TARMAC-AS
Taxi And Ramp Management And Control - Airborne System
A remarkable contrast exists between airborne and taxing aircraft: while modern aircraft are capable of flying automatically with high accuracy and at minimised fuel consumption under almost any weather condition, during taxi operations the crew is still forced to control the aircraft manually, to look out of the window, and to navigate by means of paper charts. This leads not only to severe delays under bad weather conditions. Especially on large airports taxi routes sometimes become very complex and it is not always easy to comprehend and comply to the cleared route. This frequently results in misunderstandings or, even worse, in dangerous situations, especially if runway incursion occurs. The annual incidence statistics indicate a significant number of incidents due to disorientation on the ground.

To alleviate hereto related problems the DLR Institute of Flight Guidance together with partner institutions started its A-SMGCS (Advanced Surface Management Guidance and Control System) project called TARMAC (Taxi And Ramp Management And Control). This project addresses all aspects of airport surface management, guidance, and control:

- The planning system TARMAC-PL (-Planning and Controller/Machine Interface) for a co-ordinated, efficient, and conflict-free ground movement from touch-down to on-block and from off-block to take-off.
- The integrated multi-sensor and communication system TARMAC-CNS (-Communication, Navigation, Surveillance) for continuous automatic observation of the traffic situation at the airport.
- The cockpit assistance and guidance system TARMAC-AS (-Airborne System) for improved control of the aircraft on the ground.

The Taxi Assistance and Guidance System TARMAC-AS

The Taxi Assistance and Guidance System TARMAC-AS offers the functionality to control the aircraft:
- weather-independently,
- safely, and
- efficiently even on large airports and under bad weather conditions. This is mainly due to a situation-dependent display of the airport, the aircraft position, the cleared taxi route, and the positions of other traffic participants. All information is graphically displayed on the navigation display which existing cockpit systems currently do not use while the aircraft is not airborne.

Additionally, TARMAC-AS provides the necessary functions to comply with the traffic schedule (planned e.g. by TARMAC-PL) and therefore allows for continuous gate-to-gate aircraft control. TARMAC-AS provides weather-independent aircraft control which is a key requirement for an implementation of planned traffic.

TARMAC-AS can easily be installed in existing modern cockpit structures. In addition to the navigation display it uses the existing Flight Control Unit (FCU) for pilot inputs.

TARMAC-AS is not only suitable for airline operations. It can also be installed and applied in helicopters as well as in general aviation aircraft.

Figure: "Rush Hour" situation at an airport.
The structure of TARMAC-AS

The figure above gives an overview of the structure of TARMAC-AS and its interfaces. The main component of TARMAC-AS is the situation assessment and analysis module. On the basis of the acquired data it analyses the current situation and generates an action plan. Assistance for plan implementation is presented on the navigation display.

Furthermore, TARMAC-AS continuously compares the action plan with the pilot’s actions. If a discrepancy occurs, TARMAC-AS provides an appropriate warning.

For the situation analysis, TARMAC-AS uses a database containing aircraft and airport parameters. The airport database was developed by DLR to provide functionality such as the display of cleared taxiways and the calculation of the appropriate taxi speed.

Data received by a datalink system (clearances, planning times, positions and status of other traffic participants) is also used for situation analysis. The planning data can be displayed in an additional window of the cockpit display.

TARMAC-AS can easily be integrated in a modern avionic environment as it uses common interfaces and existing formats for data exchange.

Furthermore, TARMAC-AS is open to existing position assessment systems like the Global Positioning System (GPS).

Figure above: The structure of TARMAC-AS.

Figure: The TARMAC-AS display during taxiing shortly before arriving at a blocked runway (shown in red).
**Improved situational awareness due to optimised display design**

The display of TARMAC-AS has been developed employing modern display design guidelines. It offers the following functionality:

- The airport is depicted including runways, taxiways, park positions, and buildings. The graphical representation is two-dimensional with a top view and with a permanent display of the own aircraft.
- The standard display modes and several new zoom levels are selectable. If desired, the system automatically selects an appropriate zoom level in accordance with the current situation.
- The cleared taxi route is displayed as text and as green line on the map display. The display also includes a presentation of data from planning systems like TARMAC-PL. The figure above shows this data organised in four groups: the planning times generated by the planning system and displayed along a time ladder; general information about weather and departure data; actual taxi clearance; taxi speed as suggested by the planning system.
- A clearance is displayed as yellow text and yellow line next to the previous clearance which is presented in green. If the pilot acknowledges the new clearance by pressing the RGER button, the line and text change to green and the previous clearance disappears.
- Different colours signal the runway state of occupancy. Other traffic participants are also displayed in specific colours to show their actual flight or taxi status.
- Furthermore, the speed of the own aircraft is indicated by an arrow symbolising velocity and direction of movement. The maximum steering angle is permanently displayed by magenta lines to avoid over-steering.
- Warnings are displayed in case of runway incursion, overshooting of the cleared taxi route, and conflicts with other traffic participants.

Additionally, TARMAC-AS provides all current flight display functions as provided by today’s navigational displays.
Assistance during Take-Off and Landing

TARMAC-AS provides various functions to assist the cockpit crew during take-off, landing, and in case of a rejected take-off:

- Permanent calculation and display of take-off distance based on current position, speed, and acceleration. Moreover, decision speed, rotation speed and the corresponding positions on the runway are permanently assessed.
- Assistance during rejected take-off by displaying the state of the braking system and the estimated position where the aircraft will stop.
- To minimise runway occupation time and wear out of tyres and brake disks, an appropriate wheel brake setting is calculated for the period after touchdown and transmitted to the auto brake system. Both the runway geometry and the layout of the taxiway system are taken into account.

TARMAC-AS ready for transfer to industry

TARMAC-AS was extensively tested by line pilots from different airlines. For these tests the system was installed in the DLR Technology Demonstration Cockpit and in the A340-Full-Flight-Simulator (FFS) of the Zentrum für Flugsimulation (ZFB) at the Berlin University of Technology. The main focus of these tests was on the evaluation of the system functions, the pilot acceptance regarding the representation of information, safety enhancements, and the reduction of workload during taxiing. In the full flight simulator the easy integration of TARMAC-AS into an existing cockpit was verified and crew co-ordination aspects in combination with the Standard Operational Procedures were tested.

Current work of the system includes:

- Verification of the system and its full functionality under operational conditions. For this purpose TARMAC-AS was installed in the full flight simulator in Berlin and will be installed in one of DLR's test aircraft. Additionally, operational tests with airlines are envisaged.
- Furthermore, the TARMAC-AS database will be adapted as soon as standards for airport databases are available.
- Combination of TARMAC-AS with the Enhanced Vision System (EVS) of DLR providing further assistance by reliable detection of obstacles during landing and taxiing even at lowest visibility.

The main advantage of TARMAC-AS is the consequent use of existing hardware to reduce development, installation, and certification cost. The modular structure of TARMAC-AS allows an easy adaptation to pilot requirements, a modification of functions, and an implementation of additional functions if required.

Figure: TARMAC-AS combined with the Enhanced Vision System in the A340-Full-Flight-Simulator.
The Deutsches Zentrum für Luft- und Raumfahrt, DLR, is the national aerospace center of the Federal Republic of Germany. DLR is in charge of a wide scope of research and development projects in national and international partnerships. Beyond its own research, DLR is the federal government’s space agency and carries out the German aerospace research program.

With over 4,500 employees, DLR comprises eight sites in Köln-Porz (headquarters), Berlin, Bonn, Braunschweig, Göttingen, Lampoldshausen, Oberpfaffenhofen and Stuttgart - as well as offices in Paris and Washington.