Trajectory Intents @ EFB

A proposal to invest in new technology

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***Abstract*—In order to use airspace more efficient, we should start using trajectory intent downlinks from the EFB. We should give up the "fly-what-you-filed" dogma and the idea of integrating the FMS into modern ATM concepts. Written in December 2018**

I. AIRSPACE CAPACITY

Operational delays and cancellation of flights continue to burden our industry. For the Lufthansa Group, the summer of 2018 was one of the worst in its history, with thousands of delayed and hundreds of cancelled flights. A large part of these operational disturbances happen because of inadequate airspace management. Improving this management is the main goal of SESAR and the goal of this proposal.

Main purpose of Air Traffic Management is to assure separation between aircraft. In order to do this, the Air Traffic Service Unit (ATSU) needs to know the position of all aircraft in their sector and they need to know their intent. It is obvious that a better knowledge about an aircraft's intended trajectory will lead to less surprises, better conflict predictability and thus more airspace capacity, while keeping the aircraft safely separated.

Historically, the aircraft's intent became known to the ATSU by filing an Air Traffic Services (ATS) flight plan prior to take off, which contains a string of waypoints, airways, times, flight levels and speeds and thus defining the intended strategic trajectory. After entering the sector, the ATS flight plan was enriched by position reports received from the pilot by voice and/or RADAR data, updating the ATS flight plan predictions. With the availability of transponders and their increasing set of information from Mode A and C to S and ADS-B, the tactical trajectory information available to the ATSU became better and airspace capacity increased to today's values - which are not sufficient anymore, to cope with the increasing demand due to traffic growth.

II. THE ISSUE

An aircraft's transponder receives its trajectory intent information from the Auto Pilot Flight Director System (AP/FD) and from the aircraft's Flight Management System (FMS). It only knows a fraction of what these systems know about the future aircraft trajectory and – to make things worse - AP/FD and FMS only know, what the pilot programmed into them. To give an example: After a pilot enters a new selected altitude into the AP/FD Mode Control Panel (MCP), a Mode-S transponder will know this selected altitude and transmit it, so it can be used by the ATSU. But typically, a pilot will enter the selected altitude after he/she received a clearance for this, so all the ATSU can do with this information is to confirm that the clearance it gave, was correctly entered in the MCP. The ATSU does not know, what the pilot wants, before he enters an altitude in the MCP.

We use voice and data link communication for exchanging requests and clearances. In the given example, the pilot could have asked for the new altitude through a Controller Pilot Data Link Communication (CPDLC) VERTICAL REQUEST message, then received the clearance as a CPDLC message, which he WILCO'ed and entered into the MCP. The problem with this practice is, that the requested altitude may not be available or reachable in airspaces with a lot of traffic. In this case, the controller would response to the request with an UNABLE message and maybe issue an alternative clearance, which he believes fits the intent of the requesting aircraft best. Here he has to guess, because the cause for the request and the performance capabilities of the aircraft are unknown to him. E.g. let us assume the aircraft requested a climb to Flight Level (FL) 370. However, FL 370 is unavailable due to traffic, but FL 390 is available. But the ATSU does not know, if the aircraft's performance capabilities allow it to climb to FL 390 with the current weight.

From an outsider's perspective, it seems as if these knowledge gap issues between pilot and ATSU can be easily solved using the existing technology. Why shouldn't the aircraft's FMS, which knows the aircraft's performance limitations, inform the ATSU about its capabilities through data exchanges, before a pilot asks for a clearance? The technical foundation for this has been laid down 20 years ago, when the Airlines Electronic Engineering Committee (AEEC) created Aeronautical Radio Incorporated (ARINC) characteristic 702A "*Advanced Flight Management Computer System*" which already contained a method to request, retrieve and downlink the full aircraft's intended trajectory and – if necessary – its performance limitations. In the last decade, ARINC 702A received several updates, the latest, Supplement 5, specifically to support NextGen/SESAR concepts.

Working for many years at flight standard and technical airline departments, the author knows about the challenges associated with this. First and foremost, even the 20-year-old technical foundations never made it into many of the FMS, we fly today. This is because the FMS manufacturers are very slow implementing such functionality. The author believes, that the reason for this is the high invest associated with changing the decades old data models and algorithms buried in FMS code certified to DO 178 Level C. And when only a few aircraft are capable, the ATSUs are hesitating to update their IT systems in order to retrieve and process such intent information coming from the aircraft. The well-known chicken-egg problem.

For 20 years now, trajectory intent downlinks are believed to become an important part of the future ATM system. Without doubt, many SESAR projects have been completed in this area. But the results are poor, nearly invisible. What went wrong? Why can society develop, accept and integrate new technologies like smartphone messenger systems so quickly, while it takes forever in aviation to implement and use new IT-based functions?

Most of us know the answers:

1) Aviation may be a big industry, but the IT industry is much bigger. The market for smartphones, tablets, laptops, servers is much larger than the market for FMS and ATM systems and much more money goes into their development. Therefore, avionics like the FMS, cannot match the quality, flexibility, processing power or price of Commercial Of The Shelf (COTS) IT equipment.

2) The safety criticality typically associated with aviation forbids many shortcuts possible with COTS IT. We cannot run a Flight Management Function (FMF) on a modern operating system like iOS or Windows, because this is not certifiable to DO 178 Level C ("major risk"). For the same reason, libraries can often not be used. Many existing solutions cannot be used, but need to be developed from scratch, increasing the costs.

III. A NEW HOPE

While avionics upgrade programs are slow, Electronic Flight Bags (EFBs) have been developed, accepted and integrated in today's flight operation much quicker. Today, an EFB is a tablet, receiving data from the avionics and constantly connected to the airline's IT network on the ground. It has replaced nearly all paper in the cockpit and it is there, waiting to take over more duties. On most aircraft, a single EFB tablet has more processing power and memory then all avionics equipment of this aircraft combined and it is better integrated with ground IT than any avionics system.

Some airlines, e.g. Lufthansa, meanwhile flies with EFB apps which constantly re-calculate the ideal trajectory for this flight. Based on extensive and freshly uplinked environmental data, supplemented by avionics data informing it about the aircraft's condition and programmed with airline's conditions such as fuel and time costs, passenger connecting flight values and airport delay sequence information, it offers trajectories to the pilot, which he then requests to the ATSU. Some may not have noticed it, but today, Lufthansa and other airlines, no longer wish to fly what they filed hours ago, but instead what is ideal for them NOW. The FMS, which basically showed the trajectory calculated prior to take off, no longer contains the intended trajectory. Only the EFB knows the intended trajectory. Downlinking the trajectory stored in the FMS makes no longer any sense. Downlinking the trajectory from the EFB makes all the sense. The idea of this paper is to promote this idea.

Figure 1. A portable EFB

IV. USING NON-CERTIFIED EFB FOR ATM?

As mentioned before, the EFB we have in mind here is a *portable* tablet, a *non-certified* EFB. It is only operationally approved for cockpit use. It may be mounted or viewable stowed, it could be hand-held. It may get its power from the aircraft, but it could be restricted to its own internal battery. It is a COTS tablet, running a COTS operating system like iOS or Windows. How can it be safe to use it for something as important and safety-critical as ATM functions? Isn't this the domain of expensive certified avionics?

EASA AMC 20-25 defines EFB as "*An information system for flight deck crew members which allows storing, updating, delivering, displaying, and/or computing digital data to support flight operations or duties.*" and continues "*A portable EFB is a portable EFB host platform, used on the flight deck, which is not part of the certified aircraft configuration.*"

EASA AMC 20-25 (and similarly the FAA AC 120-76D and the ICAO EFB Manual Doc 10020) do not allow safety critical functions to be performed with a portable EFB and they do not allow that an EFB takes over functions required to be performed by airworthiness regulations. Therefore, an FMF, hosted on a portable EFB and controlling the Auto Pilot, would not be allowed in an airliner. But a Flight Profile Optimizing (FPO) algorithm, which informs the pilot about the ideal trajectory, who then programs the FMS or AP/FD accordingly, can be hosted and operated on portable non-certified EFBs and it can be operationally approved. In fact, Lufthansa and other airlines are doing this since 2014.

Figure 2. GUI of an FPO app, hosted on a portable EFB, showing the aircraft's position and its intended trajectory. The colored background shows uplinked wind data, influencing the intended trajectory.

V. SAFETY IMPLICATIONS

Would safety be compromised, if we add a trajectory intent downlink as a new function to EFB hosted FPO? There is certainly no immediate and direct harm possible to an aircraft, whenever data *leaves* that aircraft. But we have to address risks, which could arise, if the downlinked data is wrong and misleading or expected but missing and thus triggers actions at the ATSU which endanger flight safety.

A. Wrong and misleading trajectory intent downlinks

If a trajectory intent downlink contains wrong data, e.g. the contained position estimates or performance limitation figures are wrong, then this has no direct safety implications, because aircraft separation is never based on this data. A trajectory intent downlink does not replace any existing avionics system. We are still using voice or CPDLC position reports, RADAR, transponder Mode S and ADS-B and separation is still based on them. It cannot be used instead of one of those systems. As it is not replacing them, there is, from an airworthiness perspective, no need to certify it to a DO level and no reason why it could not be hosted on a non-certified EFB.

A trajectory intent downlink does not contain a cleared trajectory and it does not contain a requested trajectory. It contains an intended trajectory, which may then be requested by the pilot.
A wrong trajectory intent downlink will lead to wrong data in the ATSU's computers about the intent of an aircraft. It would replace non-existing information about this intent by wrong information. The safety implications of this need to be discussed and mitigated on the ground.

B. Expected but missing trajectory intent downlinks

As the intent downlink function is not replacing an avionics system required by airworthiness regulations, such as a Mode S transponder or ADS-B, we can, from an airworthiness perspective, fly without it.

But if an ATSU gets used to receiving trajectory intent downlinks and draws value out of this information, and can increase its airspace capacity due to these trajectories, then it will certainly have to react, if these downlinks are expected, but missing. The airspace capacity would then be reduced again and safety implications of this need to be discussed and mitigated.

C. Author's thoughts about avionics software certification

Even if certification of a trajectory intent function is not required by airworthiness regulations, some will suggest it should nevertheless be certified, due to the mentioned safety implications it could have in the ATSUs.

According to Wikipedia, "***DO-178C, Software Considerations in Airborne Systems and Equipment Certification*** *is the primary document by which the certification authorities such as FAA, EASA and Transport Canada approve all commercial software-based aerospace systems.*"

As this paper promotes to move the trajectory intent function from the FMS, which is certified to DO-178C level C, to an EFB, some will argue, that the EFB should then be certified to level C, to assure the same safety level.

State-of-the-art EFBs cannot be certified to DO-178C level C (or higher). This is due to formal criteria, e.g. the non-availability of the source-code of iOS or Windows to the certification authorities and due to practical criteria, e.g. the cost and time associated with certifying an open source OS such as Linux.

The goal of certification is to reach a high assurance that the software does what it is expected to do and that the assumption is, that this serves flight safety best. But we know that certified software in avionics systems is not free of bugs. Certification of software does not assure that it works as designed. This is especially true for networked systems, where the real environment these systems later encounter, cannot be fully simulated during their certification process. Certification makes changes, e.g. bug fixes, more difficult. We have severe bugs in FMS software, even in safety-critical functions like ADS-C reporting, sitting there for years with nobody fixing them, because it is too costly to re-certify.

Certification delays new technologies by decades. This includes technologies increasing flight safety. Nowadays, safety features based on IT reach general aviation cockpits much quicker than airliner cockpits.

VI. CONCLUSION

With the exception of very simple software, no software can be delivered free of bugs. Therefore, we should restrict certification to simple software. A Full Authority Digital Engine Control (FADAC) or a Flight Control Computer (FCC) must be free of bugs. An FMS should be. But we have to keep it simple, to assure this. We should not burden FMS with complex trajectory optimizing and reporting functions. We should not increase its connections with the ground network, because this will lead to more bugs and cyber vulnerabilities in a system which, if compromised, may compromise flight safety. We should not integrate the FMS into modern ATM concepts.

The EFB is different. By definition, the flight may be completed without major safety risk, even if all EFBs on board are lost or showing misleading information. The EFB helps us to fly more efficient and safer, but an acceptable level of safety is maintained without it. The EFB is already a part of the System Wide Information Management (SWIM). It may not be as reliable as the FMS, but we shouldn't require it to be. We need to design the future ATM in a way, which keeps the FMS safely isolated and the EFB a part of the ATM network. Not using the EFB's trajectory intent downlinks due to certification concerns would mean, that we continue with what we have today: Insufficient knowledge about the aircraft's intended trajectory, performance capabilities and limitations.

Let us explore this further and let us work together. **ATSU managers, please contact us and let us define together, how we can send you our trajectory intents**. They are available on board now and it doesn't look difficult to send them to your ATSU's IT systems.

All Lufthansa aircraft already use Flight Planning Optimizer software on the EFB. Most Lufthansa aircraft already feature a connected EFB. All we would need to do is asking our software provider to develop a function to downlink the trajectory into your computers.