# UNDERSTANDING RESILIENCE IN FLIGHT OPERATIONS

Arthur Dijkstra

ADMC, Kooikerboog 7 Nederhorst den Berg, Netherlands

Arthur@ADMC.pro

**Abstract**

An effective Safety Management System requires high variety feedback from flight operations. Current methods for gathering operational data are not suitable for personal, contextual, opinions and views of the people at the sharp end of flight operations. Operational risk mitigation and the handling of disturbances is an essential quality of the flight crew. FlightStory supporting operational feedback, makes the pilots more part of a human sensor system to improve safety. The management of flight operations can learn how actual practices shaped safe performance under goal constraints and resource limitations. FlightStory provides a high variety feedback system. The pilots have access to an app on their iPad to submit their stories. Relevant aspects of Resilience Engineering and the Viable System Model are used to find patterns in effective handling of all types of events, not only safety incidents. Remarks in FlightStories show pilots appreciate the method and wish to share their experiences. The stories show how uncertainty, ambiguity and complexity can play a role in normal pilot event handling and how resilience is realised.

## 1. INTRODUCTION

Safety is a critical variable for the survival of an airline. In times where the competition is fierce, the impact of regulations is strong, traffic is increasing and technology is more and more connected, safety management is demanding. The already high level of safety of aviation requires new methods for further improvements in safety.

FlightStory is such a new method. It builds on the related fields of cybernetics, systems theory and resilience engineering. A high variety channel from the flight operations back to the organisation is needed to specify the gap between Work As Imagined,(WAI) and Work As Done (WAD) (Wears, 2015). Hollnagel (2014) describes that according to the safety-II principle all events should be evaluated, not just the undesired outcomes. FlightStory provides pilots a way to communicate their experiences and explain how system perturbations affected flight operations.

Safety-II and Resilience Engineering (RE) as described in Hollnagel (2007) are not yet part of the vocabulary of current Safety Management System (SMS) methods. Most of today's SMSs focus is put on hazard identification, mitigation and the failures that occurred. Current practices for data collection from flight operations consist of Flight Data Monitoring (FDM), the monitoring of about 160 flight parameters, Air Safety Reports (ASR), reports written by pilots giving factual data about a safety related event, and legally required flight inspections executed by flight inspectors. These practices have not changed a lot over the last 20 years except for the introduction of voluntary Line Oriented Safety Audit (LOSA) (ICAO 2002). During LOSA a trained observer fills out a LOSA form about how threat and errors were managed and what kind of errors or violations were made. The LOSA form and the introduction of an interpretative layer (the observer) is problematic given the complexity of flight operations. Page (2010) states that complexity requires a diversity of perspectives. Similarly trained observers and predetermined scoring forms do not increase the number of perspectives. The transduction of variety (Beer 1985) by the LOSA form and the observer reduce the maximum feedback variety.

Amalberti (2001) suggests that standard reports become ineffective in ultra-safe systems. FlightStory is an instrument for pilots to express themselves. It allows them to give their view of a safety related event and allow them to express how they (almost always) successfully dealt with the event. Operational risk mitigation and the handling of disturbances is an essential quality of the flight crew. FlightStory makes the pilots more part of a human sensor system so the organisation can create more information about itself in order to manage itself more effectively (Beer 1972). This can increase the requisite variety of the Safety Management System (Ashby 1958).

### 1.1. Aims and objectives

FlightStory should provide insights in how pilots disturbances and balance safety with other goals during normal, everyday flight operations. Their stories, opinions and beliefs can provide meaningful insights and help bridge in the gap between WAI and WAD. FlightStory analyses should provide directions for management interventions to further improve the resilience of flight operations.

## 2. METHOD

As an initial test, FlightStory was made available to the flight instructor pilots only. This group consists of about 200 pilots who perform regular flight, route and simulator training and checking. About half of the group is short haul pilots (flights less than 4 hours) and the other half is long haul pilots (normally longer than 4 hours).

This sample of pilots is representative for the total group of pilots since they operate on regular line flight with regular (no training) colleagues.

### 2.1. Data collection

FlightStory was built as an HTML5 single page app. Capable of working while in flight, not connected to the internet. The app has a mobile user interface suitable for usage on an iPad. After a FlightStory was completed by a pilot the answers were sent by email to the safety office following the same route as electronic safety reports. In the safety office the answers in JSON format are extracted from the email and stored in a secure database. The instructor pilots were invited by their training managers to share their experiences by FlightStory. In a letter to the instructor pilots the purpose, the installation procedure and working of the app were explained.

### 2.2. Experiment design

FlightStory is inspired by Sensemaking and Storytelling. This field of research can be traced back to the 1970's (Dervin 1983). Weick and Sutcliff (1999, 2005) applied Sensemaking concepts to understand how organisations develop and maintain high reliability in complex environments. Kurtz and Snowden (2003) included explicitly complexity theory concepts to their Sensemaking approach. Complexity theory assumes that it is not a priori possible to know all the issues and relations in a complex system. Therefore open questions are needed to collect relevant data as opposed to closed questions which assume the issues and relations are known. Standard ASRs that are currently filled out by the pilots when a safety event has occurred, have only boxes to tick and a field for a factual event summary. The pilots view on the event is not systematically collected in ASR. During analysis for SMS purposes the ASRs are categorised and grouped to find trends. This data treatment disregards the contextual data. Combined FlightStory and ASR, data remains contextual and can be analysed differently.

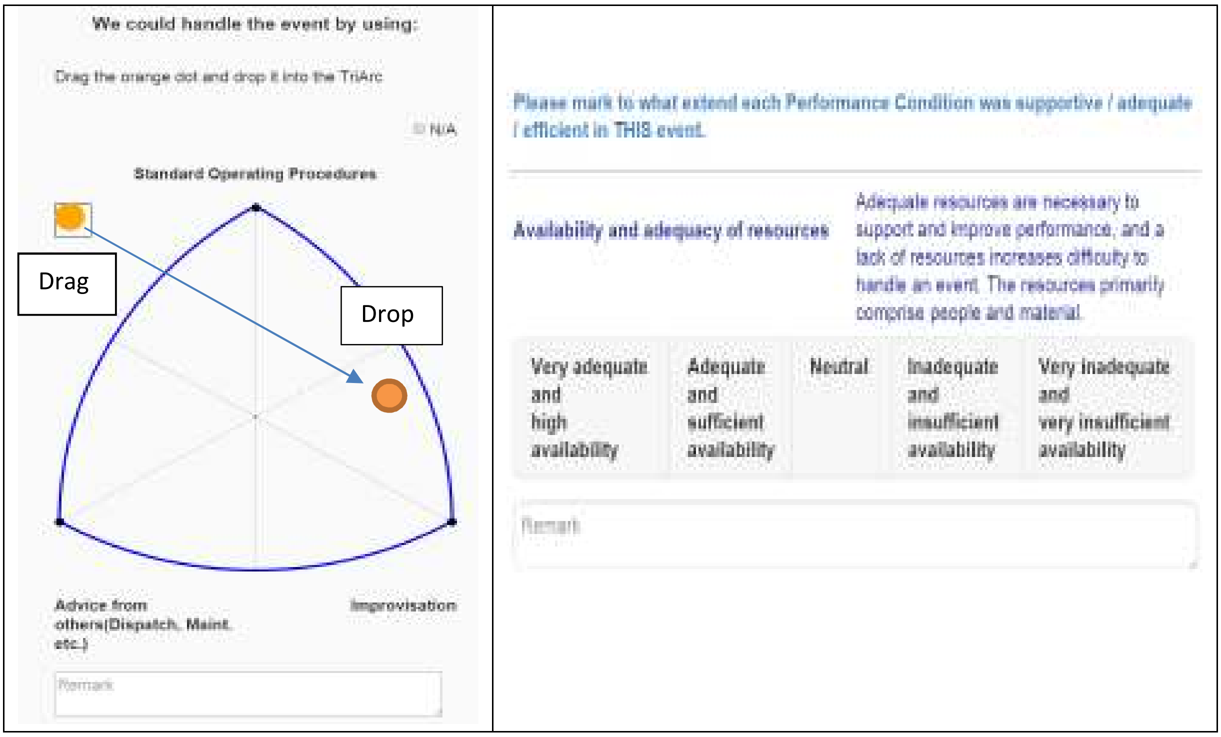
For this experiment the FlightStory will be an extension of the ASR. The narrative, describing the operational experience, provides qualitative data. The pilots indicates his view via the triangles and selection boxes. The quantitative data is used to find patterns in the data. The qualitative data is used to support understanding of the patterns found. The FlightStory form consists of three parts.

**The first part** of FlightStory starts by asking the pilot an open prompting question (such as: Please describe your experience in a way other pilots can learn from your event.") Here the pilot provides his narrative of the event. The first part also gathers some personal data such as function, experience and emotional impact (this is an indicator for the impact of the event). The pilot is also asked to assign a personal judgement to the risk level of this event. This allows comparing SMS assigned risk levels done by the safety office and the views of the pilots.

**The second part** of the FlightStory form has ten tri-arcs covering a mix of relevant RE and Viable System Model (Beer 1984) concepts. The concepts are placed in a triangle or ternary plot as used by Keidel (1995) and Allen (2007). In FlightStory these shapes are called tri-arcs. This shapes provides a better geometry since the opposite arc segment from a corner has equal distance to this corner. This is not the case in triads.

The distance between the concepts in the tri-arc allows the reporter to weight his judgement. The distance from the selection point in the tri-arc to each concept corner is a value indicative for the significance of the concept for the specific question. In this case the tri-arc provides a way to indicate what was supportive to handle the specific situation: Standard Operating Procedures, Advice from other such as Flight Dispatch, Maintenance support or Improvisation. In the example above more Improvisation was used than Standard Operating Procedures and Advice. A remark can be added. A mark in the middle would indicate all three features are equally important. If none of the labels are applicable one can choose to check the 'Not Applicable' box.

Research (Snowden 2011) has shown that respondents using the tri-arcs used more time and consideration where to place the mark than when two point scales are used. A tri-arc signifying space is richer than a two




point scale and also more two point scales than tri-arcs would be required to get the same amount of data. A tri-arc provides a way to indicate which or how trade-offs were made. Pilots can add remarks to their answer.

**Figure 1** Left: A *tri-arc showing concepts at each corner. Right: A question with radio buttons about Operational Performance Conditions*

Snowden in Mosier (2011) suggests two options to design relevant labels for the tri-arcs. One is to search for cultural established organisational constructs, the other is a researcher designed set related to the aim of the research. The labels provide references for the respondents and help to signify their judgement about the reported. The following steps were used to specify the concepts labels:

1. Identify the concepts in the field of safety, safety management and resilience by clustering subjects, behaviours, decision points, etc. from a priming set of narratives and literature. Choose the key concepts that relate strongest to the project, here resilience.
2. For each key concept create a triad with balanced negative or positive labels, the idea is to force trade-offs.

The concepts are based on a review of Resilience Engineering (RE) (Hollnagel et.al.2011) and Management Cybernetics literature (Ashby 1956, Beer 1972). Both fields of theory align well as argued in Dijkstra (2007). The following key concepts were selected and used in the questions.

1. System identification, what are the essential variables, which could be affected.
2. What was the source of the disturbance
3. How complex was the event
4. Response characteristics
5. System dynamics
6. Core competencies (ICAO 2013)
7. VSM related concepts, the four essential abilities
8. System dynamics, time, margin, fall back options.
9. Learning system

The ICAO Core Competencies answers are useful for the Alternative Training and Qualification Program (ATQP) development. FlightStory provides feedback to update an understanding on how the core competencies are applied in actual cases. This question was added after a discussion with the Head Of Training of the airline.

**The third part** of the FlightStory form contains the Common Performance Conditions (CPC) as developed by

Hollnagel (1998). The CPC can be rated on a scale for their supportiveness for handling the situation. CPCs can be viewed as the factors that are managed by the airline organisation, through the SMS, that shape the performance of their flight operations. The combination of CPC rating and resilience safety performance can provide and increased understanding of how to engineer a more operational resilience.

### 2.3. Summary

FlightStory accommodates high variety feedback from flight operations feedback on issues related to: the pilots view and opinion, RE concepts, pilot training and operational performance conditions.

## 3. RESULTS

Confidentiality agreements prevent publishing details of stories. The provided examples and excerpts in this paper are considered representative for normal work in flight operations of any airline. Outsiders normally have no access to these insiders stories. This publication provides some insights which in not unique for the particular sources of these stories.

**REPORTING RATE**

After the experiment ran for 6 months 25 FlightStories were submitted. Ten FlightStories were short haul related and 15 long haul. A submission per flight rate is hard to determine since individual pilot schemes, showing actual flight and simulator working periods are not available for this research. A rough estimate would be based on the following assumptions: pilots perform simulator and flights on about a 50/50 rate. Thus 3 months of flight means for a short haul pilot about 100 flights. For 100 pilot this totals to 10000 flights. This makes the response rate in the order of 1 in 1000 flights for short haul. 100 long haul pilots fly about 2500 flights in three months. Hence the response rate is in the order of 1 in 150 flights.

**ANALYSIS METHOD**

A specific FlightStories analysis tool is in development. This analysis is based on a simple spreadsheet overview.

**STORY TITLES**

The story titles already provide a sense for the topics that were addressed in the FlightStories. Some examples of story titles: “50 shades of grey”; “Insufficient wingtip clearance during taxi-out?”, “Always Be Prepared”, 'Acceptability' vs 'accountability'.

Topics such as uncertainty, ambiguity and trade-offs can be inferred from these titles. These titles seem to refer complex issues, the areas where resilience and operator expertise become relevant.

**EXCERPTS OF STORIES**

Each flight was without incident or specific threat to safety. These were normal operations as they are regularly encountered. Normally these events are shared among pilots and only factually reported in standard safety reports and not with the aim to share learning with colleagues.

1. When the weather conditions are outside the limits for the autopilot:

“Also we encountered a few times an updraft. This updraft with the tailwind put us high on glide, while holding power at idle and using full speed brakes. At about 10500' I disconnected the AP and continued manually, still the same turbulence and speed fluctuation. Also still holding above the glide path. At around 1000' AGL we were fully configured for landing, still above the glide but correcting this time, I decided to continue and wait for the 500' call, we were VFR and had lots of positive energy. AT 500' we were on glide, the air was a little more stable, only some overspeed.”

CPC Crew Resource Management was rated as very efficient and training and experience was rated as very adequate. An Air Safety Report was filed and no Flight Data Monitoring events were triggered. After the flight the pilot felt “relieved”

2. Disturbances, non-standard operations and delay:

”Apart from above mentioned circumstances, worth noting is that during the sequence of events, already being out-of-the-ordinary, cockpit split several times, as different parties (ATC, ground staff, marshaller, AMT and crew/pax) require attention and once considered safe, losing as little time as possible, to guarantee scheduled arrival time, the biggest threat seemed to continuously keep cockpit crew in the loop, and to adhere to SOP's to guard all barriers for safe operation. Making very short 'recaps' before second pushback, before second taxi-out and before take-off helped to minimize this threat. Luckily, we were fortunate that -even with LSF (low speed flying)- we would still arrive on time after 45' delay, so time pressure was minimal.”

CPC Human Machine Interface and Operational support was rated as Unsupportive. An Air Safety Report was filed and no Flight Data Monitoring events were triggered.

3. Winter operations:

“I was kind of surprised! I could suddenly "feel" my right hand touching my right knee as it should be. Or not? We had started that morning very early with "the Europe Works": no drinking water in tanks, de-icing and a slot time, precipitation now and then, water in tanks but no pressure, should we take extra fuel, "What's that a minimum fuel uplift?", boarding and one pax missing, etc. etc. After having been de-iced and made our slot, we had an uneventful t/o for our relatively short flight to LHR, somewhat delayed of course.”

For this flight no ASR was written (maybe because a FlightStory was filed) and no FDM events were triggered. The pilot judged the event as medium risk but since no ASR was written a discussion about SMS risk and perceived pilot risk was impossible. This example is maybe indicative for the pilot’s desire to share an experience which cannot be shared via standard reporting such as the ASR. The pilot felt worried after the event.

**PILOT RESPONSES ON THE FLIGHTSTORY APP**

“A way to improve safety and awareness without the need for an ASR.”

“I can give more background information, which is important with human factors.”

“I have to get used to the tri-arcs. But I can imagine it can give valuable information to fill them in, since you are forced to think about aspects you didn't think of beforehand.”

“Too labour some”

“Good plan, but should be more simple. Terms used too theoretical for pilots.”

“This is important! Sharing brings this experience to all! We can all benefit to this report. I also learn from it by sending the report.”

**SUMMARY**

The pilot responses indicate a desire to improve safety by sharing and learning. The stories and their titles indicate trade-offs and goal conflicts, the typical arena where resilience engineering is applicable. Event descriptions which contain context and participants opinions show insights that would otherwise be unavailable for safety management purposes.

## 4. DISCUSSION

The response rate is still below the desired rate. Pilots stated that a rate of about 1 FlightStory in 10 flights should be achievable. The time and effort to fill out a FlightStory should be outweighed by the benefit pilot perceive from sharing the stories. A promotion campaign will be started.

The analysis tool that is in development together with more submitted FlightStories will help to find patterns. These are desired to understand effective strategies and enable support for resilience via e.g. training and flight operations design.

FlightStory provides descriptions of events from the pilots perspective. These insights are normally not systematically available by other means. The stories provide e.g. issues to discuss during pilot training. Especially new captains can learn to monitor, anticipate and respond from discussing these FlightStory events.

Initial draft results have only just been shared with some managers of the flight operations department. Their reaction is positive as expressed by their desire to get more results in a monthly report and to support the promotion campaign.

## 5. CONCLUSIONS AND CONCLUDING REMARKS

FlightStory is a new way of building a high variety feedback from flight operations to flight operations management. The stories can also be shared among pilots to learn from others’ experiences. Therefore expectations by pilots and managers about FlightStory are high. Analysis shows that new information is collected for safety management, operational management and fellow pilots. The methodology has been effective in other domains(Deloitte 2010). It is expected that all pilots in the company will be invited to share their operational experiences via FlightStory to increase the understanding of the gap between WAI and WAD. Some remarks have resulted in improvements of the app and feeding the stories back to pilots will start coming months. The airline supporting this project is taking a step forward in developing effective safety management methods.

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