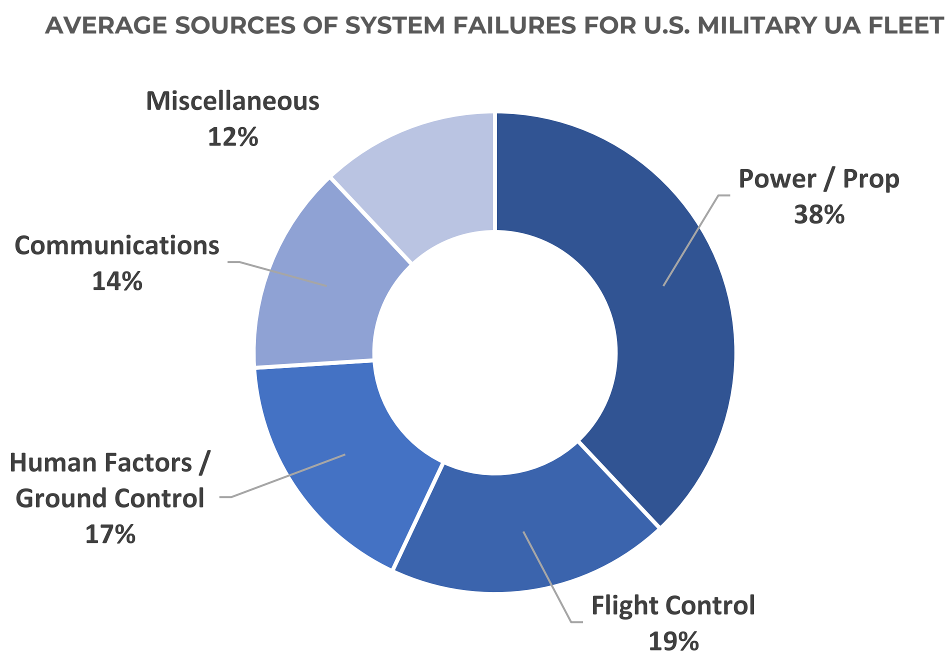
RELIABILITY SERIES 3 OF 5
DRONE CRASH CAUSES
#3 HUMAN FACTORS / GROUND CONTROL

In our last blog entry "Causes of UAV Loss" we explained what are the main causes of UAV losses and when they happen.

The US Department of Defense document "Unmanned Aircraft Systems Roadmap 2005-2030" uses the following definitions to categorize areas of a system failure leading to mission aborts or cancellations.



- **Power/Propulsion (P&P)**.
- **Flight Control**.
- **Human Factors/Ground Control**. Accounts for all failures resulting from human error and maintenance problems with any non-aircraft hardware or software on the ground
- **Communications**.
- **Miscellaneous**.

Now, let's talk about cause #3, Human Factors / Ground Control

Cause #3: Human Factors/Ground Control

With a remotely piloted aircraft system, there are many ways human mistakes can produce a crash, some of them are somewhat silly, but you know Murphy's Law, if something can fail, it will eventually fail, so the best way to avoid it is by striking out the failure element existence. Here are some examples:

- Misunderstandings between any in the communication chain that includes the internal pilot, and/or the flight engineer, and/or the external pilot assistant, and/or the external pilot, and/or the sensor operator.
- Somebody forgot to do something.
- Somebody did something wrong or not in a timely fashion if an emergency.
- There was a power failure in the ground control system because somebody pulled a power cord of the ground control station or hit the wrong power switch
- The pilot did not control the aircraft correctly and put it into a stall or a spin

Other possible tragical mistakes are not related to the aircraft being a remotely piloted type, and the following list applies also to general aviation manned aircraft, such as:

- Pouring into the tanks contaminated fuel, or not with the correct oil-gas mixture, or too low octane fuel
- Not checking the weather forecast
- Not performing a center of gravity calculation or test
- Flying into thunderstorms
- Flying into icing conditions
- Not performing correctly, a pre-flight check
- Not performing the regular maintenance program
- Not removing the pitot covers
- Not checking that the pitot tubes are free from debris
- Not complying with the pre-flight and flight checklists

This second group of mistakes is very rare and they happen with manned aviation aircraft too. It is the first group, the one related to RPAS types, that increases the crash probability so high.

Think about it, if humans are the error-inducing variable, let's minimize the risk by removing most of them. No people needed to fly, just for monitoring purposes, meaning there are no mistakes from those people. A fully automated system is a big help.

Other components, like a flight simulator to check out that the flight programming has been performed correctly, with no human errors, and redundancy features help and allow a "second chance" if a failure occurs. Another way to reduce human error and ground control mishaps is enhanced pilot and crew training.

Here are some examples of crashes due to human error/ground control

Jun 7, 2016 US Air Force MQ-9 Reaper Take-off phase (crew error) Nevada, USA

EXECUTIVE SUMMARY
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
MQ-9A, T/N 10-4113
NEVADA TEST AND TRAINING RANGE
7 JUNE 2016

On 7 June 2016, at approximately 22:29:47 Greenwich Mean Time (GMT), the remotely piloted mishap aircraft (MA), a MQ-9A, tail number 10-4113, assigned to the 432d Wing, Creech Air Force Base, Nevada, and operated by the 26th Weapons Squadron, Nellis AFB, NV, crashed while on a proficiency flight. The MA impacted the ground on U.S. government property. The MA was destroyed at a loss of $11,063,339.00. There were no fatalities, injuries, or damage to civilian property.

The mishap occurred approximately two minutes after aircraft handover from the 432d Wing's Launch and Recovery Element (LRE). At approximately 22:27:11 GMT, the Mishap Crew (MC), comprised of the mishap pilot (MP) and mishap sensor operator (MSO), gained control of the MA at 8,500 feet mean sea level (MSL). Unrecognized by the MC, the programmed minimum altitude (altimeter) was preset at 9,000 feet MSL. At 22:28:19 GMT, when MC executed handover checklist items, they unknowingly engaged the preset altitude and the MA began to climb. MSO advised MP, who was completing handover checklists, of the climb. MP incorrectly believed there was an unexpected flight condition or malfunction. To halt the ascent, MP switched from autopilot to manual mode ("landing configuration"). Landing configuration disables stall protection and auto-adjustments (airspeed and altitude). MP then directed the MA to descend to 8,000 feet MSL. The MP also reduced power to the MA, to avoid acceleration. MP resumed working on the handover checklist. MP had not adjusted the MA nose/pitch, which was positioned upward.

The reduced power and the nose/pitch resulted in a reduced energy state and aircraft stall. MP initially was preoccupied with the handover checklist and did not observe the Heads-Up Display gauges nor the audible and visual stall warnings. MSO advised MP that the aircraft was in a stall condition. MP did not apply the Flight Manual stall recovery procedures, but instead, increased power to the MA, which, due to the weight of the MA and its stalled condition, caused the MA to spiral towards the ground. The MA impacted the ground in the Nevada Test and Training Range (NTTR) at 22:29:20 GMT.

The Abbreviated Accident Investigation Board (AAIB) President found by a preponderance of the evidence the cause of the mishap was the combination of (1) MP's misprioritization to complete the handover checklist, and (2) MP's failure to observe prior warnings of reduced energy state and stall, and timely implement stall recovery procedures. A substantially contributing factor to this mishap was the MC's loss of situational awareness.

Full report at:
https://www.airforcemag.com/PDF/AircraftAccidentReports/Documents/2017/060716_MQ9A_Creech.pdf

Nov 24 2015 US Air Force MQ-9 Reaper Landing (crew error) Bagram. Afghanistan

EXECUTIVE SUMMARY
ABBREVIATED AIRCRAFT ACCIDENT INVESTIGATION
MQ-9A, T/N 10-4114
CENTCOM AOR
24 November 2015

On 24 November 2015, at approximately 1434 Zulu time (Z), the mishap aircraft (MA), an MQ-9A, tail number 10-4114, assigned to the 432d Wing, Creech Air Force Base (AFB), Nevada (NV) and operated by the 138th Attack Squadron (138 ATKS), 174th Attack Wing (174 AKTW), crashed while on intelligence, surveillance, and reconnaissance (ISR) mission in the United States (U.S.) Central Command (CENTCOM) Area of Responsibility (AOR). MA impacted the ground and damage to U.S. government property totaled $9,931,234.00. The wreckage was not recovered. There were no fatalities, injuries, or damage to civilian property.

Two different Launch and Recovery Elements (LRE) were involved in the mishap, the home station LRE and alternate LRE. The mission control element (MCE) consisted of a mishap instructor pilot (MIP), mishap pilot (MP), and mishap sensor operator (MSO). At approximately 1155Z, MCE gained control of MA from the home station LRE. At approximately 1315Z, MCE observed a "battery leaking current" warning message on the heads-down display. MCE diagnosed this as a starter generator failure and began accomplishing the checklist for this situation. After conferring with the mission crew coordinator (MCC), MCE declared an emergency and requested MCC communicate with the Wing Operations Center (WOC) to coordinate a handoff with the closest alternate LRE in accordance with current guidance. Before the handover was attempted, MCE completed all emergency checklists and noted there was enough battery power to complete the handover and land the MA at the alternate, undisclosed LRE. All required aircraft information was passed on from the MCC to the alternate LRE. It is the responsibility of the gaining LRE to accomplish the required gaining checklists prior to assuming control of an aircraft based on that information. At approximately 1432Z and at 14,000 feet (ft) mean sea level (MSL), the alternate LRE established a link with MA and assumed control of MA from MCE.

Immediately after the handover, MCE noticed a "beta" indication on the heads-up display, meaning MA entered a reverse thrust mode. Additionally, MCE saw MA airspeed drop to 75 knots. MA quickly stalled lost altitude and lost the link with the alternate LRE. The alternate LRE asked MCE to "take it back" and MCE then regained control of MA via satellite link and noticed that MA had lost 8,000 ft in less than one minute. MCE observed that all three Flight Control Assemblies (FCA) had failed as a result of the out-of-control condition. The FCAs are essential because they enable controlled flight of the aircraft. The failure of all three FCAs meant that the aircraft was not fully controllable or landable by MCE or alternate LRE. At approximately 1434Z, MIP was forced to guide the MA into the ground in an unpopulated area. The alternate LRE then stated that their detent calibrations were set wrong, meaning that they had not properly calibrated their Ground Control Station (GCS) to fly the MQ-9A.

The Abbreviated Accident Investigation (AAIB) Board President (BP) found by a preponderance of the evidence that the cause of the mishap was the failure of the alternate LRE to correctly calibrate the GCS to fly the MQ9A aircraft. The AAIB BP found by a preponderance of the evidence that the following factor substantially contributed to the mishap: starter-generator failure resulting in the need to divert to the nearest alternate LRE location.

Full report at:
https://www.airforcemag.com/PDF/AircraftAccidentReports/Documents/2016/112425_MQ-9A_CENTCOM.pdf

Dec 5 2012 US Air Force MQ-9 Reaper Mid-flight |Crew error) Nevada, US

EXECUTIVE SUMMARY
AIRCRAFT ACCIDENT INVESTIGATION
MQ-9, T/N 09-004065
Douglas County, Nevada
5 December 2012

On 5 December 2012, at approximately 03:10:30 Zulu time (Z) (19:10:30 Pacific Standard Time), MQ-9 Reaper Remotely Piloted Aircraft, tail number (T/N) 09-004065, crashed in an unpopulated area three miles northeast of Mount Irish, Douglas County, Nevada (NV), following a stall induced by an unrecognized reverse thrust condition that caused the aircraft to impact the ground after link to the aircraft was lost. The Mishap Remotely Piloted Aircraft (MRPA), one inert Guided Bomb Unit (GBU-38), a Hellfire training missile, a Mission Kit, and one M299 missile rail were destroyed. The total damage to United States government property was assessed at $9,646,088. There were no fatalities, injuries, or damage to other property.

The MRPA was an asset of the 26 Weapons Squadron (26 WPS), 57th Wing (57 WG), Nellis AFB. The Mission Control Element (MCE) Mishap Preflight Pilot (MMPP) and MCE Mishap Pilot (MMP) were temporarily assigned to the 26 WPS. The MCE Mishap Instructor Pilot (MMIP) was assigned to the United States Air Force Weapons School. The MCE Mishap Sensor Operator (MMSO) was assigned to the 26 WPS. The MCE Ground Control Station (GCS) was maintained by Science Applications International Corporation (SAIC).

The mishap sortie was part of the Intelligence Preparation of the Environment tactical scenario of the Weapons School Mission Employment phase. During the transit to the range, the MMP used a series of autopilot modes to control the aircraft. When MMP turned off the altitude hold mode of the autopilot and had the throttle positioned aft of full forward, a misconfigured throttle commanded the aircraft engine to produce reverse thrust. This specific condition went unrecognized by the MMP. Returning to base early for a perceived engine issue, the MMP allowed the aircraft to decelerate below stall speed. The MRPA stalled in flight and the link was lost. Less than one minute later, the MRPA impacted the ground in an unpopulated area.

The Abbreviated Accident Investigation Board (AAIB) president found by clear and convincing evidence that the causes of the mishap were 1) the Pilot/Sensor Operator station 1 (PSO1) (pilot seat) throttle quadrant settings of the controlling Ground Control Station (GCS) were improperly configured during the preflight reconfiguration from MQ-1 to MQ-9 operations prior to sortie execution, 2) this throttle anomaly went unrecognized because the MMP did not execute the Rack Configuration and Presets checklists on his control rack prior to gaining control of the MRPA, and 3) the MMP stalled the MRPA due to an unrecognized, commanded reverse thrust condition that existed whenever the pilot's throttle was at any position except full forward. Additionally, the AAIB found by a preponderance of the evidence that MMPP failed to execute his GCS preflight in accordance with technical order procedures substantially contributing to the mishap.

Full report at:
https://www.airforcemag.com/PDF/AircraftAccidentReports/Documents/2013/120512_MQ-9_Nevada_full.pdf

Reference Library:

We have found very illustrative the following documents or web pages:

US Department of Defense: Unmanned Aircraft Systems Roadmap 2005-2030.
Although old, this document shows an in-depth understanding of how drones started to become a core element in military operations, the implications of UAV reliability, the regulatory framework, and the future of UAV development. The full document can be found at:
https://irp.fas.org/program/collect/uav_roadmap2005.pdf

Drone Wars UK: Accidents Will Happen
Drone Wars published a dataset of just over 250 large military drone crashes that have taken place over the past decade (2009-2018). You can find the links and document here:
https://dronewars.net/2019/06/09/accidents-will-happen-a-dataset-of-military-drone-crashes/

Dedrone: Worldwide Drone Incidents
This page keeps a log of all reported drone-related incidents worldwide, from a small drone invading airport airspace to a drone trying to deliver drugs and phones into a prison yard. Here is the info:
https://www.dedrone.com/resources/incidents/all

George Slensky: Analysis of UAV Military Aircraft Mishaps
Mr. Slensky analyses the main causes of US military aircraft both, manned and unmanned.
https://www.researchgate.net/publication/327135551_Analysis_of_UAV_Military_Aircraft_Mishaps