Causes of UAV Loss

While some are keen to use UAVs in everyday applications, the number of crashes indicates that the development of this technology still has a very long way to go to become reliable enough to be widely adopted. Flying large and mid-sized aircraft remotely is extremely complicated and recent official investigations into the drone crash causes found that the complexity of the systems themselves was a key factor in the crashes.

As with general aviation, safety is the key issue to tackle. Recent development in sensors, autopilots, and automatic collision avoidance systems, among others, are crucial to increase safety so government officials can establish laws that will allow manned and unmanned aircraft to coexist in the same airspace.

Abbreviations

DoD	United States of America Department of Defense
IAI	Israeli Aircraft Industries
MTBF	Mean time before failure. The average time it takes for an airborne vehicle to suffer a fatal failure or accident. It represents its expected lifetime.
US / USA	The United States / United States of America
Drone	Is used as a synonym of UAV. Drone = UAV
RPAS	Remote Piloted Aircraft System
UAS	Unmanned Aircraft Systems. The airborne part (the aircraft plus its sensors and avionics), plus the ground part (the ground control equipment plus its ground-to-air and ground-to-ground communications system)
UAV	Unmanned Aircraft Vehicle

Historical Crash Rates

Statistics from the DOD[1]

Vehicle Type	Mishaps (per 100,000 hrs)	MTBF (calculated)
UAV		
Predator	20	5,000
Hunter	47	2,127
Global Hawk	88	1,136
Pioneer	281	350
Shadow	191	523
Manned		
U-2	6.8	14,705
F-16	4.1	24,390

U.S. MILITARY AIRCRAFT AND UA CLASS A MISHAP RATES (LIFETIME), 1986 – 2004

[1] Homeland Security Digital Library "Unmanned Aircraft Systems Roadmap 2005-2030" https://www.hsdl.org/?abstract&did=236553

This table shows the Class A Mishap Rate per 100,000 hours versus cumulative flight hours for the Global Hawk, Predator, Hunter, and Pioneer fleet for the period 1986 through 2003. Class A mishaps are those aircraft accidents resulting in loss of the aircraft (in Naval parlance, "strike"), human life, or causing over $1,000,000 in damage. These data show a mishap rate (i.e., Class A accidents per 100,000 hours of flight) of 20 for Predator, 47 for Hunter (24 since the major reliability improvements in 1996), 88 for Global Hawk, 281 for Pioneer, and 191 for Shadow. For comparison to two manned military aviation mishap rates, the U-2 and F-16 have cumulative Class A mishap rates of 6.8 and 4.1 per 100,000 hours, respectively. Compared to non-military aircraft, general aviation (GA) suffers about 1 Class A mishap per 100,000 hours, regional/commuter airliners about a tenth of GA rate, and larger airliners about a hundredth of GA rate.

Vehicle Type	**Mishaps per 100,000 hours (Series)**	**Mishaps per 100,000 hours (Model)**
RQ-1A / Predator	43	20
MQ-1B /Predator	17	
RQ-2A / Pioneer	363	281
RQ-2B / Pioneer	179	
RQ-5 / Hunter (pre 1996)	255	47
Rq-5 / Hunter (post 1996)	24	
RQ-7 / Shadow	191	191

Please note that from the RQ-1A to the MQ-1B Predator the mishaps per 100,000 hours improved from 43 to 17

From these figures, looks like a twin-engine UAV, the RQ-5 Hunter post-1996, has a mishap count (24) of about 8 times lower than a single-engine UAV (the RQ-7 Shadow) with a mishap count of 191.

The Global Hawk is an RPAS design, not a 100% autonomous system. We can not be sure if the F-16 and the Global Hawk turbine engines are FAA certified. The F-16 uses a General Electric turbine and the Global Hawk a Rolls Royce turbine.

The Predator is a turboprop UAV, its predecessor, the Reaper (not shown on the tables) has almost the same profile but with a fully automated autopilot for a turboprop UAV.

The data shows that a single turbine is more reliable than the twin Wankel engines used by the RQ-5 Hunter.

Crash statistics improved by 2016 but not dramatically as seen below [2]

Aircraft	Dates	Class A Mishap	Fleet size	Mishap (%)	Cumulative Rate (per 100,000 flight hrs.)	Hours between Mishaps	Cumulative Flight Hours
MQ-1 (Predator A)	2005-2015	122	169	72.2%	6.7	14,920	1,820,212
MQ-9 (Predator B)	2007-2015	34	165	20.6%	4.0	24,953	848,391
F-16	1975-1986	73	1,148	6.4%	7.1	14,033	1,024,414
F-16	1975-2015	365	2,210	16.5%	3.5	28,744	10,491,752
F-22	2005-2015	22	179	12.3%	5.4	10,196	224,313
F-100	1954-1979	1161	2,294	50.6%	21.2	4,712	5,471,047
A-7	1967-1991	101	1,569	6.4%	5.7	17,514	1,768,958

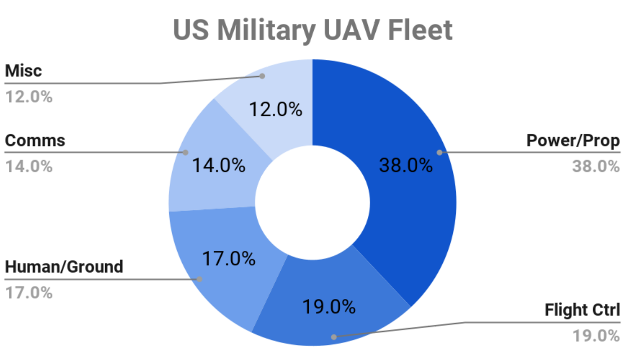
General Aviation Fatal Accident Rate 1.2% FY2011 Source NTSB

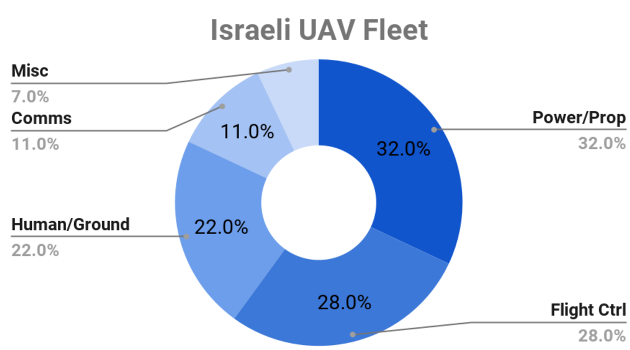
Commercial Aviation (Part 121) Accident Rate 0.2% FY2011 Source NTSB

You cannot increase an UAV reliability without experience. That is what the NTSB in manned aviation is all about: Learning from mistakes done in aircraft, in its systems, in the piloting, in the maintenance procedures, and others.

Crash Causes Breakdown

In the "Unmanned Aircraft Systems Roadmap 2005-2030", the DoD found similar data trends between the US UAV operations and the Israeli Defense Forces UAV missions.





[2] Analysis of UAV Military Aircraft Mishaps, https://www.researchgate.net/publication/327135551_Analysis_of_UAV_Military_Aircraft_Mishaps

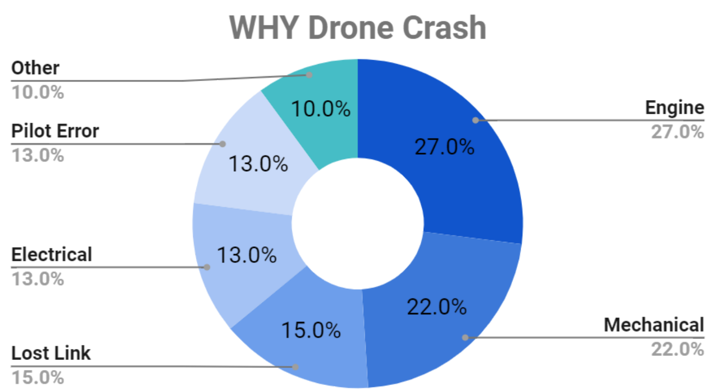
The #1 cause is power and propulsion (32-38%), flight controls (19-28%) is #2, human error (17-22%) is #3 and #4 is Comms (11-14%). These four causes represent 88% to 93% of the crash statistics causes.

A recent document published by Drone Wars UK in 2019[3] compiled a dataset of more than 250 crashes of large (more than 600 kg) military drones that have occurred over the past decade (2009-2018). The information has been drawn from official investigation reports, freedom of information requests, and press reports.

The document states that the most common reason for crashes (27%) is attributed to engine failure. These are often caused by an oil or fuel leak or the loss of coolant.

Mechanical failure adds up to 22% of drone crashes. This includes failures of particular pieces of equipment such as a turbocharger or a propeller, to pieces of wings or tails becoming detached.

Crews regularly lose contact with their drones due to communication or other problems. Often the link is re-established within a short time. If it is not, the drone is programmed to fly on auto-pilot to a particular point where the connection can be re-established. However, on occasion, the link is never reestablished and the drone flies on until it runs out of fuel and crashes or is shot down. 15% of the crashes are attributed to lost links.



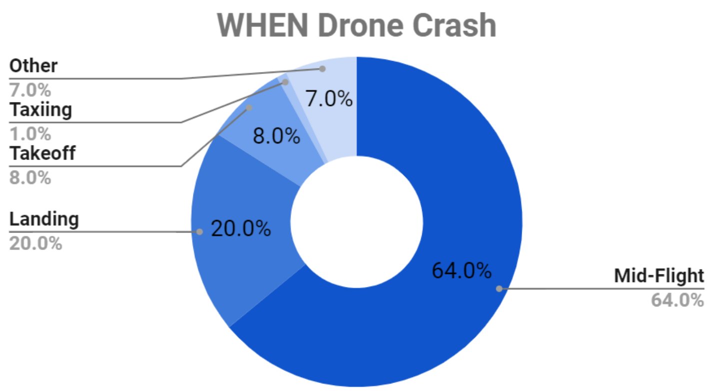
Then we have that 13% of the crashes are attributed to electrical failures. These include the failure of onboard power generators and various servomotors as well as the failure of wiring and cables bringing power to particular pieces of equipment.

Crashes are attributed to pilot or crew error when decisions they make lead directly to a crash. This is often in the situation of a crisis occurring when the crew has to make decisions in a very limited amount of time. In crisis situations, crews are supposed to follow a procedure checklist but this appears to be difficult in some circumstances. 13% of the crashes are attributed to pilot error.

The remaining 10% of crashes were caused by electronics and software failure, poor weather, enemy action, and in one case, a bird strike. Electronic equipment and computer components are vital to the successful flight of UAVs, and when systems such as electronic navigation

[3] https://dronewars.net/2019/06/09/accidents-will-happen-a-dataset-of-military-drone-crashes/

systems or GPS receivers fail, it can be catastrophic. Similarly, if the software embedded in electronic equipment fails it can lead directly to a crash. Drones are remarkably vulnerable to weather changes and a number of crashes documented in the dataset were caused by lightning strikes, ice accumulation, or strong winds. The last is by far the most common of this group



When Drone Crash

Analysis of the data enables us to gain a good understanding of when, on average, drone crashes take place.

64% of the crashes took place while the drone was in mid-flight, while 20% occurred at landing. 8% crashed during the take-off phase, with a small number of crashes (1%) taking place while the drone was taxiing along the runway.

For 7% of the recorded accidents, it is unknown at what stage the crash occurred

The Cost Of Uav Crashes: Expected Value Lost Due Of A Crash

In this definition, the cost refers to the financial or monetary value of the airborne part of a UAS divided by its MTBF as explained above. Alternatively, we can multiply the airborne value of the UAS times its loss probability. The hard part to calculate is the "operational impact" that is related to the mission the UAV performs which is commonly not included, but nevertheless, it might be very high, such as if human lives are lost due to a UAV crash.

For example, if you are a firefighter dealing with an out-of-control wildfire, you can deploy a small UAV with a camera to assess the damage and verify the position of your team. The system might be worth $50,000 USD. Just before the UAV reaches the surveillance area, you lose it. Whatever the reason, the time it takes to deploy a new $50,000 USD may produce a great deal of ecological, wildlife, economic damage, and even priceless human casualties, due to the lack of intelligence to improve the decision-making process or the firefighter task force deployment. In this scenario, the operational impact is huge and very hard to calculate.

Let's go back to the easy part, the financial or monetary cost of a drone crash. Remember the MTBF (mean time before failure)? If the UAV plus the camera or sensor it carries is worth, say, $2,000,000 USD, for a drone with an MTBF of 523 hours, you must add $3,825 ($2,000,000 divided by 523 hours) to the per-hour cost of operation, as an expected loss reserve. The same calculation is done in general aviation with what is called engine reserves, in order to calculate the cost incurred by the diminished life of the engines with their use, and calculate the money reserves needed when the time comes for their overhaul or replacement.

The true (unrecognized and unpublished) cost of operating a drone IS NEVER the fuel, engine reserves, and manpower as in General or Commercial Aviation. The main component of the operating cost in the UAV industry is, by far, the expected value of the economic and operational loss of a crash.

We must distinguish between the following user groups: A.-The group consisting of private companies, civil authorities, and routine military applications, and B.-The wartime military applications. For Group A, a long life is extremely important as the economic impact of present non-redundant designs is the highest cost component, and Group B, where reliability does not matter much, as the UAVs are subject to a much higher loss rate than component failure due to the probability that they are taken down by the enemy. In order to reduce this probability, the emphasis is not so much on redundancy but on stealth factors such as low noise signature, small form factor, low radar signature, their capability to fly close to the ground ("nap-of-the-earth"), and low heat signature.

Conclusion:

It is highly recommended for potential buyers to include this crucial consideration in their decision process. Ask the right questions when purchasing.

In UAVs, the purchase price is just a percentage of the real full price of ownership.

It can be easily seen that the key to developing UAVs that can become a practical tool for civilian applications and military routine operations (i.e. non-war applications) is reducing the accident rate.
