UAV LOSSES AND RELIABILITY

Designing a reliable, low cost, and robust platform

While some are keen to see the use of UAVs normalized, the number of crashes indicates that the development of this technology still has a very long way to go. Flying large and mid-sized aircraft remotely is extremely complicated and recent official investigations into drone crash incidents found that the complexity of the systems themselves was a 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 could allow manned and unmanned aircraft to coexist in the same airspace.

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Glossary

DoD	United States of America Department of Defense
Drone	Is used indistinctively as UAV. Drone = UAV
FAAS	Fully Autonomous Aircraft Systems
IAI	Israeli Aircraft Industries
MTBF	Mean time before failure. The average time it takes for an airborne vehicle to suffer a failure or accident.
RPAS	Remote Piloted Aircraft System
UAS	Unmanned Aircraft Systems (The aircraft plus the sensors, plus the ground control equipment plus the communications system)
UAV	Unmanned Aircraft Vehicle
US / USA	United States / United States of America

Historical Crash Rates

Statistics from a DOD document[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

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 the 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 the 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 suffers about 1 Class A mishap per 100,000 hours, regional/commuter airliners about a tenth of that rate, and larger airliners about a hundredth of that rate.

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

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

The use of a twin-engine configuration might reduce UAV mishaps by a factor of 8 (eight)

From these figures, looks like a twin-engine UAV, the RQ-5 Hunter post-1996, has a mishap rate (24) about 8 times lower than a single-engine UAV, the RQ-7 Shadow, with a mishap rate 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, which are also very noisy.

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

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

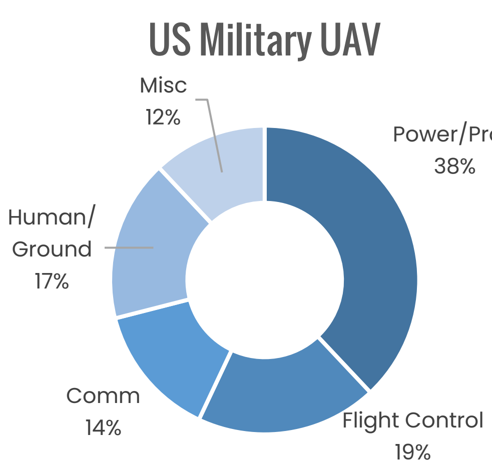
Aircraft	Dates	Class A Mishap	Fleet size	Mishap (%)	Cumulative Rate (per 100,000 flight hrs.)	Hours between Mishaps	Cumulative Flight Hours
MQ-1 (Predator A)	2005-2015	122	169	72.2%	6.7	14,920	1,820,212
MQ-9 (Predator B)	2007-2015	34	165	20.6%	4.0	24,953	848,391
F-16	1975-1986	73	1,148	6.4%	7.1	14,033	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

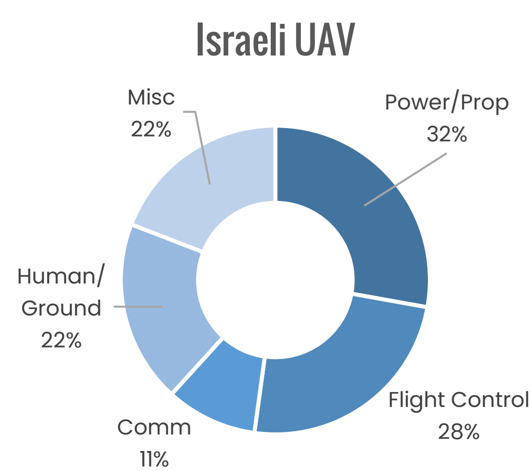
General Aviation Fatal Accident Rate 1.2% FY2011 Source NTSB
Commercial Aviation (Part 121) Accident Rate 0.2% FY2011 Source NTSB

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

Crash Cause 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.



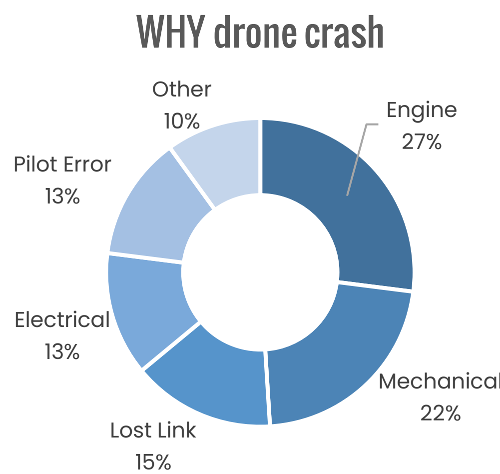


A Heron-1 operated by the Indian Air Force crashed soon after take-off in a residential area on Dec 13, 2013. Credit: The Hindu

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. However, these are often caused by an oil or fuel leak or the loss of coolant.

Mechanical failure reason adds up to 22% of drone crashes. This includes failures of particular pieces of equipment such as a turbo-charger 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 it is hoped 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 for which we have a cause are attributed to lost links.

Then we have 13% of the crashes (for which we have cause details) 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 directly lead to a crash. However, 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 crises, crews are supposed to follow a procedure checklist but this appears to be difficult in some circumstances. 13% of the crashes for which we have a cause are attributed to pilot error.

The other 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 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

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

several crashes documented in the dataset were caused by lightning strikes, ice accumulation, or strong winds.

As of when drone crashes happen, 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 the point of 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

Financially speaking is easy to calculate the cost, simply add the airborne UAV cost and the payload cost, but that is not all.

> *<u>Expendable</u>. The UAV is minimally survivable. Loss of the UAV has a minimal cost and operational impact; the UAV can be quickly replaced or is not critical to operational success.*

In this definition, cost refers to the financial or monetary value of the equipment, the hard part to calculate is the "operational impact" that is related to the mission the UAV performs.

If you are a firefighter dealing with an out-of-control wildfire in California, 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 USD 50,000. Just before the UAV reaches the surveillance area, you lost it. Whatever the reason, the time it takes to deploy a new USD 50,000 may cause a great deal of forest, wildlife, and even human casualties, because of the lack of intelligence to improve the decision-making process or the task force deployment. In this scenario, the operational impact is huge and hard, if not impossible, to calculate.

It can be easily seen that the key to having UAVs as a practical tool for civilian applications is reducing the accident rate. This would then be the norm for many tasks and not the exception

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, USD 2,000,000, for a drone with an MTBF of 523 hours, you must add $3,825 (2,000,000 divided by 523) 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.

The DroneTech Approach

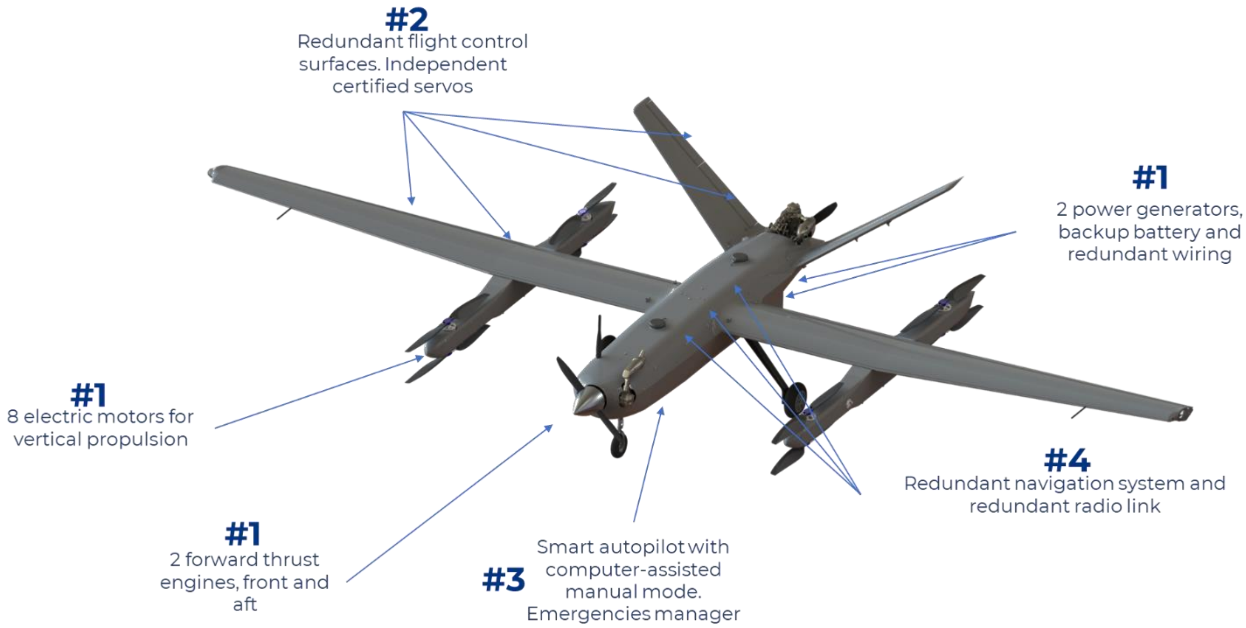
At DroneTech, we have addressed all the major causes of drone crashes by embedding redundancy systems in all of our UAV designs.

We took seriously all remarks and recommendations from the DoD, prospective customers, friends, and worldwide available documents to improve our products and stay one step forward to improve UAV flight safety, increase reliability and deliver a cost-efficient UAV.

Our solutions deal positively with failures due to the power or propulsion, the flight controls, the remote and local pilot crew, the communications systems, and most of the human/ground loss causes. This reduces the crash causes about tenfold. Let's recall the main drone crashes causes and how DroneTech tackles them.

Power and Propulsion	We use 4-stroke fuel injection engines instead of the common 2-stroke or Wankel engines. 4-stroke engines are heavier and more complex mechanically, but they have historically proved to be the most reliable. They are much more fuel efficient than 2-stroke engines and offset their higher weight, also, if properly silenced, they are almost noiseless at very low altitudes. Our dual or twin-engine configuration allows the aircraft to continue flying in case of engine failure. We have two power generators, redundant wiring, and a backup battery to operate when the generators fail. In our VTOL, we use 8 powerful electric motors
Mechanical	All navigation control surfaces are divided into two sections, each actuated by an individual certified servo and independent control wiring. A single servo failure is not critical for the aircraft operation
Lost Link	Communication glitches do not produce instability in our autonomous UAVs. We have gone one step further as we installed an Inertial Navigation System (INS) as a backup for GPS signal loss. In case of a communication lost link, the autopilot takes over to return the UAV to the base in a safe way. The routine is standard on all our UAS. A triple redundant autopilot system is offered as an option
Pilot Error	100% automated flight, one-click operation from taxiing, takeoff, ascend, cruise, descend, and landing. Computer-assisted manual mode operation prevents the execution of high-risk maneuvers

We do not cut corners and choose only the most trustworthy components because that gives value to our customers in long-term lifecycle costs. We deliver not only the highest performance but value and the lowest lifecycle cost of any, by far.



Example	Pelican	Others
UAV price	$500,000	$500,000
Camera or Sensor price	$200,000	$200,000
Total airborne cost	$700,000	$700,000
Mean time before failure (h)	1,500	500*
Cost per flight hour	$467	$1,400

Prices for explanatory purposes only

Recommendation
Never decide an UAV purchase on ticket price

Our design promises much higher reliability than present systems and it will be possible to have cost-per-hour rates in the order of just $400 to $600, instead of today's $1,200 to $2,000, in our size bracket (depending on the sensors aboard). The current worldwide high rental prices of several thousand dollars per hour are due to the present high crash rates. With our increased MTBF (expected low crash rates), we are less expensive than any general aviation, helicopter, or multi-copter.

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 by far is always the expected value of the economic and operational loss of a crash.

Potential buyers must include this crucial consideration in their decision process. Ask the right questions when purchasing, some manufacturers, by ignorance or policy, tend to hide this important data from the buyers.