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REDUNDANCY FOR UAVS - GROUND CONTROL STATIONS[2][3]

The systems of Unmanned Air Vehicles essentially contain Ground Control Stations – GCS. The common GCSs are *designed for a Mission Commander, Pilot, and Observer or payload operator – in ruggedised shelter with three operator station. Although each station is equipped with hot-swappable PCs the systems request further measures for real redundancy.*
In this paper the review of existing solutions and our University's experiences will be presented.

PILÓTA NÉLKÜLI REPÜLŐ ESZKÖZÖK REDUNDANCIÁJA – FÖLDI IRÁNYÍTÓ ÁLLOMÁSOK

A pilóta nélkül légi járművek rendeltetésszerűen használnak földi irányító állomást (Ground Control Stations – GCS). A földi irányító állomások a bevetésirányító, pilóta és a megfigyelő – vagy hasznos teher irányító – részére kialakított három munkahelyet tartalmazzák. Bár mindegyik rendelkezik "melegtartalékkal", az igazi redundanciához további feltételek megléte is szükséges.
Ebben a cikkben a jelenlegi megoldások áttekintésén kívül az Egyetem kutatásainak tapasztalatait is bemutatjuk.

INTRODUCTION

The general request for aviation: transporting high-value payload, flying in hazardous airspace, - above the crowds, sent a particularly important task for the aircraft to improve safety multiple - at least duplicate - on-board and ground control system components shall be used. When pilot on board he should recover some fault of system – that chance is lack for unmanned air vehicles (UAV).

The redundancy as method is the duplication of critical components or functions of a system with the intention of increasing reliability of the system, usually in the case of a backup or fail-safe. On the other hand redundancy requires added energy, – weight, – space and cost of system. In fortunate case – when all primer equipment work properly – the charge became as loss for user, but only minor defect requiring replace some function in main line can turn this balance over.

In many safety-critical systems, such as fly-by-wire and hydraulic systems in aircraft, some parts of the control system may be even triplicated. The probability of all three failing is calculated to be extremely small and if one is different from two others than the "voting logic" should activated and ignore the exotic source for longer work. User should be immediately notified about reduced – since "only" doubled – performance, deciding if mission to be continue or terminate. As rule the civilian application prefer "safety first" as

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long as military the “mission first” principle.

UAV systems are no less complicated than manned on board – that means take care for safety we should spend often more devices, software and time to develop, than until now. Economize the “back up” pilot requires the similar knowledge and skill at sticks of airplane what should be just in “brain” of onboard computer.

Moreover the system consists – besides flying part – the ground control station, take off and recovery equipments and duty personal that should be in reserve for all mission period. In stage of design and engineering we have to count what a necessary level of safety should be provided – to tune redundancy no less than required and the same time not exceed too much because the expenses.

THE PARTS OF UAV SYSTEMS – SUSCEPTIBLE TO FAILURE

The UAV systems – as a long chain – are based on connecting to each other subsystems and devices. Even one of them fails, the mission can not be completed – and may be other unwanted event occurring. The GCS personal primer task is manage the take off and landing procedure. As at all flying vehicles for UAV the start and the recovery are the most critical tasks. Every UAV has – depending on construction, weight, size and actual circumstances – one or more take off procedures. The regularly is for small – up to 5 kg – UAVs launching from hand. Accelerate up to take off speed could be by drop or bungee assistance. Both require skilled personal and meteorological minimum (wind, temperature, precipitation, etc.). When lack some of them the take off may fail – as happen quite often according to videos [[1]][[2]][[3]]. To elaborate difficulties from small to heavy weight UAV widely apply the catapult equipment – driven bungee, compressed air, rocket, etc.. The “airplane size” UAVs as Global Hawk, Predator, Dark Star etc. take off from wheels and require equipped airfield to land. The small UAVs able to land on flat ground, water or special net, even capturing some rope as ScanEagle do it [[4]].

Fig. 1. Launch UAV by hand-drop, bungee, catapult and gear[4 5 6 7]

[4] http://pakmr.blogspot.com/2011/04/us-to-provide-85-hand-launched-rq-11.html

The "built in" landing procedure should contain besides regular – automatic or assisted/guided by pilot – one or more version to escape if primary is not working well. The "back up" landing-procedures are often the "deep stall" or parachute recovery – in case fail of critical onboard system, or loss control. Some UAVs (Skylark, Skylite, Sperwer, KZO, Mirach) use special inflated bags for shock-absorbing. After all "forced landing" the airframe, avionics, communication and payload should be observed attentively – to find possible damage or deviation.

After takeoff – still landing – the GCS personal should pay no less attention to correct work onboard systems, communication and GCS equipments. The flight pattern – preliminary stored in memory or online transmitted from GCS – may include altitude, speed, actual/achieved coordinates, and command for payload. Sensors on board continuously measure all data for computer – which compares with prescribed and elaborate necessary control signals for actuators. This "chain" – from sensors to actuator – contains numerous bottlenecks as following:

Altitude sensor – measuring the altitude may be by air pressure, some radiated (ultrasonic-, laser or radio) wave propagation delay or using GPS service. As rule one device alone is always risky – by Murphy law – so design should contain alternative altitude data too. The optimum is using different method from main sensor – avoid catch the same source of error for example icing – but this requires often complicated circuits/programs.

Airspeed sensor – the airspeed should higher than Vst – stall speed (important for fixed wing's fly-control) and lower Vne – never exceed speed. That is why the pitot tube is heated – to avoid icing – and should doubled (Murphy). There are other measures to avoid Vst and Vne – programming the motor rpm (thrust) upper the minimum speed even at maximum climbing ratio and limit the descend ratio by idle rpm – both requests advanced inertial measurement unit – IMU to be on board. The IMU helps to limit yaw, roll angle and stabilize the wing level and pitch of UAV.

Navigation, mission control - autopilots are the most important and still the most expensive part of UAV. They role is to navigate by GPS and the same time manage the fly control, take off and landing and payload subsystem's work. As rule in they memory is stored the mission plan and they are connected with ground control station (before -, in time and after mission) to exchange information. Autopilot as key element should be doubled for safety – as Micropilot [[5]] decided maybe even triplicated. They combined three premier MP2128HELI autopilots in one triple redundant MP21283X board – with "pass or fall" voting logic. The first (primary) GPS receiver works on 20Hz (2nd and 3rd 4 Hz).

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[5] http://www.armedforces-int.com/news/british-army-gets-upgraded-desert-hawk-uavs.html

[6] http://upload.wikimedia.org/wikipedia/commons/6/6f/ScanEagle_UAV_catapult_launcher_2005-04-16.jpg

[7] http://www.army-technology.com/projects/shadow200uav/shadow200uav2.html

Fig. 2 MP21283X motherboard of three independent autopilots – with voting logics [8]

As MiroPilot emphasize each of three has enough information to continue the mission – in the event of failure. The MP21283X includes provision for multiple communication links, backup high current drivers, backup power supplies, and independently-generated servo signals. Moreover, two different types of global positioning system receivers are used to improve its reliability [[6]].

Ground control system – The most "stable" by position, but higher responsible for proper work of all system is the GCS and its habitants. The advanced UAV systems are use inherently doubled workstations for uninterruptible control where all necessary functions are reached for both operators. That should planned thoroughly and as rule is working fine – in exception some mistake in design multiplied by pilot error as reported [[7]].

The border patrol Predator UAV crashed in Arizona – because operator switching the control from console PPO-1 (Pilot Payload Operator) to PPO-2 not verified by checklist if they are in equal position. Unfortunately at the PPO-2 the "FUEL CUTOFF" switch stayed still in before start position and the engine shouted down immediately.

Fig. 3 The happening[9] and the reason – red sticks at left hand of pilot [10]

But what was the reason – by official Predator UAV crash report the following:

„The flight was being flown from a ground control station (GCS) located at HFU. The GCS

[8] http://www.micropilot.com/news-2010-nov-10.htm
[9] http://lemonodor.com/archives/001391.html
[10] http://coreydonovan.com/test/predator-drone-pilot

contains two nearly identical consoles, pilot payload operator (PPO)-1, and PPO-2. During a routine mission, a certified pilot controls the UAV from the PPO-1 console and the camera payload operator (typically a U.S. Border Patrol Agent) controls the camera from PPO-2. The aircraft controls (flaps, stop/feather, throttle, and speed lever) on PPO-1 and PPO-2 are identical. However, when control of the UAV is being accomplished from PPO-1, the controls at PPO-2 are used to control the camera.

The pilot reported that during the flight the console at PPO-1 "locked up", prompting him to switch control of the UAV to PPO-2. Checklist procedures state that prior to switching operational control between the two consoles, the pilot must match the control positions on the new console to those on the console, which had been controlling the UAV. The pilot stated in an interview that he failed to do this. The result was that the stop/feather control in PPO-2 was in the fuel cutoff position when the switch over from PPO-1 to PPO-2 occurred. As a result, the fuel was cut off to the UAV when control was transferred to PPO-2.

The pilot stated that after the switch to the other console, he noticed the UAV was not maintaining altitude but did not know why. As a result he decided to shut down the GCS so that the UAV would enter its lost link procedure, which called for the UAV to climb to 15,000 feet above mean sea level and to fly a predetermined course until contact could be established. With no engine power, the UAV continued to descend below line-of-site communications and further attempts to re-establish contact with the UAV were not successful."

That was the factual official report and lesson can be learned as follows:

Pilot – as professional – should not be stay alone. (In actual situation the second pilot went away and told some suggestion by telephone to primary according to failure. The "border patrol agent" can not take effective part in a hurry, responsible operations.)

The implementation should have been a simple "flip of a switch" rather than a multiple-step checklist to re-figure PPO-2 under contingency conditions. (Here was certainly more than "pilot error" the design philosophy of PPO was an underlying cause. Using the same lever for engine condition and camera iris setting [[8]] – that is more than „frivolity")

All system should be preliminary attentively tested not allowing – even intentional – faulty operation. (So expensive UAVS like Predator should not make so elementary mistakes.)

THE UNIVERSITY'S RESEARCH – INCREASING SAFETY OF UAV SYSTEMS

The National University of Public Service – earlier National Defense University – playing a vital role in UAVS research in Hungary. We take part in UAVNET international workshops since 2001 with many presentations. In this years more than 10 PhD aspirants finished own work with UAVS–related thesis. At last Conference of Aeronautical Science in 2012 author and coauthors from University's student presented papers in topics related to redundancy at UAVS [[9]][[10]][[11]][[12]][[13]][[14]]. Behind all theoretical issue there are many hours of practice and experiments. We work on UAVs with different size and purposes as well their part and development whole system. The general rules are at our research the safety – for civilian and the reliability – for military applications. Thanks to cooperative work together with civilian institutes and developers we can accept request both kind of users. One of our favorite topics is “Avoid Aircraft Accident – Scaring Birds with UAVs at Airports [[15]][[16]][[17]]. Those results are universally used at airfield/airport areas of course. Here we base on related “redundancy for UAV” project’s results. Also is related to UAVs the “Infrared Thermography for Non Destructive Testing and Evaluation (NDT & E) – in Airspace Technology” research program. Until now we published numerous articles according to NDT like [[18]][[19]][[20]][[21]]. As far as composites are – almost exceptionally – use for UAV’s constructions the NDT & E is related to timely as well. The infrared cameras – together with proposed by us ultrasonic and microwave excitation – provide the new level of quality in UAV industry.

CONCLUSIONS

As mentioned above the redundancy are extra cost until the second/third line must step to charge – but in this case may spare much more money (and tear) equals the possible lost. All pieces of chain should be strong and safe enough – the UAVS are highly complicated and expensive to make some of them lightly. We work on all elements – just the Ground Control Stations was analyzed briefly. That was our goal – to show our possibilities in this interesting topic. This is only the surface – we welcome cooperative researchers, developers for further deeper discussion.

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[4] http://www.naval-technology.com/projects/scaneagle-uav/
[5] http://www.micropilot.com/products-new.htm
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