

# Extended Safety Nets in Aircraft- and Vehicle-Surveillance by combining A-SMGCS and Digital Flight Strip Data

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## Introduction

Safety nets are based on the knowledge of assorted data describing the current traffic situation on an airport. Controllers frequently use tools like Flight Strips, Approach Radar, A-SMGCS, Stopbar Switches, etc. which are more or less operated independently from each other. So no system has the complete picture about the traffic situation, and in particular about the state of each aircraft. Important information like clearances etc. are either not available or are isolated in single systems. Especially during peak traffic hours there is a higher risk that the ATCO cannot react properly in critical situations.

AviBit has implemented ways how to integrate such data from different systems in order to implement safety nets based on all information on a flight. An integrated solution is demonstrated with a combined A-SMGCS and Digital Flight Strip system which allows the current A-SMGCS alarms to be extended and new alarms to be implemented.

## The current situation

A controller usually works with various sources of information to get the required situational awareness. Usually these sources are:

- Approach radar (ASR)
- Flight Strips
- A-SMGCS
- Stopbar control panel
- ...others

He normally uses surveillance tools to observe the present traffic situation while using paper Flight Strips as a redundant representation of the current situation but also for planning purposes. In addition Flight Strips are used for conflict resolution and coordination.

The above mentioned systems are usually not interconnected with each other and the controller has to combine data from different sources "in his mind" to get a comprehensive picture of the traffic situation. Under

light and medium traffic and under good weather conditions this task is manageable by the controller but as soon as special cases occur like low visibility, high traffic peaks, etc. the controller has a higher risk to overlook critical situations due to his high work load.

This risk can – of course – be significantly reduced by the safety nets built into the various systems. However these single isolated safety nets are quite limited concerning the type of alarms they can trigger because they usually do not have the complete traffic data available. By combining the traffic data from the various systems and by implementing a common safety-net it is possible to both, extend and improve existing alarms and implement new types of alarms.

This fact is well illustrated by an example as depicted in Figure 1:

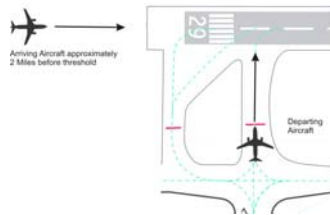


Figure 1: Runway Incursion. A typical alarm situation for an A-SMGCS

Alarm processing in a conventional A-SMGCS (simplified):

A conventional A-SMGCS would detect that the departing aircraft moves onto the runway while the arriving aircraft is approaching. If the arriving aircraft is closer than 1 minute (configurable parameter) an alert would be given to the controller and he has less than 1 minute time to resolve the problem.

Advanced alarm processing when data from A-SMGCS and digital-flight strips are available:

The A-SMGCS detects that the departing aircraft begins to line-up (e.g. it starts moving from the holding point towards the runway). Now when the clearance status from the Digital Flight Strip system is available, the safety net can issue an alert right away (and not only if an arriving aircraft is already very close to the threshold) giving the controller much more time to react and to solve this critical situation. Additionally, depending on the status of the stopbar, the A-SMGCS would additionally trigger a red-stopbar-crossing alarm. Please note that this is an additional alarm and is not intended to replace conventional runway incursion alerts in an A-SMGCS.

The system presented in this paper includes advanced alarm processing and helps the controller to detect such critical situations and give him/her more time to solve them. The following sections explain the details.

## The state of an Aircraft

Aircraft handling on ground is in 95 % of all cases very well following a work-flow which is illustrated in the following Figure 2

Starting at the parking position an aircraft follows the following work-flow:

- Parking: The aircraft is at its parking position. No action required by the controller
- Pushback Clearance: The pilot calls the controller and requests pushback. Controller approves pushback.
- Startup, Controller approves startup
- Taxi, Controller approves taxiing
- Lineup, controller approves lineup
- Takeoff, controller approves takeoff

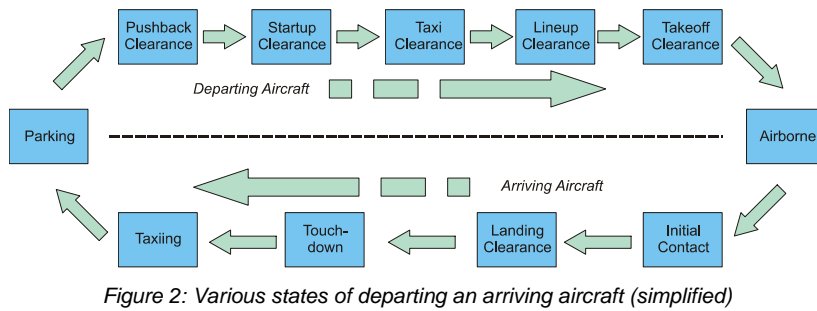


Figure 2: Various states of departing an arriving aircraft (simplified)

Finally the aircraft is airborne and further controlled by Approach- or En-route units. As soon as it approaches an airport again, a workflow as shown on the lower part of Figure 2 applies:

- Initial contact by the pilot
- Landing Clearance issued
- Touch Down
- Taxiing, controller gives taxi clearance
- Parking

Of course the workflow shown above can have numerous exceptions and shortcuts and also differs from airport to airport. However the basic principle stays the same. AviBit's experience at Vienna Airport shows that usually about 95% of all flights follow the defined workflow.

## Digital Flight Strip System

In order to support a workflow as described above the controller needs an instrument which allows him to enter clearances, and to move a flight (or flight strip) through a given work-flow. One instrument to do this is DIFLIS – the Digital Flight Strip System by AviBit which is in operation at Vienna Tower since one and a half year.

DIFLIS is a fully digital representation of paper flight strips on a computer touch-pen display. It offers a number of bays where the controller can arrange the Digital Flight Strips. DIFLIS flight strips layout closely resembles the familiar paper strips. Each strip contains a number of data fields that are filled by the system with configurable information derived from the flight plan. Each of the fields can be edited by the controller and this modified information is then returned to the flightplan processing system.

Updated information is always kept in sync with other CWP's (controller working positions) Figure 3 shows the system as installed at Vienna Tower



Figure 3: Digital Flight Strip System as installed at Vienna Tower

As shown above, the DIFLIS touch screen is built into the desk of the CWP. Controllers use a special pen to work with the system. This is only one example, however. The system can be installed on arbitrary screens (touch-pen based or conventional).

Figure 4 shows a screenshot of a typical DIFLIS screen.

In order to support the controller in his daily tasks, DIFLIS includes a configurable pre-defined workflow (similar as the one described in Figure 2) which allows the controller to move a flight strip from it's current state to the next state as defined in the work-flow. For example: A flight has performed its pushback and is now waiting for taxi clearance. The controller just needs to press the "Action Button" for that and the system updates the internal state of the flight. The "Action Button" is located on the right side of each strip (See Figure 4, Buttons labelled "TFR" (transfer), "CTC" (contact), "LUP" (line up) etc.).

DIFLIS as a standalone system already includes safety features that help the controller to see and avoid critical situations. These features only consider the state of a flight in the work-flow and the bay where the strip is located. It does not consider data from any other source.

The following list of digital-flight strip safety net features is just exemplary and not complete:

- Moving a strip into the Taxiing Bay is only possible after giving a taxi-clearance
- Taxi-Clearance is only possible after push-back clearance
- No landing clearance without initial contact.
- Trying to issue a landing clearance gives a warning when there is a vehicle strip in the runway bay
- And many more....

LOCAL	TAXI	CLEARANCE DELIVERED (SORTED)
<p>OE9362 KL 33 CITY TFR</p> <p>VFR 0017</p> <p>DIMO- LOAR X</p> <p>POLIC1 VFR 1572 DMV X TFR</p> <p>HEL- LOAR X</p>	<p>SCHLEPPER45 Run up full AUA = F45</p> <p>KLM1840 KOVXC OILIT 29 LUP</p> <p>F100 33 ENAH</p> <p>DLH43A LANIC LANIC 5160 29 LUP</p> <p>EDDT</p>	<p>ADR143 CR32 LUGIC +26 29 START</p> <p>CAL064 A333+ 56 ABLIC 29 PUSH</p> <p>CSA4AT AT45 LANIC 29 START</p>
ARRIVALS	RUNWAY TRAFFIC	STANDING BY
<p>BER8375 B738 16 CTC</p> <p>AUA7FG F300 16 CTC</p> <p>AUA2KL NERDU 60 16 CTC</p> <p>DH8C B93 LOWL 16 CTC</p> <p>AUA458M A321 16 CTC</p> <p>DLA8072 BALAD 300 0230 16 CTC</p> <p>AT45 LFX X</p> <p>DLH44E B735 42 16 CTC</p> <p>ADR284 CR32 B84 16 CTC</p> <p>MLD867 E320 H42 16 CTC</p> <p>AUA2GQ DH80 16 CTC</p> <p>LOT223 E370 K51 16 CTC</p> <p>LOT227 AT45 K48 16 CTC</p> <p>THY1883 B738 B05 16 CTC</p> <p>MAK911 CR39 H46 16 CTC</p>	<p>DAT77R MOTIC FRE 29 TCL</p> <p>R305 EBR</p> <p>FBL1 RWY 16 29</p> <p>DIFPS MABOD 170 2272 16 LCL</p> <p>C340- ETHU</p> <p>DLA8072 SNRJ 5 300 0238 16 APP</p> <p>AT45 6G LFX 5</p> <p>AUI845 MABOD 430 4612 16 LCL</p> <p>B733 H45 UK88</p> <p>CTN440 BALAD 255 6534 16 LCL</p> <p>AT43 LQ2A</p> <p>AUA540T BALAD 420 0410 16 LCL</p> <p>CR32 B96 LDHL</p>	<p>GW1751 MOTIC FRE 7223 29 7 START</p> <p>A319 6E EDDK</p> <p>LGLB852 MOTIC FRE 7212 29 TAXI</p> <p>E345 6C ELK</p> <p>DEGRR SITAC SETNE -13 TAXI</p> <p>L355 LFLB 29 TAXI</p>
STARTING / PUSHING	<p>1024 UNDO FIND INFO FPL VEHIC ICE BLUE ABORT TRASH DLV GDW GDE TW1 TW2 COO NO FPL NO STAND 08:56:58</p>	

Figure 4: Screenshot of the DIFLIS system.

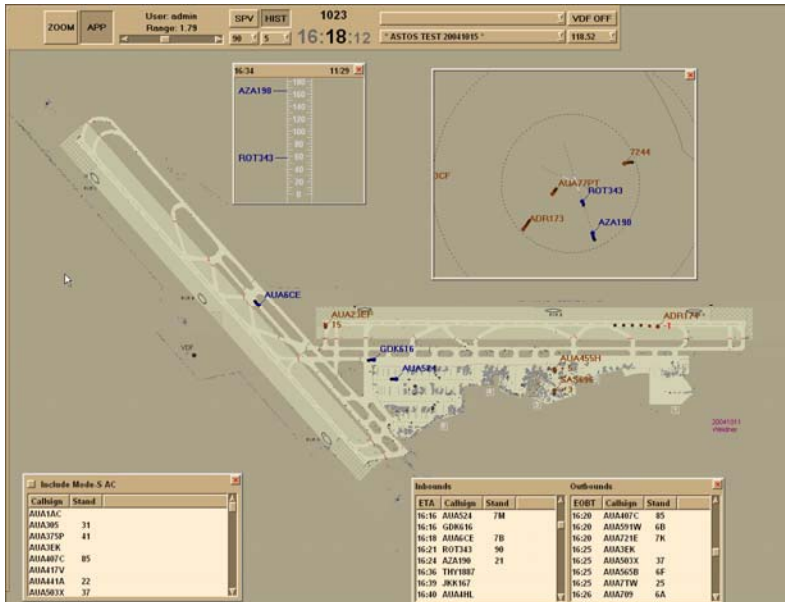


Figure 5: HMI of the A-SMGCS Vienna

## A-SMGCS

The A-SMGCS is one source of data for the extended safety nets features and shortly described in this section.

The AviBit A-SMGCS as installed at Vienna Airport is a Level 2 A-SMGCS according to the specifications by Eurocontrol and ICAO. It fuses and tracks data from ASR, three SMRs, ADS-B and Multilateration System. Furthermore the system integrates data from the airport lighting system, direction finder data, RVR-, QNH-database, flight plan and airport stand-information system. The controller finally gets a full traffic information picture as shown in Figure 5.

The A-SMGCS as a standalone system includes already safety nets which go far beyond the definitions of Eurocontrol A-SMGCS Level 2 specifications.

The following list shows an example of the safety net features of the standalone A-SMGCS:

- Aircraft on a closed-area: The A-SMGCS allows the ATCOs to define arbitrary "closed areas" (for example construction sites, etc.). When an aircraft taxis into such an area, an alarm is triggered. Closed areas can also be assigned a start- and/or end time, meaning that the alarm is only triggered within this time frame.
- Identified vehicle on a closed-area: Same as above but for vehicles.

- Identified vehicle on an arrival protection area: The arrival protection area is comprised of the runway safety-strip including the ILS protection areas. When a vehicle is located within this area while an aircraft is approaching, an alarm is triggered.
- Arriving aircraft and another aircraft on the arrival protection area of the landing runway: An aircraft is still in the arrival protection area while another aircraft is approaching.
- Multiple Line-up: An aircraft is on the departure protection area in front of a departing aircraft: The departure protection area is basically the runway safety-strip. If an aircraft is within this area in front of another aircraft and the aircraft behind accelerates to a certain speed, this alarm is triggered.
- Arriving aircraft and another aircraft on an intersecting runway: This case is for intersection runway configurations (like the one shown in the A-SMGCS screenshot above). It is checked that a departing aircraft on one runway has a certain separation to an aircraft arriving on the intersecting runway.
- Departing aircraft and another aircraft on an intersecting runway: Two departing aircraft on intersecting runways are checked.
- Stop bar crossing: This alarm is triggered when an aircraft crosses a red stop bar.

The AviBit A-SMGCS distinguishes between "Hints" and "Alerts". A hint is an indication on the HMI that a special condition has occurred. A hint is also called a "Stage 1" Alert in

common A-SMGCS literature. The hint display at the ASTOS HMI is designed to be visible but not to disturb the controller at his work. It is the decision of the controller how to deal with the hint. Unobtrusive colors are used at the HMI to indicate hints (see Figure 6).



Figure 6: A-SMGCS Hint Display.

An Alert is a strong indication (RED COLOR) on the HMI that a special condition has occurred. It requires immediate attention by the controller (See Figure 7).



Figure 7: A-SMGCS Alarm Display.

All alerts and hint are kept in a log including the parameters and circumstances which caused the alert. They have to be acknowledged by the controller.

A large set of parameters (timing, aircraft distance limits, speed limits etc.) are associated with each alarm/hint type listed above. In addition the A-SMGCS systems allow to switch between different safety-net operating modes to accommodate different weather conditions etc. where other procedures (smaller separations etc.) are in place.

## Safety Nets using combined Information

The following list summarises the new safety net features which have been implemented in the integrated A-SMGCS / Digital Flight Strip System:

### Digital Flight Strip

For outbound flights:

- Aircraft pushes back without clearance: The A-SMGCS detects a pushing (moving) aircraft and if no clearance has been given, the system warns the controller. No "Standard A-SMGCS" can do this if it does

not know if a clearance has been given to the pilot.

- Line-up without clearance: The A-SMGCS recognises if an aircraft starts to line-up. If no clearance has been given, the system triggers an alert.
- Take-off without take-off clearance: Again, the A-SMGCS detects when an aircraft starts its takeoff run. If no take off clearance has been given, the system warns the controller.
- Aircraft taxis to the wrong take-off runway: As one of the most important items, the electronic strip holds the planned take-off runway. If the A-SMGCS detects that an aircraft moves to the wrong runway, an alert is generated.

For inbound flights:

- Aircraft approaching without landing clearance: The system detects arriving aircraft by using radar (ASR) data. When the aircraft is ILS-aligned the system checks from the flight strip if a landing clearance has been given, and if not, it warns the controller.
- Wrong landing runway: From ASR data the A-SMGCS detects the runway an aircraft is approaching. If this runway does not match the runway which it is cleared for, an alert is generated.

Vehicles:

- If a vehicle enters the runway and the controller has no vehicle strip, the system generates an alert.

Whenever an alert occurs, the system highlights both, the label on the A-SMGCS and the strip on the Digital Flight Strip System. This ensures that the controller reacts properly and can quickly make the right decision. This finally reduces the controller's work load and increases safety.

## Implementation

AviBit has integrated appropriate interfaces for its A-SMGCS (ASTOS) and Digital Flight Strip (DIFLIS) products in order to integrate them into a common system. Nevertheless both are still independent products and do not necessarily rely on each other.

As all systems need to share data which describe the state of aircraft, the logical solution for the integration was to have a common flight database (FD) and exchange data by

sending it to the FD from where it is available to all interested parties. For this purpose, our FD was extended to allow arbitrary information to be stored along with the standard flight plan. For the safety-net implementation this is basically a list of events which describe the current state of the aircraft (as well as all past states). All processes are required to send all occurring events via flight plan updates to the FD. Events can have different sources: One source will be the Digital Flight Strip system sending clearance events to the FD. Another source is the A-SMGCS event generator process which is configurable to track the current position of an aircraft both on the ground and in the air. The following figure shows the configuration:

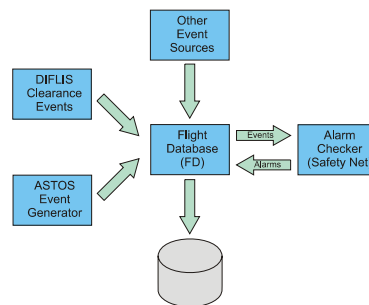


Figure 8: System Configuration

The Alarm Checker implements the safety-net logic. It receives all flight plan updates from the FD containing the flight basic data as well as all relevant flight events and the current flight status. In addition the Alarm checker can be configured on-line for various operation modes which change the behaviour of the safety net in order to accommodate different weather situations (low visibility procedures (LVP), NON-LVP) etc. The output of the alarm checker are alarm messages which, in turn are sent as events to the FD. All participating HMIs can use these alarm messages to highlight the associated aircraft accordingly.

## Open FD Interfaces

Third party products can be accommodated in this scheme by providing them an access to the FD. For this purpose an open FD interface is defined which allows a standardised access to all FD data. So third party products can either be used to import events into the system or to use the alarms created by the safety-net. This allows this basic concept to be extended to A-SMGCS and/or Digital Flight Strip products of other vendors.

## Events

Events are attached to the flight plan in the FD and can have various sources.

Events from the DIFLIS system typically comprise:

- Landing clearance issued
- Touchdown issued
- Taxi clearance issued
- Park position reached
- Pushback clearance issued
- Startup clearance issued
- Lineup clearance issued
- Takeoff clearance issued
- ... and many more also for exceptional cases like de-icing etc.

Events from the ASTOS A-SMGCS system typically comprise:

- Estimated time of arrival in XX minutes (when the aircraft is ILS aligned)
- Aircraft crosses runway threshold
- Actual on-block event
- Actual off-block event
- reached holding point area
- lineup detected
- takeoff roll started
- airborne

In addition the alarm checker knows the current state of all stopbars at the airport. Red-stopbar crossings also cause an alert to be triggered.

Figure 9 shows an example of a flight status window in the ASTOS A-SMGCS HMI. The event list contains the typical events for an outbound flight. For testing, the flight was not touched in the digital flight strip system (no clearances given) which caused all associated alerts to be triggered. The events are:

- ASTOS\_AOBT: Off-block event, the aircraft has left the parking position (Stand 6C in this example).
- ASTOS\_JOINED\_HP/HPQ: The aircraft has joined the holding point queue for holding point A1
- ASTOS\_ALERT: Taxi w/o clearance: The aircraft was taxiing without an associated taxi clearance
- ASTOS\_ALERT: Lineup w/o clearance: The aircraft was beginning to line-up without an associated clearance.
- ASTOS\_WHEELS\_ROLL: The aircraft started the take-off roll.
- ASTOS\_ALERT: The take-off roll has been started without a take-off clearance
- ASTOS\_ATOT: The aircraft took off runway 29.

Of course under normal circumstances, aircraft get all required clearances and the ASTOS\_ALERT events are listed only in cases of real violations:

## Other integration benefits

Apart from vastly improved safety nets, a tight connection between A-SMGCS and Digital Flight Strip System offers additional benefits which are listed below:

**Workflow Support:** Whenever the A-SMGCS detects a certain event an appropriate message is sent to the other systems. For example: When the A-SMGCS detects that an aircraft has landed it transmits this information to the Digital Flight Strip System which then can automatically move the respective strip from the Tower to the Ground position. Moreover the state of the flight can be changed to "landed". This functionality is not limited to automatic landing detection but could also be applied for example for automatic take-off detection, etc.

**Better CWP integration:** The A-SMGCS only shows labels for which an appropriate flight strip is available on the CWP. All other labels are still visible and can be dimmed. This means that only aircraft labels which the controller is responsible for are highlighted in the A-SMGCS

**Shared label highlighting:** Whenever a controller selects a label on the A-SMGCS the respective flight strip is highlighted (and vice versa).

Also for these features open interfaces are available which offer other vendors to implement integrated solutions.

```

IFPLID: AA59046084
(FPL-NLY8735/A7246-I
-A320/M-SEHIRWXY/S
-LOWW1320
-N0446F380 MOTWV MOTIX1C NITE1/1333 SW293/1334 SW232/1336 SW231/1338
SBY3P/1344 MOTIX/1351 L610 FRE/1354 PABSA/1356 RENKA/1358 GONBA/1401
STAUB/1403 MAMOR/1406 UNKUL/1412 ALB/1413 INBED/1416 IGT01/1417 LANGI/1417
VADR0/1421 HAB/1426 LOHRE/1428/N0447F360 L984 ESATI/1429 BOMB1/1432 FFM/1433
PEMAX/1435 ADENU/1443
-LFPG0129
-REG/OELEX OPR/NLY RVR/75 )

IATA Flight: HG8734
SID: MOTIX1C
Track ID: MDS:0444-#4401E2
IFPLID: AA59046084
Mode-A: 7246
Mode-S: #4401E2
FL/SPD: 17/132
DEPRWY: 29
Events: (ASTOS_AOBT,2007-01-31 13:25:03,Stand 6C,UNCHANGED)
(ASTOS_JOINED_HP,2007-01-31 13:27:36,A1,UNCHANGED)
(ASTOS_JOINED_HPQ,2007-01-31 13:27:36,A1,UNCHANGED)
(ASTOS_ALERT,2007-01-31 13:27:42,Taxi w/o clearance,UNCHANGED)
(ASTOS_ALERT,2007-01-31 13:27:48,Lineup w/o clearance,UNCHANGED)
(ASTOS_WHEELS_ROLL,2007-01-31 13:28:20,RUNWAY29,UNCHANGED)
(ASTOS_ALERT,2007-01-31 13:28:20,Takeoff w/o clearance,UNCHANGED)
(ASTOS_ATOT,2007-01-31 13:28:33,RUNWAY29,UNCHANGED)

```

Figure 9: Flight Status Example

## Conclusion

Controllers are currently using surveillance instruments like A-SMGCS to get a picture of the traffic situation. On the other hand they use flight strips to represent the current traffic situation but also for planning and coordination purposes. Reliable safety nets require that these systems are combined into integrated solutions and to use clearances, other information entered into a Digital Flight Strip System and actual aircraft positions for an acceptable alerting system.

AviBit has implemented both, interfaces to combine these systems and an improved safety net which uses this combined data for generating new types of alarms. This solution lead to an excellent acceptance by the controllers. The interfaces are open to customers and other vendors which enables them to create integrated solutions.



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