Flight Crew Assistance Functionality Concept for Commercial Aircraft

Improving the Situation Awareness of Airline Pilots by means of a Rule-Based Flight Status Evaluation

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In state-of-the-art cockpits, various sources of information need to be considered and evaluated by the pilots. Besides operating an aircraft from departure to destination, flight crews of today's commercial aircrafts are faced with an ever increasing amount of additional tasks and responsibilities. Especially in peak workload situations the eye for bare essentials is impaired. Even though technical solutions in terms of assistance logics already exist, a complex interpretation of the flight state needs to be performed by the pilots, all the more difficult under special circumstances as adverse weather, time pressure or malfunctions resulting in a degradation of automation.

Rule-based flight state evaluation; future cockpit design; flight crew assistance functionalities; pilot notification logics

I. Introduction

Nowadays, commercial airline cockpits are to a great extend subject to an alteration process pertaining to the ever increasing amount of accountabilities and ancillary tasks flight crews are exposed to. Moreover, the environment in which airline flight operation takes place becomes more and more complex and challenging. Clashing interests as safety, efficiency, profitability and passenger wellbeing have all to be taken into account by airline pilots.

Especially in high workload situations the likeliness for errors increases, oftentimes owed to either information overflow or missing information. Therefore, specific flight condition monitoring and informational assistance is desirable in order to reduce the number of workload peaks and thus pilot errors resulting from impaired situation awareness.

In [1] situation awareness is defined by Mica Endsley as: *"[…] the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future"*. As a consequence, decisions and resulting actions by the flight crew are based on a mental picture which is significantly affected by the actual environmental conditions. The performance of the flight crew is influenced by factors as workload level, the familiarity with the situation (experience) and their psychological and physiological constitution.

The improvement of the situation awareness in straining flight phases has been subject to earlier studies [2]. A concept for a cockpit notification system has been developed in which real-time NOTAM and weather data has been connected to a charting application. As a result, flight phase related notifications to the flight crew have been generated.

Beyond that, the complexity of the coherences pilots have to consider during the taxi phase and the concept of a taxi guidance system that counteracts the risk of omission of relevant parameters has been shown in [3].

In the following, a concept will be presented that aims on a holistic pilot assistance logic providing comprehensive support during all phases of flight. The rule-based flight state evaluation is designed to provide the pilots a continuous understanding of the overall flight state.

II. Incident & Accident Statistics

A safety study of the National Transportation and Safety Board from 1994 [4] illustrates the number of errors per accident and error type within a twelve year period. The error distribution mainly corresponds with the assessment of the actual Boeing accident summary from 2013 [5].

Both studies show that more than 50% of the investigated incidents and accidents were related to the approach and landing phase (Fig. 1).

The investigated irregularities of the Boeing accident summary from 2008 [6] support the conclusion that the major part of the incidents eventuated in a "loss of control" or a "undershoot or overshoot" of the landing runway (Fig. 2). According to the NTSB study [4], the key factors have been summarized as follows:

- Adherence to Procedures
- Monitoring and Challenging of the Pilot Flying (as part of the crew resource management)
- Tactical Decision Making
- Aircraft Handling.

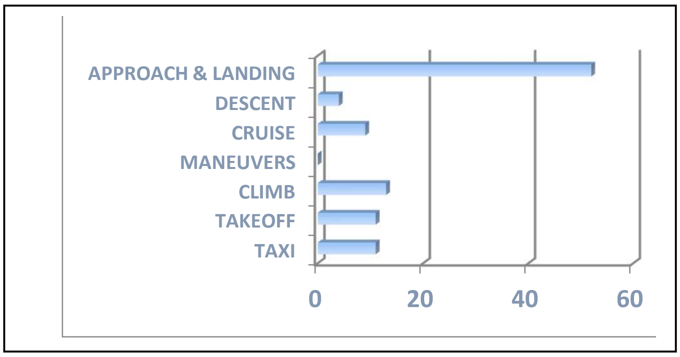

Figure 1. Combined percentage of flight phase related accidents types, [4] [5]

Available flight incident reports show that the majority of recent incidents correspond with the implications stated in the above mentioned studies. Therefore, the scope of these documents has been incorporated in the course of the initial system concept phase. In order to consider the identified deficiency areas, the focus of the envisaged technology has been outlined in five partly interchangeable critical areas:

1) Aircraft System Setup & Handling
2) Adverse Weather Situation
3) Tactical Decision & Situation Awareness
4) Handling of Standard Operating Procedures
5) Monitoring & Challenging.

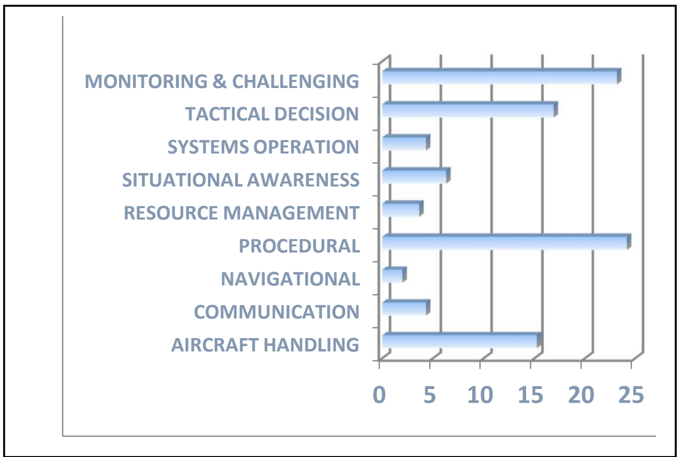

Figure 2. Percentage of error types per flight accident, [6]

III. OBJECTIVE OF THE TECHNOLOGY

The flight state evaluation concept focuses on an inherent pilot assistance functionality which is able to assess the global flight condition taking into account all relevant aircraft systems and sub-systems, operational parameters and ambient external conditions during all phases of flight at a high level of automation, especially in failure situations. A continuous validation of pre-defined tasks (e.g. flight plan processing, aircraft system setup) and the connection of the variety of operational information from different data sources with respect to respective correlations is the main objective of the technology. Autonomous plausibility checks (e.g. verification of flight parameter inputs and sensor data, ambiguous system outputs) as well as the monitoring of operational limitations (e.g. operational procedures, flight performance) are part of the system tasks.

As independent instance the flight state evaluation system performs autonomous monitoring and challenging of crew tasks on a superordinate data level based on internal parameters (aircraft type specific) and external data received via aircraft interfaces (data link). System advices resulting from the above mentioned evaluation are generated by a predefined logic with respect to importance and/or anticipated consequences of the information content.

In case of a failure situations, the assistance functionality offers reconfigurations at a high level of resilience, either fully automatic or semi-automatic (on pilots' request) depending on the workload the flight crew is faced with. Thus, information provisioning will be prioritized and filtered. In a later development stage, under predefined conditions the system may be given the authority to intervene up to a certain level and according to a set of specified rules (e.g. exceptional high workload, risk of human error or crew incapacitation).

IV. FLIGHT STATUS EVALUATION

A safety study from the National Aeronautics and Space Administration (NASA) [7] concludes that "*(...) Research is needed to develop ways to help pilots stay in the loop on system status, aircraft configuration, flight path, and energy state. These new designs must be intuitive and elicit attention as needed, but minimize effortful processing that competes with the many other attentional demands of managing the flight.*"

As mentioned before, it is desirable to identify the development of a critical operational constellation as early as possible in order to support the pilots. For the purpose of determining deficiencies in the pilots' situation awareness, an automatic evaluation process is being developed to monitor the overall flight condition. In the following, the required interfaces will be specified and the data processing will be described.

A. Interfaces

The interpretation of the flight status as well as the monitoring of flight phase related crew tasks including level of automation and means of assistance is realized with respect to the interfaces shown in Fig.3. The blue shaded boxes depict the access to aircraft specific data such as the onboard navigation data base (e.g. flight management, charting applications), technical data (e.g. equipment status, aircraft condition monitoring), performance data (e.g. flight management, performance module) and sensor data (e.g. Air Data Inertial Reference Unit (ADIRU)). The data exchange with the aircraft specific onboard systems is provided via the ARINC429 data bus. Furthermore, operational flight data is exchanged by utilization of the Electronic Flight Folder standard (EFF, ARINC 633), which enables a continuous data update via data link (e.g. satellite communication, SATCOM).

The green elements represent data sources related to operational parameters received via data link from external ground stations such as airport and airspace data (e.g. operational notices and weather reports), information from third-party ground stations (e.g. deicing coordination,) and the Airline Operating Center (e.g. ATC restrictions, flight dispatch).

Furthermore, to identify critical constellations an interface to other air stations (e.g. Automatic Dependent Surveillance, ADSB) has been assembled. The maintenance data is both, linked to the ground and onboard unit.

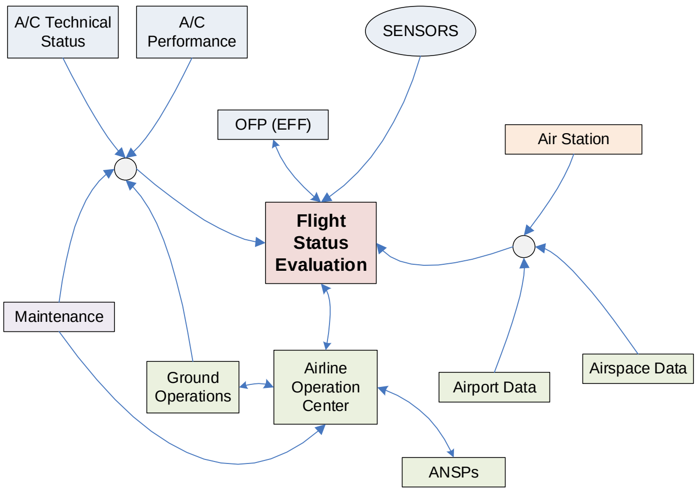

Figure 1. Flight State Evaluation, Interfaces

B. *Data Processing*

Fig.4 shows a simple example of how the data will be processed by the flight state evaluation logic. A station issues a data set (operational content) which is processed by the respective data processor on the ground and published as aeronautical service. The data set is directly uploaded to the aircraft or provided via the AOC uplink. The aircraft receives the data update and stores the relevant information content in a centralized database. The actual flight phase is determined using actual aircraft sensor information.

Depending on the workload corresponding to the actual phase of flight and the environmental conditions, the flight state evaluation processor automatically determines the operational relevance and therewith induces the priority and kind of a potential pilot notification. The logic will also ensure that any resulting system behavior will be sensitive to the overall flight context, the current flight situation, and the data content itself.

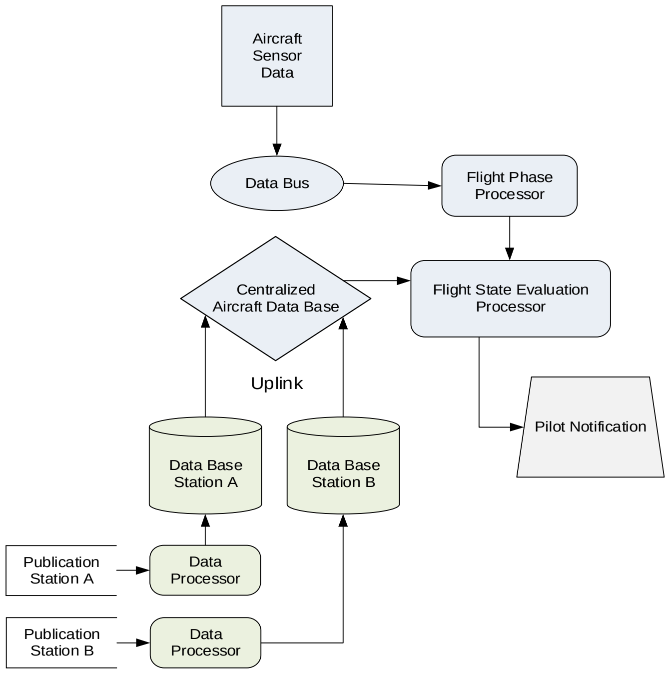

Figure 2. Flight State Evaluation, Data Processing

V. USE CASES

In the following, a selection of sample scenarios will be presented that may occur to any flight crew at any time in this manner, whereas the characteristics of the happenings are adapted to the average level of automation of a state-of-the-art commercial aircraft cockpit. Furthermore, the scenarios will be described as they are expected to happen if the pilots handle each respective situation by means of the previously described cockpit assistance technology. Thereby, the above mentioned capabilities of the anticipated technology shall be shown.

A. *ATC infrastructure*

Due to turbulence in African airspace a flight crew requests a flight level change (via high frequency (HF) or controller pilot data link communications (CPDLC)) and initiates the climb after confirmation from Air Traffic Control (ATC). During their climb the pilots are instructed to descend back to the initial flight level on request of the adjacent ATC sector.

1) While descending to the initial FL the crew receives information about crossing traffic at the same flight level via the air to air broadcasting procedure. Poor HF radio telephony

(RT) conditions do not allow for a clarification on time (late response via data link).

2) As the system receives ADSB data from conflicting traffic in the area around the actual position of the aircraft, a notification to the pilots is initiated. Depending on the severity of the situation a warning or even an intervention (protection mode) may be triggered by the system.

B. Altimeter Setting

While descending to an altitude a flight crew receives the instruction from ATC to stop the descent at a specified flight level.

1) At first the pilots adhere to the instruction by changing the reference altitude on the aircrafts' Mode Control Panel (MCP). As a result of a high workload level, they fail to switch the altimeter setting back to standard reference pressure.

2) As the system observes the descent procedure including all parameters (published transition flight level) it prevents the pilots from descending through the assigned flight level by initiating a time-sensitive notification.

C. Cockpit Crew Incapacitation

Upon initiation of descent towards the destination aerodrome a cockpit crew member (pilot flying) becomes unconscious.

1) The pilot monitoring (PM) takes over aircraft control and requests support from ATC, cabin crew members and/or a pilot travelling onboard.

2) On request, the system supports the single pilot by presenting actual operational information including an overview of the weather and operational situation at the destination aerodrome. It gives recommendations for an adequate system setup and observes the landing preparation conducted by the pilot. An electronic checklist incorporates all essential and safety relevant items and indicates potential errors.

D. Technical Malfunction

After departure a flight crew encounters a technical malfunction and needs to evaluate the options for a safe landing.

1) A return to the departure aerodrome is not assured as low visibility procedures are in progress (degraded system capability). The flight crew needs to recall and validate all available and relevant information in order to decide for the best option to proceed.

2) The system detects the technical failure and supports the crew giving recommendations regarding suitable diversion aerodromes for landing. The logic considers parameters as essential system malfunctions (e.g. engines, electric, hydraulic, pressurization), adverse weather conditions and balances a time critical scenario against the suitability of an aerodrome.

E. Operational Factors

During cruise flight the crew of a transatlantic flight encounters stronger head winds than forecasted pre-flight. As a result of the strong winds a fuel stop is mandatory.

1) The pilots decide to divert to the closest enroute alternate aerodrome. They are not fully aware about every single operational influencing factor of the refueling process (e.g. availability of fuel, on ground operation restrictions and crew dispatch matters at the time of arrival).

2) As the system also incorporates the validation of operational information regarding airports authorized for landing by the Airline Operating Center (AOC), the flight crew will be notified about the selection of a diversion aerodrome not meeting the required environmental conditions.

VI. Perspective

Currently, the Technische Universität Braunschweig is working in the area of flight state evaluation in ACROSS, a research and development project co-funded by the European Commission under the Seventh Framework Program. The technology described above will serve as a basis for the research being conducted to meet the first of three objectives [8]: *THE ACROSS PROJECT WILL CONTRIBUTE TO A COCKPIT ENVIRONMENT THAT MITIGATES THE IMPACT OF CREW WORKLOAD PEAKS IN THE FLIGHT DECK AND ENSURES THAT PILOTS HAVE THE OPPORTUNITY TO ADDRESS ALL RELEVANT ISSUES IN A TIMELY AND EFFECTIVE MANNER.*

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