FLIGHT VALIDATION USING VIDEO CAMERAS

Stefan Jagieniak
Dipl.-Ing.-
Aerodata AG,
Braunschweig, Lower Saxony. Germany
Phone: +49 531 2359-135
Fax: +49 531 2359-222
E-mail: jagieniak@aerodata.de

Frank Musmann
Dipl.-Ing.-
Aerodata AG,
Braunschweig, Lower Saxony. Germany
Phone: +49 531 2359-341
Fax: +49 531 2359-222
E-mail: musmann@aerodata.de

ABSTRACT

The quality assurance process for instrument flight procedure design includes the validation of the procedure in flight. During the flight validation the pilots evaluate all associated aspects related to the procedure, including: flyability, pilot workload, obstacle assessment, runway markings- and lighting, approach path indicators as well as TAWS warnings/alerts.

Many aspects need to be evaluated simultaneously. Especially if anomalies are detected and need to be noted, the workload for the flight validation pilots may reach a very high level. It is likely that when mentally focusing on one suspicious subject of the validation, the attention for the evaluation of other elements might suffer, resulting in overlooking other anomalies. The verification of obstacles can be extremely challenging under certain circumstances, e.g.: flying in dense traffic in combination with an unfamiliar and mountainous environment with numerous obstacles.

For documentation and evidence collection during flight validation it is desirable to have a video recording, which allows replaying all phases of the validation.

This paper describes the implementation, certification and experiences gained by using video cameras for the recording of pilot's view and the cockpit flight instruments during procedure validation. The results of highlighting the obstacles' positions as online overlay to the video will be provided.

INTRODUCTION

During flight validation, several aspects cannot be "measured" by objectives. A lot of information needs to be visually gathered by the pilots-in addition to their main task of flying the airplane safely. This makes up a huge difference compared to flight inspection of conventional navaids, where the majority of the task is performed automatically by the AFIS. These visual tasks add up to:

- Challenges during Flight Validation:
  - Obstacle Verification:
    - Numerous Obstacles
    - Dense traffic
    - Mountainous terrain
    - Identification of obstacles
    - Verification of heights
    - Difficult documentation / evidence collection
  - Approach Light checks
    - Numerous lights
    - Difficult documentation / evidence collection
  - Cockpit Workload / Flyability
    - Difficult documentation / evidence collection

The basic idea of using a digital camera to support the documentation of all these aspects is not new. What has not been seen before is the way of integration outside the cabin for totally unobstructed view and the fully synchronized combination of video footage and flight inspection measurements. This allows the analysis of multipath, protection violations, unknown obstacles etc. including their actual impact on the guidance signals.

When permanently installing a camera system, several issues have to be considered:

- Viewing Angle of the camera(s)
- Obstruction of pilots' field of view
- Mounting position. Inside the cabin or outside?
- Environmental conditions, temperature, humidity
- Power Supply-integrated or own battery
- Recording interface to AFIS or local
- Aerodynamics
- Certification
- Time synchronization and -stamping

INSTALLATION AND CERTIFICATION

Viewing Angle and mounting position

It is desirable to cover the whole horizon at +/-90° in relation to the aircraft's nose direction. In addition, a reasonable picture resolution in flight direction is required.

In order to observe pilots' workload as well as avionics indications, an additional view inside the cockpit is required.

Placing the cameras inside the cabin eases up environmental requirements quite significantly, as temperature and humidity are comparably comfortable. However, the cameras would have to be placed inside the viewing field of the pilots providing some obstruction to it. On the other hand, the cockpit window frame would not allow covering 180° viewing angle to the front. For this project, it was an essential requirement to minimize the obstruction of the pilots' view as much as possible. An arrangement of 3 outside cameras on the nose of the aircraft and one camera at the back partition of the cockpit was chosen.

Fig. 1: Ruggedized Camera

Fig. 2: Three Cameras mounted on Aircraft Nose (Source: [1])

The camera as shown in Fig. 1 comes with a ruggedized housing designed for airborne applications including built-in heating system for installation outside the cabin. In Order to cover the whole horizon and have a good video resolution in flight direction, three of them with different lens were arranged as shown in Fig. 2.

Fig. 3 shows the overlapping viewing area of the three outside cameras. In order for a seamless transition between them, the mounting can be adjusted mechanically and the final calibration of angular offsets is done in software. This allows to software-wise overlay camera video with e.g. obstacle symbols and a line to indicate the horizon.

The camera to observe the cockpit (see Fig. 4) is permanently installed at the cockpit partition. It is adjusted to record the instrument panel including displays, annunciators and switches and their operation. In order to comply with German law, it may only be operated if the pilots give their written consent to be observed by video camera. In addition, they have full authority about switching the recording off manually any time.

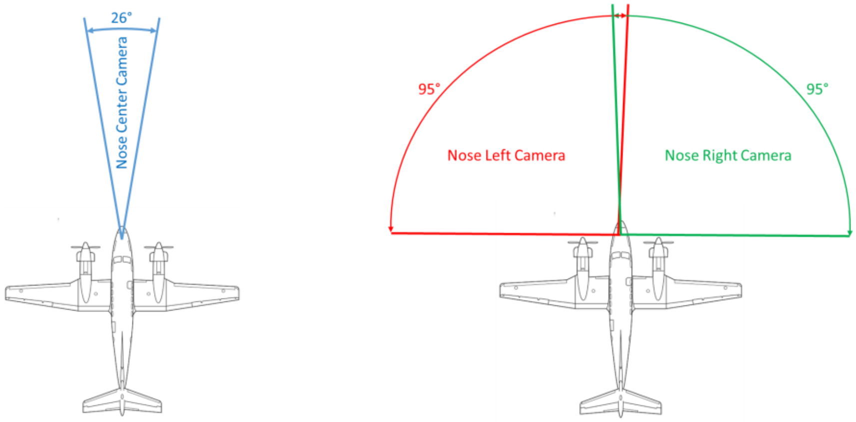

Fig. 3: Viewing angles of outside cameras

Fig. 4: Cockpit camera at LH partition

Each of the cameras provide a full HD video stream over wired Ethernet connections. A dedicated Video computer (see Fig. 5) is responsible for processing the video streams like performing correction on optical distortions, overlay of symbols, format conversion and provides the video data for recording. The streams are time stamped to allow synchronous display to the FI data.

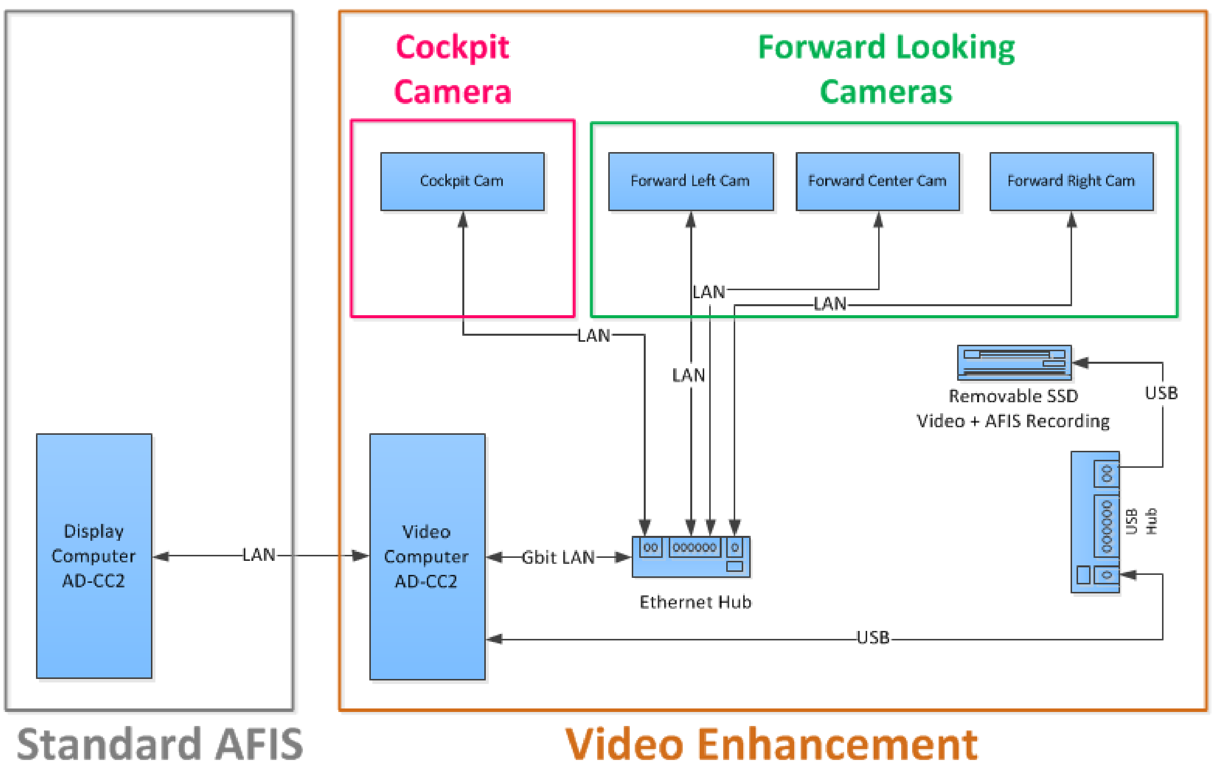

Fig. 5: Block Diagram

In order to provide the necessary recording data rate (16 GByte / hour) and capacity, a dedicated removable SSD drive as DZUS unit is being used (see Fig. 6). The SSD recording contains not only the video, but also all FI data.

Fig. 6: SSD Removable Storage Device Station

<u>Aerodynamics and Airworthiness</u>

The external installation of the cameras on the aircraft nose is certified by EASA STC. During the certification process it had to be proven, that the additional installation has no significant impact concerning the following aspects:

- Vibration
- Ice accreditation and ice shedding
- Bird Strike
- Buffeting
- Flight Performance / Drag
- Stability and controllability
- Pilot View

The above aspects have been subject to various theoretical and FEM analysis (see Fig. 7) and final flight testing involving an EASA certified test pilot (TP1).

The Flight Test Results verified the results of the theoretical analysis:

- No vibration, buffeting or change in flight performance, stability or controllability was found
- Some pilots can see it (depending on seating position), but the obstruction is minor and considered fully acceptable
- Some pilots even like to have the camera assembly as a nose center reference during taxi.

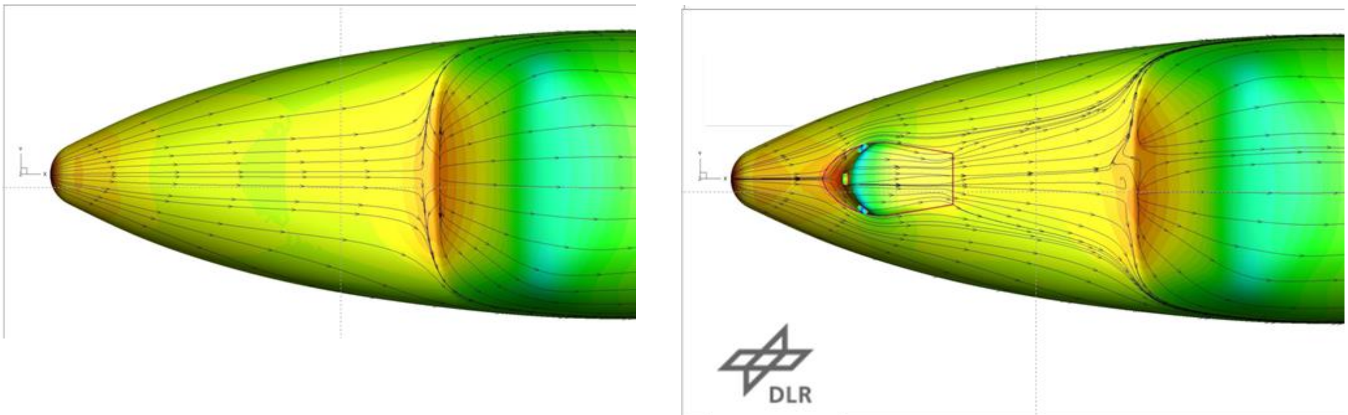

Fig. 7: Simulation Result: Impact of Camera Mount to Airflow

SOFTWARE INTEGRATION

Video Display Page

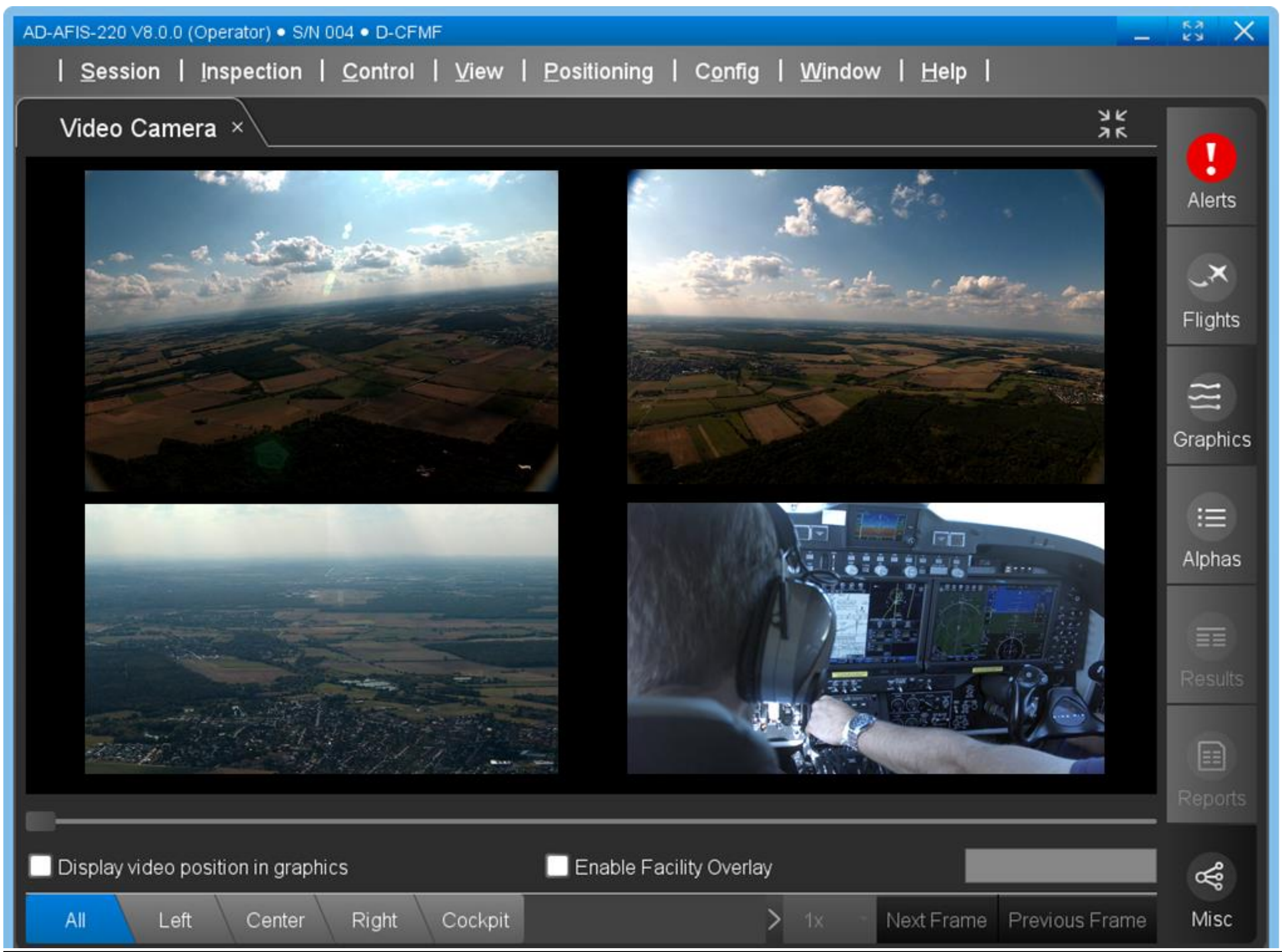

Fig. 8: Camera Display for Online and Replay

The software fully integrates the video streams to the operator screen (see Fig. 8). Either all camera streams are shown together at the same time, or one can be selected to be enlarged to the full screen (see Fig. 9 or Fig. 11).

Match FI data with Video

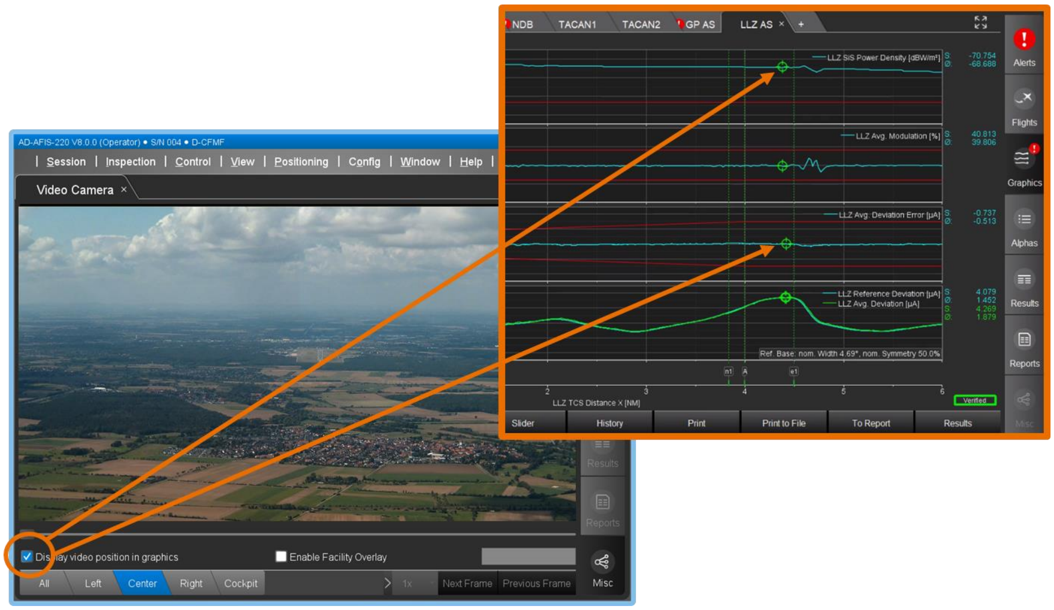

Fig. 9: Correlation of Video and Data Display

Correlating the video with FI data like deviation or modulation like depicted in Fig. 9 has proven as a powerful tool to identify potential reflections or signal obstructions.

The video view has a slider on the time axis to navigate to an interesting detail. The Flight Inspection Graphic Display shows a mark at exactly the corresponding data in time. Vice versa, a Slider in the graphic can be moved and the corresponding video picture is shown.

The example in Fig. 10 shows, how the disturbance of the localizer deviation clearly is explained by a truck crossing the approach area right in front of the threshold.

Fig. 10: Correlation of Video and Data Anomaly (Source: [1]). Moving truck vs. LOC deviation error

Overlay of known obstacles

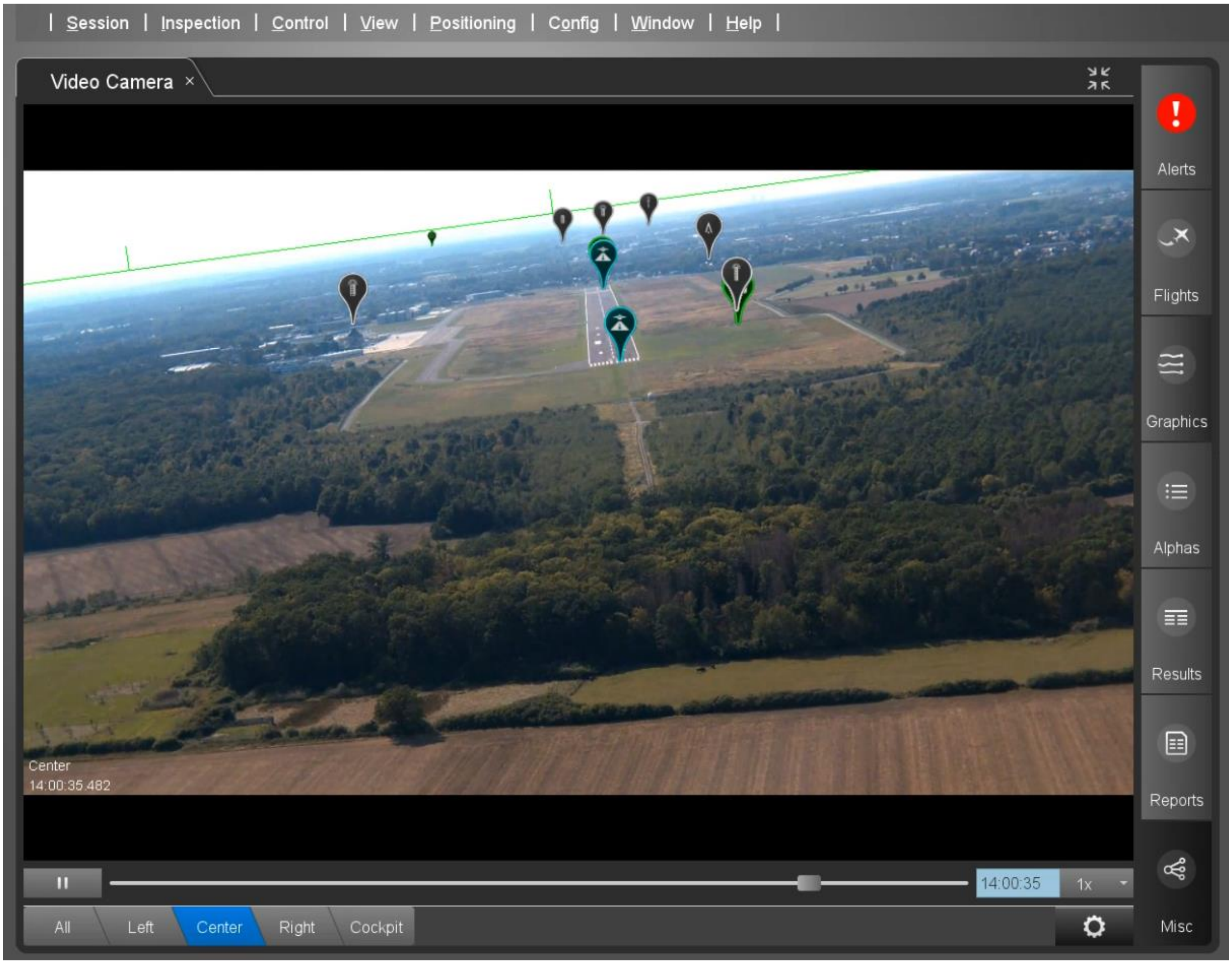

Fig. 11: Center Camera display with Runway and Obstacles as Overlay

The procedure design of instrument flight procedures shall ensure that aircraft flying the procedure have sufficient clearance to obstacles. It is essential to periodically verify that all obstacles are considered with correct coordinates and height. For obstacle evaluation, the obstacles, based on their WGS84 coordinates and height, can be online overlayed to the displayed video. By this feature, known obstacles can be easily identified and their height can be verified in comparison the horizon line which is displayed in the aircraft's altitude. Any new obstacles that might have not been considered during the design of the instrument flight procedure can easily be identified. Furthermore obstacles of temporary nature, like parked or taxiing aircraft, construction work going on or even trucks passing through the localizer course sector are well documented. Fig. 12 shows an Example with pinpointed moutain peaks in a procedure in the Swiss Alp mountains.

Fig. 12: Mountain Peaks from Database and their map representation

<u>**Unforeseen Applications**</u>

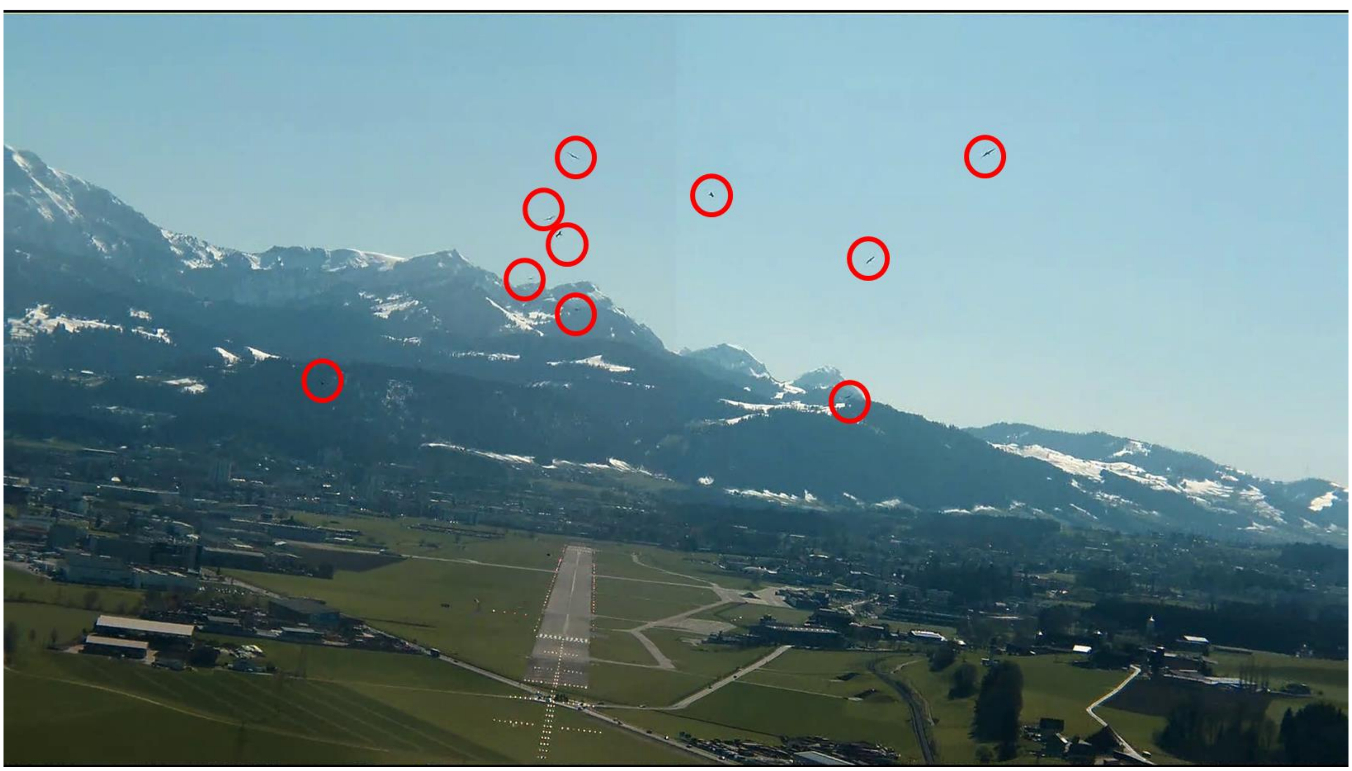

Fig. 13: Bird Control at Runway (Source: [1])

During the first flights it became obvious, that also the assessment of bird population in airport areas shows to be a well suitable task for the depicted system. Fig. 13 shows the impressive amount of rather big birds at a runway in the Alp mountains. This picture is assembled from the left and the right camera view.

CONCLUSIONS

The system is in full operation since more than two years now. It has proven its outstanding value in documentation of circumstances concerning obstacles, possible signal reflectors, birds and runway lighting. The workload to manual documentation all these issues is released from the pilots and the objectivity of the information is fully ensured and can be verified any time.

The higher effort for aircraft modification compared to a dashboard camera installation has fully paid off by providing totally unobstructed HD videos and not compromising the cockpit view for the pilots. The high speed and high capacity recording device ensures that all data can be carried from the aircraft without any time consuming copy action.

The synchronous visualization of video and flight inspection measurement is of great value to explain signal anomalies, either online during the flight or in replay for in-depth analysis.

ACKNOWLEDGMENTS

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