as part of MONUSCO peacekeeping mission. In August 2013, the Italian defense company, Selex ES, provided an unarmed surveillance drone to be deployed in the Democratic Republic of Congo to monitor movements of armed groups in the region and to protect the civilian population more effectively [14].

4.2.3 Search and Rescue Applications

UAVs were used in search and rescue after hurricanes struck Louisiana and Texas in 2008. Predators, operating between 18,000 and 29,000 feet above sea level, performed search and rescue operations and damage assessment. Payloads carried were an Optical sensors and a synthetic aperture radar was carried as a payload that provided real-time images through clouds, rain, or fog, both in daytime or nighttime conditions. Photos taken before and after the storm were compared by a computer that highlighted areas of damage. Micro UAVs, such as the Aeryon Scout, have been used to perform search and rescue activities on a smaller scale, such as searching and rescuing missing persons [15]. UAVs have also been tested as airborne lifeguards, locating distressed swimmers using thermal cameras and dropping life preservers to them.
The Space Assets for Demining Assistance program from the European Space Agency aims to improve the socioeconomic impact of land release activities in mine action. It is developing and has tested UAV technology for demining in Bosnia-Herzegovina.

4.2.4 Scientific Research

Unmanned aircraft are especially useful in penetrating areas that may be too dangerous for manned aircraft. The U.S. National Oceanic and Atmospheric Administration has used the Aerosonde unmanned aircraft system as a hurricane hunter since 2006. The 35-pound system can fly into a hurricane and communicate real-time data directly to the National Hurricane Center. The Aerosonde system provides measurements from closer to the water's surface than previously captured. This set of data includes measurements beyond the standard barometric pressure and temperature typically culled from manned hurricane hunters. NASA has also begun

using the Northrop Grumman RQ-4 Global Hawk for extended hurricane measurements. In 2009, a drone carrying a thermal-imaging camera was used above a beach in southern France to let scientists check levels of pollution in the sea.

4.2.5 Conservation

By 2012 The International Anti-Poaching Foundation also started was using UAVs in 2012. In June 2012, World Wide Fund for Nature(WWF) announced it will begin using UAVs in Nepal to aid conservation efforts following a successful trial of two aircraft in Chitwan National Park [16], with ambitions to expand to other countries, such as Tanzania and Malaysia. The global wildlife organization trained a dozen personnel to use UAVs for operational use. In August 2012, UAVs were used by members of the Sea Shepherd Conservation Society in Namibia to document the annual seal cull. In December 2013, the Falcon UAV was selected and used by the Namibian government and WWF to help combat rhino poaching and monitor rhino populations with the use of RFID in Etosha National Park [17].

In 2012, the WWF supplied two FPV Raptor 1.6 UAVs to the Nepal National Parks. These UAVs were used to monitor rhinos, tigers, and elephants and deter poachers. The UAVs were equipped with time-lapse cameras and could fly 18 miles at 650 feet elevation. In December 2012, the South African National Parks Authority started using a Seeker II UAV against rhino poachers at Kruger National Park.

4.2.6 Animal Rights

Anti-whaling activists used an Osprey UAV (made by Kansas-based Hangar 18) in 2012 to monitor Japanese whaling ships in the Antarctic. In 2012, the Ulster Society for the Prevention of Cruelty to Animals used a quadcopter UAV to deter badger baiters in Northern Ireland. In March 2013, the British League Against Cruel Sports carried out trial flights with UAVs and planned to use a fixed-wing Open Ranger and an "octocopter" to gather evidence to make private prosecutions against illegal hunting of foxes and other animals. In Pennsylvania, Showing Animals Respect and Kindness used drones to monitor people shooting at pigeons for sport. One of their octocopter drones was shot down by hunters.

In 2014, Will Potter proposed using drones to monitor conditions on factory farms. The idea is to circumvent ag-gag prohibitions by keeping the drones on public property, but equipping them with cameras sensitive enough to monitor activities on the farms [18]. Potter raised nearly $23,000 in 2 days for this project on Kickstarter.

4.2.7 Maritime patrol

Japan is studying how to deal with the UAVs that China is using to enforce their claims on unmanned islands [19].

4.2.8 Oil, Gas, and Mineral Exploration and Production

UAVs can be used to perform geophysical surveys, in particular geomagnetic surveys where the processed measurements of the Earth's differential magnetic field strength are used to calculate the nature of the underlying magnetic rock structure. A knowledge of the underlying rock structure helps trained geophysicists to predict the location of mineral deposits. The production side of oil and gas exploration and production entails the monitoring of the integrity of oil and gas pipelines and related installations. For above-ground pipelines, this monitoring activity is performed using digital cameras mounted on one or more UAVs.

4.2.9 Disaster relief

Drones have been used to provide help in disaster relief by gathering information from across an affected area to build a picture of the situation and give recommendations to direct resources [20].T-Hawk and Global Hawk drones were used to gather information about the damaged Fukushima Number 1 nuclear plant and disaster-stricken areas of the Tōhoku region after the March 2011 tsunami.

4.2.10 Archaeology

In Peru, archaeologists use drones to speed up survey work and protect sites from squatters, builders, and miners. Small drones helped researchers produce three-dimensional models of Peruvian sites instead of the usual flat maps – and in days and weeks instead of months and years. Drones have replaced expensive and clumsy small planes, kites, and helium balloons. Drones costing as little as $1,000 have proven more useful than other equipment. In 2013, drones flew over at least six Peruvian archaeological sites, including the colonial Andean town Machu Llacta 4,000 m (13,000 feet) above sea level. However, drones continue to have altitude problems in the Andes. An archaeologist said, "You can go up three meters and photograph a room, 300 meters and

photograph a site, or you can go up 3,000 meters and photograph the entire valley." In September 2014, drones weighing about 0.5 kg were used for 3D mapping of the above-ground ruins of the Greek city of Aphrodisias [21].

4.2.11 Cargo Transport

UAVs can transport medicines and medical samples into and out of remote or otherwise inaccessible regions [22].The RQ-7 Shadow can deliver a "Quick-MEDS" canister to front-line troops. Initial attempts at commercial use of UAVs, such as the Tacocopter company for food delivery, were blocked by FAA regulation. A 2013 announcement that Amazon was planning deliveries using UAVs was met with skepticism. In 2013, in a research project of DHL, a small quantity of medicine was delivered via a UAV.

In 2014, the prime minister of the United Arab Emirates announced that the UAE plans to launch a fleet of UAVs to deliver official documents and supply emergency services at accidents. Google revealed in 2014 it had been testing UAVs for two years. The Google X program aims to produce drones that can deliver items.

In July, 2015, A NASA Langley fixed-wing Cirrus SR22 aircraft, flown remotely from the ground, operated by NASA's Langley Research Center in Hampton and a hexacopter drone delivered pharmaceuticals and other medical supplies to an outdoor free clinic at the Wise County Fairgrounds, Virginia. The aircraft picked up 10 pounds of pharmaceuticals and supplies from an airport in Tazewell County in southwest Virginia and delivered the medicine to the Lonesome Pine Airport in Wise County. However, the aircraft had a pilot on board for safety. The supplies went to a crew, which separated the supplies into 24 smaller packages to be delivered by small, unmanned drone to the free clinic, during a number of flights over two hours. A company pilot controlled the hexacopter, which lowered the pharmaceuticals to the ground by tether. Health care professionals received the packages, then distributed the medications to the appropriate patients.

4.2.12 Crop spraying

Japanese farmers have been using Yamaha's R-50 and RMAX unmanned helicopters to dust their crops since 1987 [23]. Some farming initiatives in the U.S. use UAVs for crop spraying, as they are often cheaper than a full-sized helicopter. In September 2014, the Pape Clement castle vineyards in Bordeaus, France used a drone fitted with an infrared camera to assess the maturity of grapes.

V. FAA REGULATIONS FOR UNMANNED AERIAL VEHICLES (UAVs)

According to the Federal Aviation Administration (FAA), users must obtain a Certificate of Authorization to operate a UAV for non-recreational purposes. The use of UAVs for law-enforcement purposes is also regulated at a state level. For commercial use in the United States, the FAA mandates that operators must first petition for an exemption under Section 333 to be approved for commercial use cases. Even after obtaining a license to operate drones, there are following limitations. FAA allows a government public safety agency to operate UAVs

- Weighing 4.4 pounds or less.
- A UAS must be flown within the line of sight of the operator.
- Less than 400 feet above the ground, during daylight conditions.
- Inside Class G (uncontrolled) airspace
- By a licensed pilot.
- More than five miles from any airport or other location with aviation activities.

VI. DEFENSE AGAINST UAVs

The United States armed forces currently have no defense against low-level drone attack, but the Joint Integrated Air and Missile Defense Organization is working to repurpose existing systems to defend American forces. Two German companies are developing 40-kW lasers to damage UAVs. Three British companies have jointly developed a system to track and disrupt the control mechanism for small UAVs.

VII. DESIGN AND DEVELOPMENT CONSIDERATIONS

UAV design and production is a global activity with manufacturers all across the world. The United States and Israel were initial pioneers in this technology, and U.S. manufacturers had a market share of over 60% in 2006, with U.S. market share due to increase by 5–10% through 2016.Northrop Grumman and General Atomics are the dominant manufacturers in this industry on the strength of the Global Hawk and Predator/Mariner systems [24]. According to the Stockholm International Peace Research Institute, Israeli companies were behind 41% of all UAVs exported in 2001-2011. The European market share represented 4% of global revenue in 2006.

In December 2013, the Federal Aviation Administration announced its selection of six states that will host test sites emphasizing respective research goals: Alaska (sites with a wide variety of climates), Nevada (formulating standards for air traffic control and UAV operators), New York (integrating UAVs into congested airspace), North Dakota (human impact; use in temperate climates), Texas (safety requirements and airworthiness testing), and Virginia (assessing operational and technical risk).Some universities offer UAS research and training programs or academic degrees.

On October 12, 2014, the Linux Foundation and leading technology companies launched the open source Drone code Project. The Drone code Project goal is to help meet the needs of the growing UAV community with a neutral governance structure and coordination of funding for resources and tools which the community needs. The development of air-vehicle autonomy has largely been driven by the military.

VIII. CONCLUSION

Researchers and operators are continuously working to produce more capable and less expensive UAVs and coming up newer application in business and commerce. The FAA is devising newer regulations so as to make drones useful for everyone but the FAA is also concerned with safety, both of the aviation activities as well as the general public.

Several corporations like Google and Amazon are pressurizing and lobbying to formulate regulations so that drones can be advantageously utilized for delivering packages and medicines for emergency as well as on a regular basis. Some researchers are working on developing powerful batteries to fly for a longer duration and longer distance. Amazon claims to deliver packages within two hours of receiving orders when drones are allowed for payloads and commercial applications. Software companies are developing systems for drones to be autonomous and capable of communicating in real-time between the UAV and its controller. Nevertheless, one thing is definite – the use of UAVs, if permitted for commercial purposes, will change the landscape of logistics and supply chain operations.

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