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DYNCAT

DYNAMIC CONFIGURATION ADJUSTMENT IN THE TMA

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Abstract

DYNCAT aims at enabling more environmentally friendly and more predictable flight profiles in the TMA, namely on approach. To this end, DYNCAT supports the pilots in energy management through the dynamic computation of the position of configuration and speed change pseudo-waypoints and an energy-optimised vertical profile resulting in an idle thrust approach.

Relying on the preliminary high-level system requirements from deliverable D3.1, this document provides the plan to validate that DYNCAT is enabling more environmentally friendly and more predictable flight profiles by implementing into the Flight Management System (FMS) and Cockpit Display System (CDS) new and innovative energy management capabilities. As it is an Exploratory Research phase, the prototype focuses on the major add-on compared to the current state of the art, with the objectives to prove the viability and to demonstrate the potential of the new concept. This document thus describes the validation objectives and exercises consistently with the preliminary high-level specification.

This experimental validation plan contributes to the project main goals that are to demonstrate the feasibility and to evaluate the benefits of the concept during the Real Time Simulation exercise. It presents the context of the validation, reminding the operational service provided by DYNCAT capability through a short reminder of the prototype content and a description of the new operating methods. It also provides an overview of the air/ground exchanges required to execute the capability in an operational environment. Regarding the validation plan itself, it describes the validation strategy, the flight test bench and associated means of simulations, introducing the stakeholder's expectations and the validation objectives that match the functionality requirements. Finally, this report describes the validation exercises and scenarios planned in the Real Time Simulation and suggest an associated planning.

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1 Introduction

1.1 Background

DYNCAT aims to improve the situation in the TMA related to noise exposure and fuel consumption. Part of the Work Package 3 that in overall aims at prototyping the DYNCAT operational concept for further evaluations, the present activity provides the validation plan of the software implementation done by the engineers involved in the project. This Implementation Validation Plan is a result of the task T03.01 (System Definition) and is based on the previously delivered system high-level specification for the prototypical FMS and CDS functionalities, and more specifically the high-level system requirements provided in this Deliverable D3.1 [4].

This document will support the Real Time Simulation Exercises (WP4 T04.01) and will serve as an input for the DYNCAT Function Experimental Implementation Report (D3.3).

1.2 Purpose and Structure of the Document

This document starts from the Preliminary System High-Level Specification (D3.1) [4] also delivered by the task T03.01 of DYNCAT project. It aims to describe the validation plan, meaning that it presents the way that the DYNCAT prototype will be tested, verified and evaluated in order to prove the feasibility and estimate the benefits. The corresponding validation exercises will be conducted in 2022 through the WP4.

This document first reminds the context of the validation through a brief description of the operational service brought by DYNCAT, with a focus on the prototype content and the associated new operating methods introduced by the DYNCAT concept.

Then, it presents the validation plan established to validate the system requirements and their implementation in the FMS and CDS prototypes. This chapter starts with the validation strategy and the means of simulations that will be used and available for the Real Time Simulation in 2022. It details the stakeholder's expectations and the validations objectives in relation with the requirements that have been defined in the preliminary system specification.

Finally, it describes specifically the validation exercises that will be performed in 2022. An overall description of the exercises is provided with the link to the objectives previously defined, in order to ensure the prototype scope coverage. Then, this report details the validation scenarios and the methodology to apply for fuel and noise measurement. The final part presents the activities related to the Real Time Simulation organization, presenting the roles and responsibilities of each participants, and suggesting a forecast planning.

1.3 Acronyms

The following table contains a list of acronyms used in this report.

Acronym	Meaning
4D	4 Dimensions
A/C	Aircraft
ADS-C	Automatic Dependent Surveillance - Contract
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
AMAN	Arrival Manager system
AP	Auto-Pilot
ATC	Air Traffic Control
ATCO	Air Traffic Control Operator
ATM	Air Traffic Management
CDA	Continuous Descent & Approach
CDS	Cockpit Display System
D<no.>	Deliverable <no.>
DECEL	Deceleration pseudo-waypoint (FMS transition from descent to approach phase)
DTG	Distance to Go
DYNCAT	Dynamic Configuration Adjustment in the TMA
EPP	Extended Projected Profile
ER	Exploratory Research
EUROCAE	EURopean Organisation for Civil Aviation Equipment
FAF	Final Approach Fix
FCU	Flight Control Unit
FG	Flight Guidance
FMS	Flight Management System
FPLN	Flight Plan
FT	Feet
GW	Gross Weight
H2020	Horizon 2020
HDG	Heading
IMB	Integrated Modular Bench
ITA	Indicated Time of Arrival

Acronym	Meaning
KCCU	Keyboard Cursor Control Unit
MFD	Multi-Functions Display
ND	Navigation Display
NM	Nautical Miles
PRT	Permanent Resume Trajectory
R&D	Research & Development
RTS	Real Time Simulation
SESAR	Single European Sky ATM Research
T<no.>	Task <no.>
TMA	Terminal Manoeuvring Area
VDEV	Vertical Deviation
VFE	Maximum flaps extension speed
V/S	Vertical Speed
VSIB	Virtual Simulation Integration Bench
WP	Work Package

Table 1: Acronyms used in this report

2 Context of the validation

This section provides first a short synthesis of the D3.1 on which the validation plan is based. It reminds the provisional content of the DYNCAT prototype as defined within the preliminary system high-level specification.

Then, it presents the two different operating methods that have been retained for the evaluations, one based on the Distance To Go (DTG) information sharing, the other based on the Indicated Time of Arrival information sharing. The objective is to clarify the functional content and the new operational service provided by DYNCAT in order to well derive the validation activities.

2.1 Operating methods

As for the ground practices, DYNCAT has been imagined to facilitate the energy management on-board (reducing the unstable approaches) without affecting the safety level. The solution increases the situation awareness by providing to the pilots some cues, in both lateral selected and managed modes, specifically the flaps and landing gears sequences.

But to be relevant in the cockpit, the energy management cues shall be based on the information coming from the ATC and reflect the controller’s intent.

The most critical information to compute an efficient vertical profile is the determination of the lateral trajectory consistently with the expected track miles and the expected geographical lateral path. This is the first required add-on for DYNCAT algorithms to be applicable. This functionality will rely on the Permanent Resume Trajectory (PRT) that acts as an enabler for the DYNCAT feature.

Operationally, two situations can be distinguished. The first one is obvious: when the aircraft flies in lateral managed mode, the relevant lateral trajectory is very well known. Indeed, it corresponds to the active FPLN along which DYNCAT solution will improve the existing situation awareness to support the energy dissipation optimization.

The second operational situation is much more complex, but also very common and not well addressed in the state of the art. It corresponds to the radar vectoring use case whose the occurrence increases with the traffic density, in order to ensure the flights separation and thus, their safety in dense airspace.

As an example, according to the D2.3 [2] document that provide the analysis of the current operations in Zurich, a lateral instruction is used in almost 97% of the flights, meaning that this use case cannot be neglected as it is today in the airborne systems.

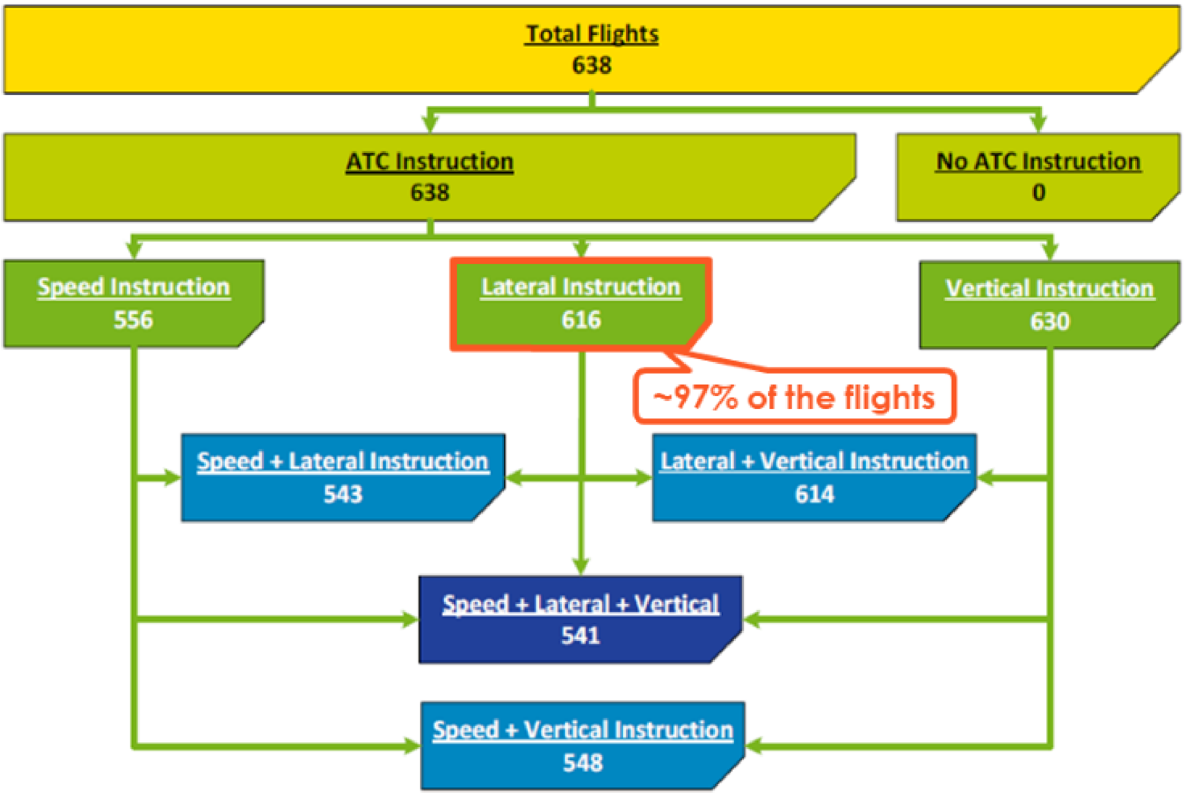

Figure 1: DYNCAT overall flight data records clustering (from D2.3 Deliverable)

On another note, it can be noticed that altitude and speed restrictions are also very common, but the lateral ones are really the most impacting from the Flight Management System point of view. An altitude clearance, for instance, does not always impact the descent path as it might be updated before reaching the corresponding Flight Level, thus, avoiding the level-off situations. A speed clearance might also be "compliant" with the initial reference profile computation, which is never the case with a heading instruction that aims to shorten or lengthen the trajectory in order to gain or lose some time.

As a matter of fact, when the lateral path is "open", the reference is no more defined, the real distance to destination is unknown. In addition, using an approximation of the remaining length to destination, as it is done today, is not satisfying and prevents from optimizing the vertical path, and thus, the fuel consumption and the noise footprint.

Nevertheless, when an altitude restriction is constraining, it would be useful to anticipate it in the cockpit as soon as possible. It is also the case for a speed instruction that is always constraining, even when it is compliant with the profile slope of reference, being within the speed margins. For these two types of constraints, even if the FMS is able to make assumptions unilaterally based on the FPLN knowledge, it would be more accurate to retrieve more information from the ground. This is the objective of the new functional items that might be developed in the FMS to support the management of the speed and altitude restrictions (cf. Flight Management System evolutions).

For the reasons described above and to comply with the project constraints, DYNCAT operational evaluations will mainly focus on the evolutions required in the Flight Management System and the Cockpit Display System to manage efficiently the lateral instructions. The objective is to identify the best way to transcribe the intention of the controller into an information that can be used by the on-board system, without affecting unreasonably the workload on both ground and airborne segments.

The general idea is to better characterize this kind of instruction, and to systematically complement the heading/track target that it is often the only shared information today. To separate the aircraft and organize the arrival flow, the controllers might be supported by an AMAN which is a system that prepares the sequence. It indicates how much time the A/C should gain or lose to comply with their position and the order or arrival that have been defined. The controller can interact with this ground system, and in a future implementation, DYNCAT on-board solution could even be directly linked to the AMAN system.

This AMAN time information could then be shared with the aircraft in two different ways:

- as a **distance** computed from the AMAN time (cf. Practice #1: Radar vectoring with DTG information sharing).
- as a **time indication** directly (cf. Practice #2: Radar vectoring with ITA information sharing)

In order to determine the best trajectory within the on-board system, the pilot needs to enter one of these required parameters in addition to the heading/track selection on the FCU. Another possibility would be a direct datalink transfer. The FMS will then be able to adjust its active trajectory in accordance with the controllers' indications.

This section describes these two practices that will be experimented during the validation phase in order to enable the FMS to compute a relevant continuous and Permanent Resume Trajectory (PRT) along which will be presented the DYNCAT energy management cues. This PRT capability will permit to display a trajectory from the aircraft that joins the FPLN when the aircraft is in selected mode, with the objective to reflect the most likely path. It will then be the lateral reference for the vertical optimized descent profile computation and will support the piloting tasks by enabling a display of the FMS's underlying assumptions.

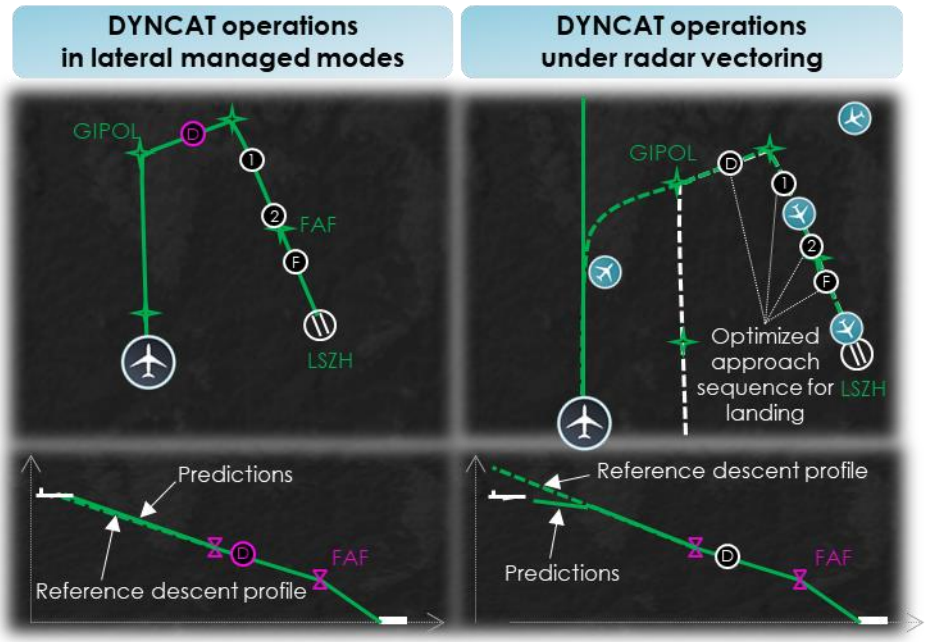

Figure 2: DYNCAT operations in managed and selected modes

The objective is that the PRT coupled with dynamic configurations adjustments in the TMA can reduce the additional workload due to the radar vectoring and helps to reduce the environmental impact of such operations. These capabilities aim at improving situation awareness and aircraft manual guidance, in the lateral plan for the PRT that acts as an enabler for the DYNCAT feature in the vertical plan. Thus, these new functions put together will constitute a major progress and an enabler towards greener operations.

2.1.1 Practice #1: Radar vectoring with DTG information sharing

This first practice is particularly adapted to the ATC centres that are not equipped with AMAN systems. In these centres, the Air Traffic Controllers use classical heading instructions and radar vectoring methods, generally with a Distance To Go in mind in order to ensure the aircraft separation.

The pilot will enter into the system the following data with the following interactions means:

- ✓ A **lateral instruction**
  The pilot enters the instruction on the FCU, for instance, "HDG 200".
- ✓ An **indicative Distance To Go**
  The pilot can enter the distance to touchdown on the MFD, by clicking on the destination and entering for instance "45 NM" as a "Distance To Go" parameter.
- ✓ A **capture waypoint**
  The pilot defines the capture waypoint on the MFD FPLN page (or equivalent means), by clicking on this waypoint that needs to be designated as the capture one, for instance "Capture AT GIPOL".

  Note: The default capture point selected by the system is the FAF.

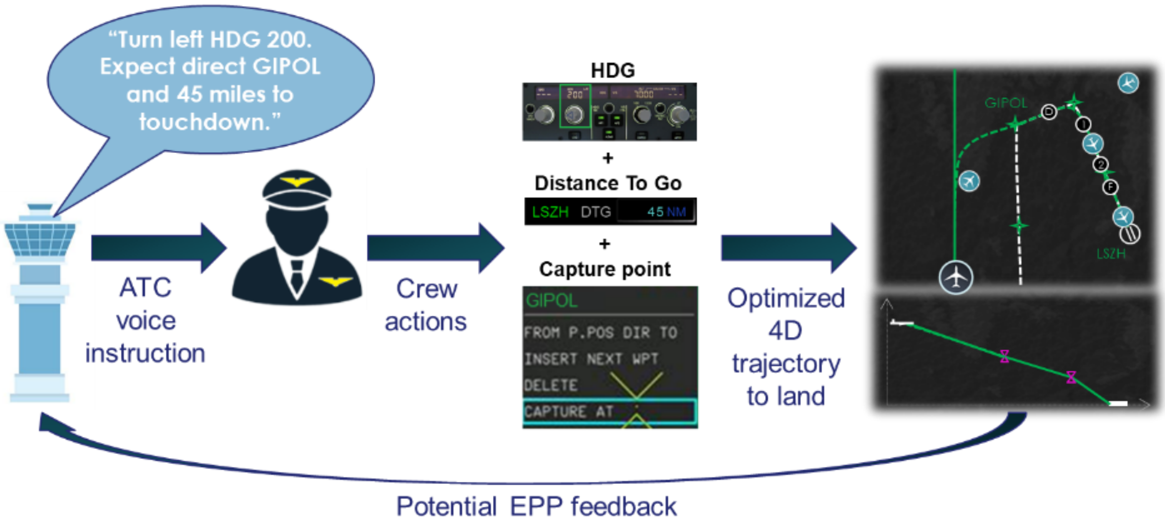

Figure 3: Radar vectoring with DTG information sharing operational process

As a side note, this operational process offers the possibility to send back the optimized trajectory to the ground via the ADS-C/EPP. It would offer the possibility to get a clearance on the optimized solution and to engage earlier the full managed mode in the cockpit that would be very convenient for the pilots. Indeed, this would really tend to facilitate the energy management and to reduce the workload on-board, taking advantage of the air/ground connectivity and exploiting the systems' full potential. Another opportunity to alleviate the workload, for both ground and airborne segments, would be to substitute the voice instruction by a datalink message interpreted directly by the cockpit systems to build the optimum trajectory. This trajectory could then be checked by a "deconfliction" tool on the ground, in order to secure a clearance on it. This would be even more disruptive but it could really support greener and easier operations.

2.1.2 Practice #2: Radar vectoring with ITA information sharing

This second practice is particularly adapted to the ATC centres that are equipped with AMAN systems, in which the Air Traffic Controllers work directly in time separation, avoiding the time to distance conversion.

The pilot shall enter into the system the following data:

- ✓ A **lateral instruction**
  As for the airborne practice #1, the pilot enters the instruction manually on the FCU as it is done today, for instance, "HDG 200".

- ✓ An **indicated time of arrival on a capture waypoint**
  The pilot enters the indicated time of arrival and defines the capture waypoint by one unique operation on the MFD FPLN page (or equivalent means), by selecting the waypoint that needs to be designated as the capture one, and entering for instance "08:30:45" as an "Indicated Time Of Arrival" parameter.
  Therefore, the pilot may also modify the capture waypoint. This situation corresponds to an alternative practice, in which the indicated time of arrival is set for instance on the destination waypoint (to meet ATC time separation needs) whereas the capture point is located upstream in the flight plan.

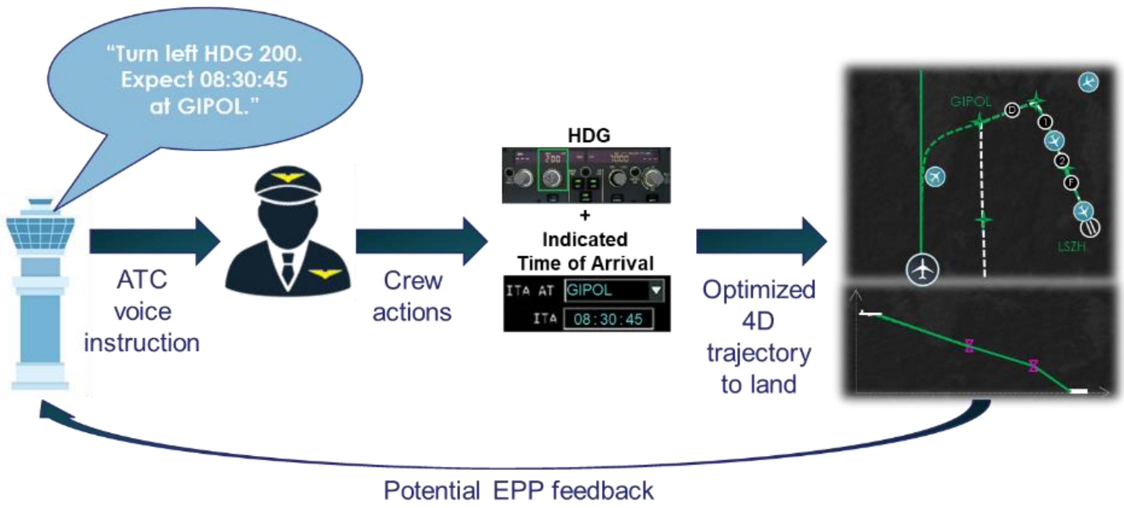

Figure 4: Radar vectoring with ITA information sharing operational process

As for the first practice, if offers the opportunity to be coupled to ADS-C/EPP capability in order to close the loop and clear the aircraft on its optimized path that should correspond to the ATCO intent.

2.2 Prototype content

The prototype content is divided into several functional items, each one contributing to the facilitation of the energy management in approach.

2.2.1 Flight Management System evolutions

The main product involved in DYNCAT realization is the **Flight Management System** in which 4 functional items will be implemented:

Figure 5: Flight Management System equipment

- **The dynamic pseudo-waypoints**

  This functional item consists in a new dynamic adaptation of the DECEL, "1", "2" and "F" configuration pseudo-waypoints for an Airbus A320 family to ensure the aircraft energy stabilization at 1000 ft AGL gate, based on an energy criteria and hysteresis applied at the stabilization point (e.g. 1000 feet AGL). The concept is scalable and applies to all types of aircraft. The aircraft type specified here is only for the purpose of demonstrating the concept. The "F" final pseudo-waypoint (or energy gate) groups the flaps 3 (or the flaps full) and the landing gear extensions, according to the landing configuration chosen by the pilot(s).

  All the configuration pseudo-waypoints are speed limited, respectively lower limited by the corresponding manoeuvring speed (F/S/O) to be usable in managed modes, and upper limited by the operational flight envelope (VFE). In addition, the position of the DECEL, "1", "2" and "F" configuration pseudo-waypoints is shifted upstream to be consistent with the flight dynamics transitory and to avoid any additional thrust, without exceeding the operational speed limitations.

- **The optimized vertical profile**

This functional item consists in computing any deceleration segment in approach that is free of altitude constraint with a vertical slope of -500 feet per minute, which is considered as the optimal compromise to be usable in both managed and selected lateral modes.

In addition, any constant speed segment in approach that is free of altitude constraint is computed as an open descent idle thrust segment to maximize fuel and noise efficiency.

- **The lateral path determination**

  This functional item offers the possibility to receive and process either the Distance-To-Go (DTG) information, possibly associated to a capture waypoint, or the Indicated Time of Arrival (ITA) information on a capture waypoint in order to compute the lateral path consistently with the ATCO intent.

  Then, the FMS is in charge of the computation of a permanent trajectory called the PRT (Permanent Resume Trajectory), when in lateral selected mode, taking into account the ITA or DTG constraint when available. When the aircraft is in lateral selected mode, the flight plan capture is computed at the provided capture point when available, at the FAF otherwise.

- **The speed and altitude restrictions**

  This functional item consists in supporting the speed (respectively the altitude) selected mode by maintaining the current selected speed (respectively the current selected altitude) until the start of deceleration (respectively start of descent) to satisfy the next restrictive descent speed (respectively the next restrictive altitude constraint).

2.2.2 Cockpit Display System evolutions

In addition to the FMS, the **Cockpit Display System** needs to be upgraded and the evolutions have also been split into 4 functional items that will be implemented:

- **Controller intent entry**

  This functional item consists in providing to the crew the capability to enter:

  - the DTG and the PRT capture point on a downstream waypoint (defaulted to FAF),
  - the ITA on a downstream waypoint that will also be assumed to be the PRT capture point by default (limited to FAF).

- **Strategic energy management cues**

  This functional item consists in providing to the crew the following strategic energy management cues:

  - the optimum distance to land in nautical miles,
  - the optimum distance to land margin in nautical miles :

- in green when there is no energy issue, considering aggressive slats/flaps and speed brakes strategies when needed,
- in amber otherwise, when aggressive strategies are not sufficient to land safely.

➢ **Tactical energy management cues**

This functional item consists in displaying in the cockpit the following tactical energy management cues:

- the DECEL and “1”, “2” and “F” configurations pseudo-waypoints, along the active FPLN trajectory.

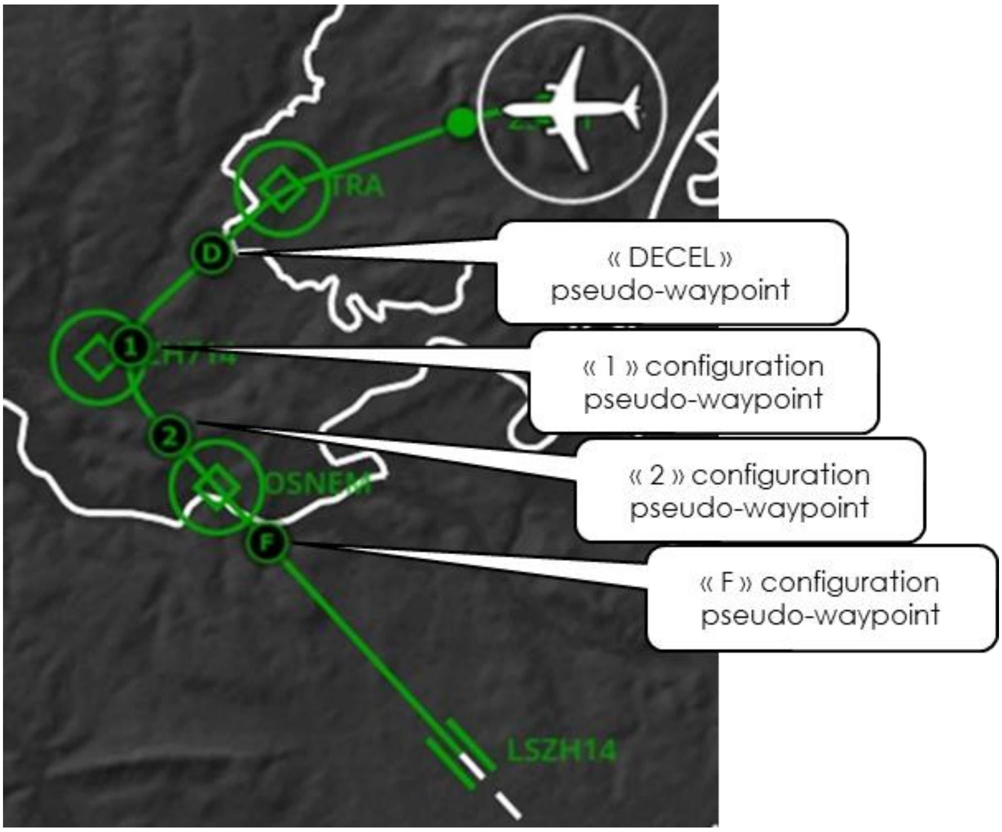

Figure 6: Pseudo-waypoints display in the cockpit

- Wen flying in vertical selected mode, the information to follow the DYNCAT optimized vertical profile along the PRT lateral path are added. For instance, to indicate that V/S mode is expected with -500ft/min.

In addition, the FMS warns the pilot when a configuration pseudo-waypoint is predicted to be missed due to an over-energy situation, by displaying the pseudo-waypoint in amber when there is an energy issue, in green otherwise. The over-energy situation will be based on kinetic energy only as the over-altitude does not prevent from extending the flaps, and it might even be beneficial to converge faster when the vertical deviation is positive.

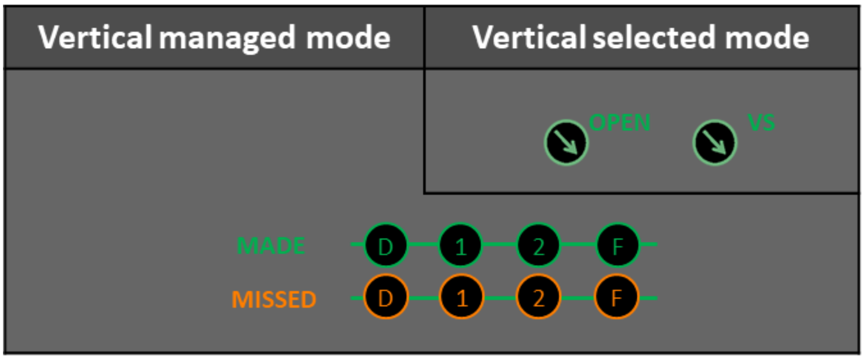

Figure 7: FMS pseudo-waypoints available according to the engaged vertical mode

- **DYNCAT capacity management**

  This functional item consists in proposing a means to activate/de-activate the DYNCAT capability, mainly for the benefits evaluation purpose.

2.2.3 System under test

In this project, DYNCAT will be implemented in both the Flight Management System and the Cockpit Display System. Nevertheless, **the only product and system under test is the Flight Management System**, any other modifications being made to support the FMS validation, including the CDS evolutions are not part of the test. Indeed, the CDS will "only" be considered as the way to provide the pilots with the information computed by the FMS and required to support the energy management task.

The objective here is not to validate the way the information are presented into the cockpit, but to validate that the data computed by the Flight Management System and provided to the pilots enable more environmentally friendly flight profiles. This data package includes the continuous and permanent trajectory coupled with the energy management cues. The objective is to demonstrate that the FMS outputs are sufficient and relevant to alleviate the pilot workload and permit to fly an optimum path compared to today's operations, thus providing fuel and noise benefits, irrespective of the graphic code and symbology used to display the information into the cockpit.

Furthermore, DYNCAT new capability aims to be generic and thus might be carried on different kind of aircraft, on which different interfaces might be used according to each aircraft manufacturer wishes, habits and thus, Cockpit Display System specification. However, in order not to disturb the way the flight crews are used to pilot the aircraft, in particular the A32X family, a particular attention will be paid to the representativeness and the relevance of the symbols used to display the information.

3 Validation Plan

This section provides the validation plan established to make sure that the system requirements and the implementation into the FMS and CDS equipment's are consistent.

This chapter starts with the validation strategy, thus presents the means of simulations that will be used and available for the Real Time Simulation (RTS) in 2022. It details the stakeholder's expectations and the validations objectives in relation with the requirements that have been defined in the preliminary system specification.

3.1 Validation strategy

The validation activity started with the flight records analysis and will end with the RTS analysis and benefits evaluation. The general idea is to benefit from the experience acquired thanks to the flight test campaign in order to organize exercises based on relevant operational scenarios. This will be done with the objective to formally cover and verify the implementation of all the requirements defined in the preliminary system specification.

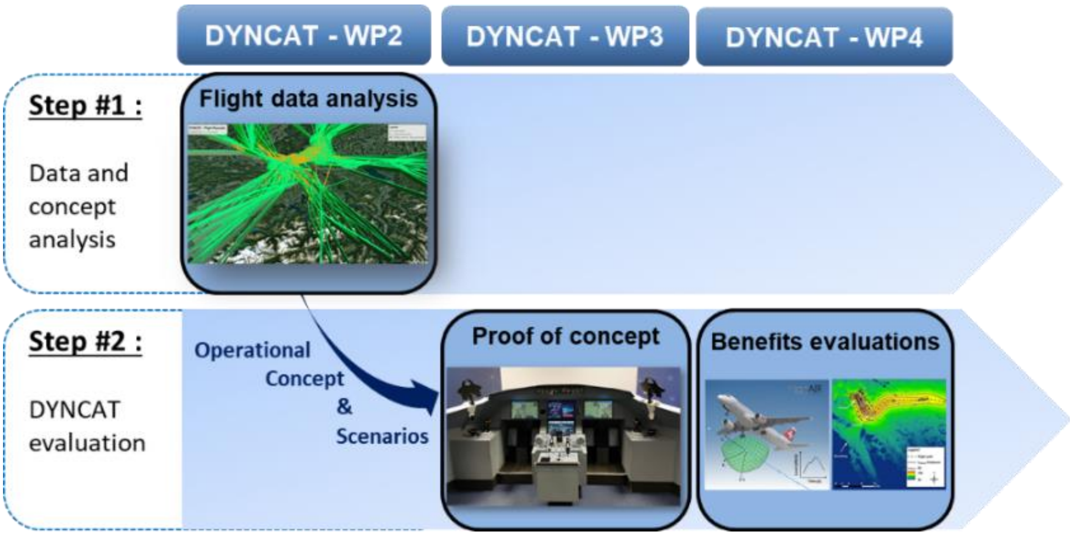

Figure 8: Validation strategy overview

Taking advantage of the flights data records, the operational scenarios will be picked-up among the ones available with some adaptations when necessary in order to comply with the validation objectives.

The simulation validation campaign will be done in Zurich area, which is consistent with the background of the actors involved in the project in addition to the fact that it will permit a direct comparison analysis with the real flights and operational situations previously analysed (D2.3). The flight data collection includes the aircraft data itself, but also the meteorological ones, the Air Traffic Control (ATC) instructions, the radar data and the acoustical measurements. It will really support the demonstration of the DYNCAT concept potential by allowing us to select the most relevant scenarios for the validation phase. The use cases will be chosen in order to be representative of the operations, avoiding very specific flights such as the ones with extremum landing gears extension for instance.

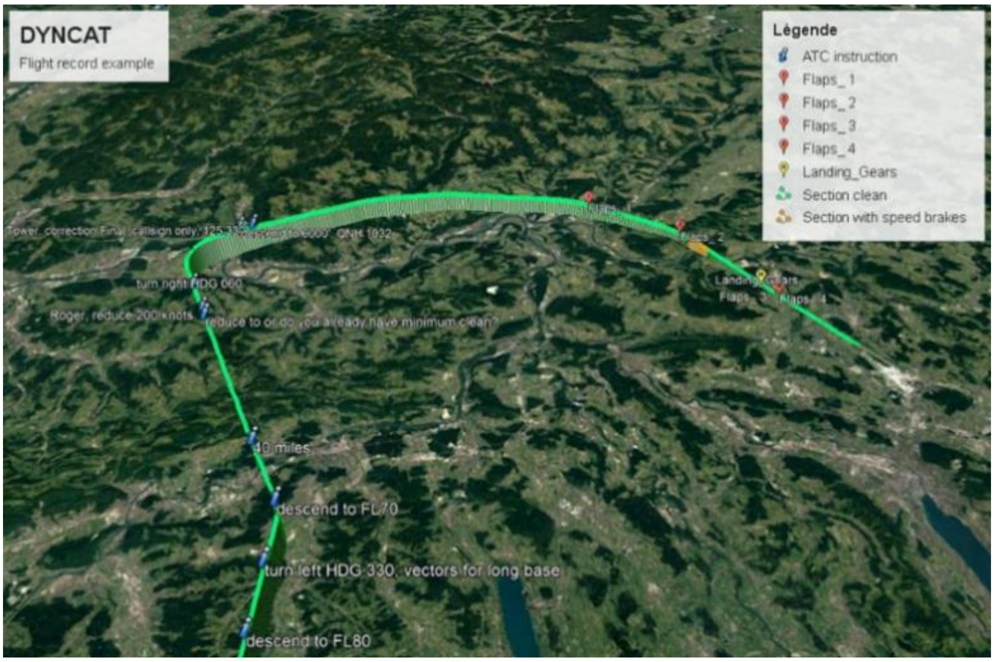

Figure 9: DYNCAT flight data record example (Earth data: Google)

As a reminder, the prototype will focus on a limited but representative set of items submitted in the Operational Concept Document (D2.4) [3] to validate its feasibility and operability during the Real Time Simulation test campaign with pilots and controllers.

The corresponding evolutions are specified in the Deliverable D3.1 and each requirement will be linked to one or more validation objectives, each validation objective being associated to a unique success criteria aiming at being verified during at least one validation scenario. The Figure 10: Validation process overview describes the corresponding process and the links between the objects handled.

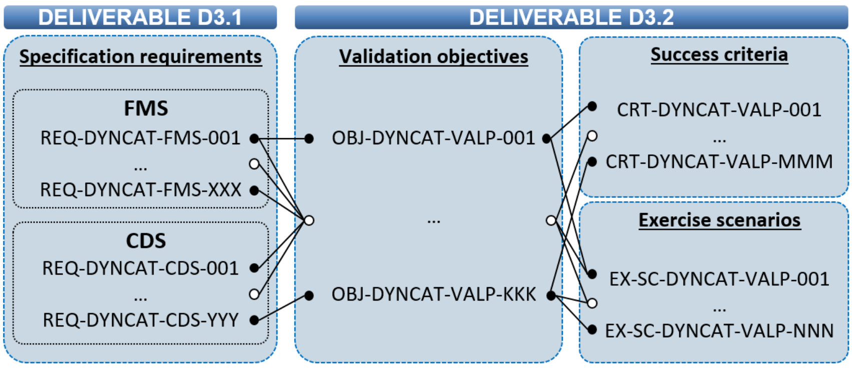

Figure 10: Validation process overview

Each scenario will be simulated without DYNCAT first in order to set a reference for the comparison and, will then be executed with different realistic operational situations involving progressively the DYNCAT evolutions. As an example, different Automatic Pilot (AP) modes will be experimented, and two different types of information will be exchanged between the pilot and the controller as already described in the Operating methods chapter. The produced results should permit to characterize DYNCAT operations' benefits and to identify the most valuable items that deserve to be further developed in Industrial Research phase.

3.2 Flight test simulation bench

3.2.1 Airborne simulation means

The Thales research test bench in Toulouse will support the evaluation planned in 2022 for which in-service pilots and controllers will be involved. For each scenario, a proven flight model will bring the fuel results on one side. On the other side, the well-established SonAir model from Empa will enable to measure and analyse the noise along the resulting trajectories.

Figure 11: Flight Test Simulation bench

The research test bench is a Virtual Simulation Integration Bench (VSIB) with a hybrid configuration. Its customization is adapted to the rapid prototyping phase, thus easing the continuity between the specification and the early validation steps. The infrastructure is based on EUROCAE Vistas Standard to simulate communications between the systems. The bench is modular and includes real equipment such as an A320 FCU or an A350 KCCU, and "simulated" one (real software runs on computers) such as the future Thales FMS PureFlyt™ or an A321 FG (Flight Guidance computer).

Figure 12: Focus on the Flight Management Display and interactions means (KCCU)

The bench offers the capability to perform the system integration tests and will enable to execute the following steps for each DYNCAT exercise scenarios:

1. The trajectory will be flown by pilots, first without, then with DYNCAT evolutions
2. The flown trajectories will be recorded
3. For noise measure, records will be sent to Empa so that SonAir will be used
4. For fuel measure, records will be managed by Thales to evaluate the fuel consumption

The bench integrates a new generation of Display System with the objective to facilitate the evolutions and thus, to permit a rapid prototyping and an early validation phase. It is particularly adapted to DYNCAT context in which new energy management cues will be experimented prior to be potentially integrated into a flying product.

Figure 13: Focus on the Cockpit Display System new generation

Regarding the cockpit control devices, the configuration is classic with the usual cockpit means in order not to disturb the pilot handling during the trials.

Figure 14: Focus on the Flight Control Devices

3.2.2 Ground simulation means

No ground simulations nor traffic simulation means are integrated on the bench, and thus, the RTS will only be based on voice communications between the controllers and the pilots, with a theoretical and predefined flight scenario inspired by the real flight data.

3.3 Stakeholder's expectations

The main stakeholders and their related expectations are listed in the table here below.

Stakeholder	Involvement	Why does it matter to stakeholder?
ANSP	Direct (participation to Real Time Simulation and expert groups)	**Fuel Efficiency and Environment** • Improved energy management reduces fuel burn and related emissions (CO_2 and NO_x). • Optimised trajectories in TMA airspace should reduce the need for tactical interventions (more direct route) **Predictability in the TMA** • Predictability and stability of aircraft energy management, both for speed and altitude. **Safety (and fuel efficiency)** • Reduce risk of over energy and cases of go-around procedure activation
Airspace users	Direct (SWISS involved)	**Fuel efficiency and Environment** • Better management of energy reduces fuel burn and related emissions (CO_2 and noise footprint on the ground)
Air industries and research institutes	Direct (Thales and DLR involved)	**Product and knowledge improvement** • Products (platform, tools and systems) enhancement enabling CO_2 and noise emission reduction
Pilots and Air traffic controllers	Direct (participation to Real time simulation and expert groups)	**Human Performances** • Increase of Situation Awareness through increased energy management improvements and dedicated cues display in the cockpit • New operating methods providing more anticipation and more collaborative control of the trajectory management **Safety and fuel efficiency** • Reduce risk of over energy and cases of go-around procedure activation • Reduce fuel burn during descent phase

Table 2: Stakeholders' expectations

3.4 Validation objectives

3.4.1 General objectives

Considering the required maturity level and the R&D needs identified for the DYNCAT solution, the general objectives of the validation activities will be:

- To clarify the concept through operational and technical feasibility assessments of the facilitation and implementation of DYNCAT sub-capacities.
- To conduct a preliminary performance assessment in particular in terms of environment, human performances and safety in a representative operating environment.
- To evaluate the flight predictability improvements thanks to the FMS trajectory stabilization in lateral selected mode.

The next section goes more into details and describes the implementation validation objectives, directly linked to the Preliminary High-Level Specification (D3.1).

3.4.2 Objectives

This section describes the way the Flight Management System and the Cockpit Display System needs to be validated with regards to DYNCAT implementation.

Identifier	OBJ-DYNCAT-VALP-001	
Title	Energy management facilitation through dynamic sequence	
Objective	Assess the operational facilitation of energy management in approach through the dynamic configuration pseudo-waypoints position proposed.	
Success criteria ID	CRT-DYNCAT-VALP-001	
Success criteria description	The pilots consider that the display of a dynamic sequence facilitates the energy management in approach to ensure stabilization at 1000Ft AGL.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Dynamic pseudo-waypoints Tactical energy management cues
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-001 REQ-DYNCAT-CDS-006 REQ-DYNCAT-CDS-008

Table 3: OBJ-DYNCAT-VALP-001 - Energy management facilitation through dynamic sequence

Identifier	OBJ-DYNCAT-VALP-002	
Title	Sequence display simplification relevance	
Objective	Assess the relevance of grouping "3", "F" and Landing Gear.	
Success criteria ID	CRT-DYNCAT-VALP-002	
Success criteria description	Grouping "3", "F" and Landing Gear does not affect the stabilization at 1000 feet nor the pilots understanding.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Dynamic pseudo-waypoints
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-002

Table 4: OBJ-DYNCAT-VALP-002 - Sequence display simplification relevance

Identifier	OBJ-DYNCAT-VALP-003	
Title	Flight envelope consistency	
Objective	Assess the consistency of the aircraft speed with regards to the pseudo-waypoints positions.	
Success criteria ID	CRT-DYNCAT-VALP-003	
Success criteria description	Flaps pseudo-waypoints are within the correct flight envelope.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Dynamic pseudo-waypoints
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-003

Table 5: OBJ-DYNCAT-VALP-003 - Flight envelope consistency

Identifier	OBJ-DYNCAT-VALP-004	
Title	Thrust minimization	
Objective	Assess that the pseudo-waypoint anticipation is sufficient to avoid a local thrust rise.	
Success criteria ID	CRT-DYNCAT-VALP-004	
Success criteria description	Pseudo-waypoints anticipation enables to avoid a local thrust rise.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Dynamic pseudo-waypoints
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-004

Table 6: OBJ-DYNCAT-VALP-004 - Thrust minimization

Identifier	OBJ-DYNCAT-VALP-005	
Title	Sequence stabilization	
Objective	Assess the stability of the high-lift actuators sequence.	
Success criteria ID	CRT-DYNCAT-VALP-005	
Success criteria description	Configuration pseudo-waypoints are not toggling and the pseudo-waypoints never jump behind the aircraft location (so that it does not disturb the pilots' energy management tasks).	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Dynamic pseudo-waypoints
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-005

Table 7: OBJ-DYNCAT-VALP-005 - Sequence stabilization

Identifier	OBJ-DYNCAT-VALP-006	
Title	Continuous Descent Profile	
Objective	Assess the continuity of the vertical profile.	
Success criteria ID	CRT-DYNCAT-VALP-006	
Success criteria description	The vertical approach profile never includes a level-off, except when due to: - procedural altitude or FPA constraints, - pilots defined altitude constraints , - ATC explicit instruction.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Optimized vertical profile
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-006

Table 8: OBJ-DYNCAT-VALP-006 - Continuous Descent Profile

Identifier	OBJ-DYNCAT-VALP-007	
Title	Optimized constant speed segment in approach	
Objective	Assess the optimization of constant speed segments in approach.	
Success criteria ID	CRT-DYNCAT-VALP-007	
Success criteria description	In approach flight phase, constant speed segments are flown with IDLE thrust when the aircraft sticks to the reference profile (reducing the fuel consumption to the minimum possible).	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Optimized vertical profile
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-007

Table 9: OBJ-DYNCAT-VALP-007 - Optimized constant speed segment in approach

Identifier	OBJ-DYNCAT-VALP-008
Title	Distance To Go information consideration
Objective	Assess the Distance To Go information consideration by the cockpit systems, both CDS and FMS.
Success criteria ID	CRT-DYNCAT-VALP-008
Success criteria description	In lateral selected mode, the operator can enter the Distance To Go data into the system and the resulting trajectory has the corresponding length (when achievable).

Relationship	Linked Element Type	Identifier
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Lateral path determination Controller intent entry
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-008 REQ-DYNCAT-FMS-010 REQ-DYNCAT-CDS-001

Table 10: OBJ-DYNCAT-VALP-008 - Distance To Go information consideration

Identifier	OBJ-DYNCAT-VALP-009
Title	Indicated Time of Arrival information consideration
Objective	Assess the Indicated Time of Arrival information consideration by the cockpit system, both CDS and FMS.
Success criteria ID	CRT-DYNCAT-VALP-009
Success criteria description	In lateral selected mode, the operator can enter the Indicated Time of Arrival data into the system and the resulting trajectory is built so that the ITA is respected (when achievable).

Relationship	Linked Element Type	Identifier
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Lateral path determination Controller intent entry
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-009 REQ-DYNCAT-FMS-010 REQ-DYNCAT-CDS-003

Table 11: OBJ-DYNCAT-VALP-009 - Indicated Time of Arrival information consideration

Identifier	OBJ-DYNCAT-VALP-010	
Title	Capture point consistency	
Objective	Assess the Capture Waypoint information consideration by the cockpit system, both CDS and FMS.	
Success criteria ID	CRT-DYNCAT-VALP-010	
Success criteria description	In lateral selected mode, the operator can enter a capture waypoint information into the system and the resulting trajectory is built so that the published procedure is resumed at the capture point.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Lateral path determination Controller intent entry
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-011 REQ-DYNCAT-CDS-002

Table 12: OBJ-DYNCAT-VALP-010 - Capture point consistency

Identifier	OBJ-DYNCAT-VALP-011	
Title	Speed release point relevance	
Objective	Assess the speed release point relevance.	
Success criteria ID	CRT-DYNCAT-VALP-011	
Success criteria description	The FMS correctly computes and proposes to the pilot the last point to decelerate from the ATC speed instruction to respect the next constraining speed.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Speed and altitude restrictions
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-012

Table 13: OBJ-DYNCAT-VALP-011 - Speed release point relevance

Identifier	OBJ-DYNCAT-VALP-012	
Title	Altitude release point relevance	
Objective	Assess the altitude release point relevance.	
Success criteria ID	CRT-DYNCAT-VALP-012	
Success criteria description	The FMS correctly computes and proposes to the pilot the last point to descent from the ATC altitude clearance to respect the next altitude constraint.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Speed and altitude restrictions
<VERIFIES>	<Requirement>	REQ-DYNCAT-FMS-013

Table 14: OBJ-DYNCAT-VALP-012 - Altitude release point relevance

Identifier	OBJ-DYNCAT-VALP-013	
Title	Optimum distance to land and associated margin relevance	
Objective	Assess the optimum distance to land and associated margin relevance.	
Success criteria ID	CRT-DYNCAT-VALP-013	
Success criteria description	The system correctly computes the optimum distance to land and associated margin.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Strategic energy management cues
<VERIFIES>	<Requirement>	REQ-DYNCAT-CDS-004 REQ-DYNCAT-CDS-005

Table 15: OBJ-DYNCAT-VALP-013 - Optimum distance to land and associated margin relevance

Identifier	OBJ-DYNCAT-VALP-014	
Title	Energy management facilitation through optimum distance to land and associated margin	
Objective	Assess the operational facilitation of energy management in approach through the presentation of the optimum distance to land and its associated margin.	
Success criteria ID	CRT-DYNCAT-VALP-014	
Success criteria description	The pilots considers that the optimum distance to land and the associated margin facilitates the energy management in descent and approach, and understand well the meaning of this information that is judged unambiguous.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Strategic energy management cues
<VERIFIES>	<Requirement>	REQ-DYNCAT-CDS-004 REQ-DYNCAT-CDS-005

Table 16: OBJ-DYNCAT-VALP-014 - Energy management facilitation through optimum distance to land and associated margin

Identifier	OBJ-DYNCAT-VALP-015	
Title	Continuous Descent Profile flyability in vertical selected mode	
Objective	Assess the capability to fly along the optimized vertical profile when in vertical selected mode.	
Success criteria ID	CRT-DYNCAT-VALP-015	
Success criteria description	The pilots consider that the vertical approach profile is adapted to the approach phase operations and manage to maintain the A/C along the optimized vertical path thanks to the provided cues.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	Tactical energy management cues
<VERIFIES>	<Requirement>	REQ-DYNCAT-CDS-007

Table 17: OBJ-DYNCAT-VALP-015 - Continuous Descent Profile flyability in selected mode

Identifier	OBJ-DYNCAT-VALP-016	
Title	DYNCAT activation	
Objective	Assess the capacity to activate/deactivate DYNCAT.	
Success criteria ID	CRT-DYNCAT-VALP-016	
Success criteria description	DYNCAT capacity can be deactivated without any impact on the legacy behaviour.	
Relationship	**Linked Element Type**	**Identifier**
<SATISFIES>	<SESAR Solution>	SESAR-ER4-05-2019 Environment and Meteorology for ATM
<SATISFIES>	<Specification>	DYNCAT D3.1 - Preliminary System High-Level Specification
<ALLOCATED_TO>	<Function>	DYNCAT Capacity management
<VERIFIES>	<Requirement>	REQ-DYNCAT-CDS-009

Table 18: OBJ-DYNCAT-VALP-016 - DYNCAT activation

4 Validation Exercises

4.1 Description and scope

As previously mentioned, the operational situations analysed (D2.3) allow an understanding of the way of working in the TMA, the needs and the current limitations. The prototype developed for this project embeds the DYNCAT new capability which is expected to remove the actual limitations and to provide an efficient operational new service.

To validate the concept, a Real Time Simulation will be performed in 2022 on a flight test simulation bench in Thales facilities (cf. "Flight test simulation bench") with the different stakeholders. The objective is to perform some TMA typical scenarios in an environment as close as possible from the real one. Air traffic controllers will give instructions to the crew in order to simulate a representative sequencing and to ensure the aircraft separation for a safe landing.

To evaluate the improvements brought by DYNCAT, the scenarios will be run firstly on the reference systems without any evolution. This first set of results will be the reference for the environmental analysis (fuel/noise) and for the piloting experience.

Then, some tests will be performed with DYNCAT evolutions to assess the contribution of the functionality.

The Figure 15: RTS presents the validation exercises high-level principles for the Real Time Simulation.

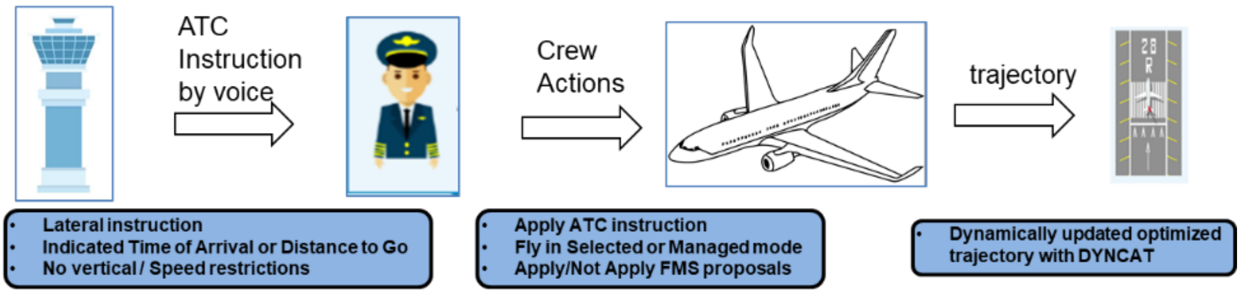

Figure 15: RTS high-level principle

As explained previously in the "Operating methods" section, two main scenarios will be addressed according to the air controller way of working, either exchanging a distance or a time instruction. A third one that consists in flying the procedure without any ATC heading instruction can also be tested.

These scenarios will be flown in both selected and managed modes when relevant to evaluate different ways of piloting as described in the following table.

Aircraft Guidance Mode / ATC lateral instructions		Heading (radar vectoring) + Distance To Go	Heading (radar vectoring) + Time of Arrival	DIRECT TO
Full SELECTED	Today **reference** (without DYNCAT nor PRT)	EX-SC-DYNCAT-VAPL-001	*Not relevant*	*Not relevant*
	The **pilot** follows the FMS vertical strategy relying on DYNCAT cues	EX-SC-DYNCAT-VAPL-002	EX-SC-DYNCAT-VAPL-004	*Not relevant*
Lateral Managed with Vertical Selected	Today **reference** (without DYNCAT nor PRT)	*Not relevant*	*Not relevant*	EX-SC-DYNCAT-VAPL-005
	The **pilot** follows the FMS vertical strategy relying on DYNCAT cues	*Not relevant*	*Not relevant*	EX-SC-DYNCAT-VAPL-006
Full MANAGED	Today **reference** (without DYNCAT)	*Not relevant*	*Not relevant*	EX-SC-DYNCAT-VAPL-007
	The **system** follows the FMS 4D strategy (with the pilot relying on DYNCAT cues for flaps extension)	EX-SC-DYNCAT-VAPL-003 (assuming PRT « clearance »)	*Not tested*	EX-SC-DYNCAT-VAPL-008

Table 19: Validation exercises overview

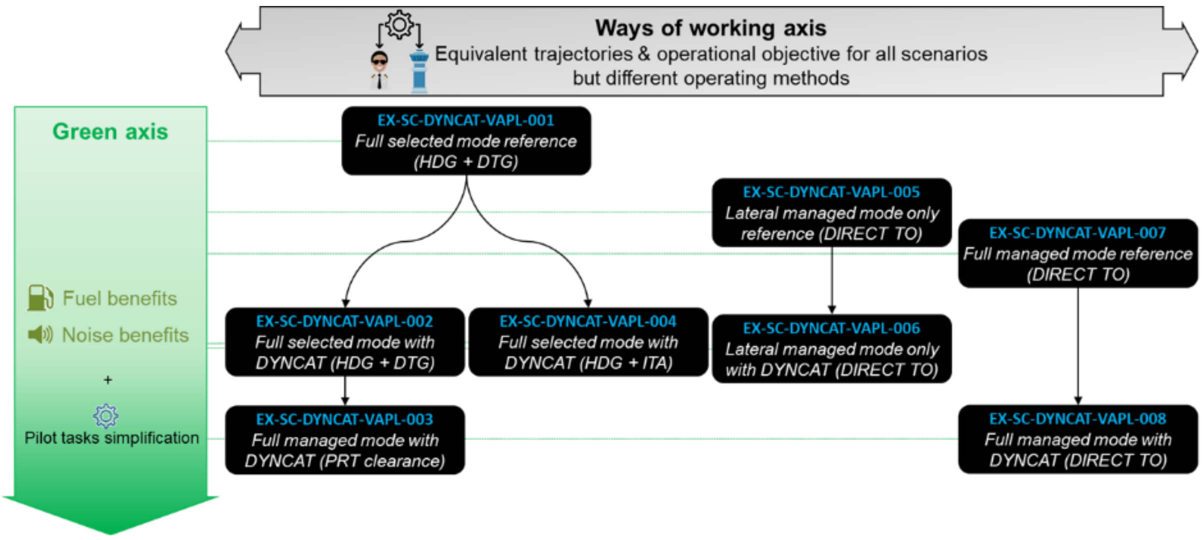

Table 20: Validation exercises connections & expected benefits diagram

Following the simulations, on the one hand, a fuel/noise data analysis will be performed to assess the DYNCAT's environmental impact and on the other hand, operators' feedbacks will be collected to assess DYNCAT's impact on the way of working (workload, awareness, etc.).

The validation exercises have been defined to evaluate the potential of DYNCAT concept to fly more environmentally friendly flight profiles, but also to be able to compare the additional value with regards to the working method and process used by the pilot and the ATCO. Indeed, heading lateral instruction will be compared to DIRECT ones, with the objectives to demonstrate that the Permanent Resume Trajectory coupled to DYNCAT enables to maximize fuel and noise benefits in all situations.

These results will be used as inputs for the final data pack delivery to enhance the concept and its system specification.

4.2 Objectives

The validation objectives (cf. "Objectives") will be fully covered by the different scenarios of the exercises. Each scenario reflects an operational situation and each objective might be addressed multiple times in multiple scenarios (since the aim of DYNCAT is to be efficient in any situation).

VALIDATION		Is Exercised By	Verifies
Validation objective ID	Success criteria ID	ID of the scenario	Identifier
OBJ-DYNCAT-VALP-001	CRT-DYNCAT-VALP-001	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-001 REQ-DYNCAT-CDS-006 REQ-DYNCAT-CDS-008
OBJ-DYNCAT-VALP-002	CRT-DYNCAT-VALP-002	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-002
OBJ-DYNCAT-VALP-003	CRT-DYNCAT-VALP-003	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-003
OBJ-DYNCAT-VALP-004	CRT-DYNCAT-VALP-004	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-004
OBJ-DYNCAT-VALP-005	CRT-DYNCAT-VALP-005	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-005
OBJ-DYNCAT-VALP-006	CRT-DYNCAT-VALP-006	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-006
OBJ-DYNCAT-VALP-007	CRT-DYNCAT-VALP-007	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-007

OBJ-DYNCAT-VALP-008	CRT-DYNCAT-VALP-008	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003	REQ-DYNCAT-FMS-008 REQ-DYNCAT-FMS-010 REQ-DYNCAT-CDS-001
OBJ-DYNCAT-VALP-009	CRT-DYNCAT-VALP-009	EX-SC-DYNCAT-VALP-004	REQ-DYNCAT-FMS-009 REQ-DYNCAT-FMS-010 REQ-DYNCAT-CDS-003
OBJ-DYNCAT-VALP-010	CRT-DYNCAT-VALP-010	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003	REQ-DYNCAT-FMS-011 REQ-DYNCAT-CDS-002
OBJ-DYNCAT-VALP-011	CRT-DYNCAT-VALP-011	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-012
OBJ-DYNCAT-VALP-012	CRT-DYNCAT-VALP-012	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-FMS-013
OBJ-DYNCAT-VALP-013	CRT-DYNCAT-VALP-013	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-CDS-004 REQ-DYNCAT-CDS-005
OBJ-DYNCAT-VALP-014	CRT-DYNCAT-VALP-014	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-CDS-004 REQ-DYNCAT-CDS-005
OBJ-DYNCAT-VALP-015	CRT-DYNCAT-VALP-015	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006	REQ-DYNCAT-CDS-007
OBJ-DYNCAT-VALP-016	CRT-DYNCAT-VALP-016	EX-SC-DYNCAT-VALP-001 EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-005 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-007 EX-SC-DYNCAT-VALP-008	REQ-DYNCAT-CDS-009

Table 21: Traceability matrix between validation objectives and scenarios / requirements

4.3 Scenarios

4.3.1 Reference flights

The present section describes the reference scenarios on which DYNCAT is deactivated. As previously described, an arrival procedure at Zurich airport is chosen as the reference for the flight plan. This procedure is flown with the systems equivalent to the "state of art", meaning without any additional help. Different scenarios are proposed to build a consistent reference for both environmental analysis (fuel/noise) and for the piloting experience. The reference scenarios will be performed on the same test environment as the solution ones (notably the CDS) in order to avoid bias in comparison.

Since these scenarios are only used for reference, no particular objectives are associated concerning the DYNCAT prototype except that it allows to be de-activated to retrieve the "state-of-art" behaviour.

- Flights with a heading instruction and an indicative DTG as today

  During the flight, the controller assigns a specific heading, until he provides a clearance for landing or to re-join the FPLN.

  The strategy for energy dissipation or fuel optimization is completely left to pilots: the controllers provide all heading instructions and the DTG indication is used by the pilots to define the vertical and energy dissipation strategy.

Exercise Identifier	EX-SC-DYNCAT-VALP-001
Title	Fly with lateral instructions and indicated Distance To Go without DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-0016

Table 22: EX-SC-DYNCAT-VALP-001

The controller provides the indicated track miles to touchdown (also called Distance to Go (DTG)).

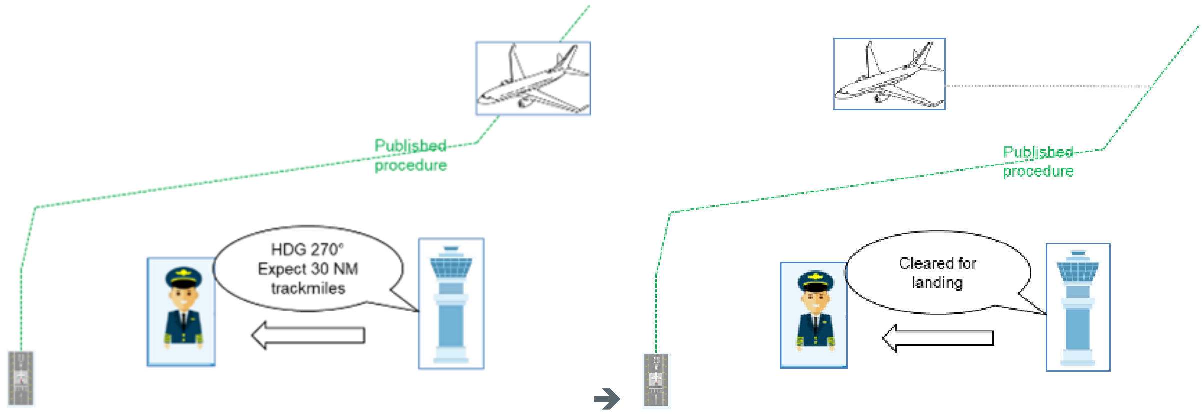

Figure 16: EX-SC-DYNCAT-VALP-001 illustration

- Flights along published procedure with a DIRECT instruction

  The published procedure is flown with a shortcut provided as a DIRECT by the controller, creating an over-energy situation.

  Some existing indications (VDEV, static pseudo DECEL, etc.) may help for energy dissipation or fuel optimization.

  - In vertical selected mode

Exercise Identifier	EX-SC-DYNCAT-VALP-005
Title	Fly with vertical selected mode a published procedure modified by a DIRECT instruction without DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-0016

Table 23: EX-SC-DYNCAT-VALP-005

The flight is performed with the vertical axis under crew responsibility in vertical selected mode).

  - In vertical managed mode

Exercise Identifier	EX-SC-DYNCAT-VALP-007
Title	Fly with vertical managed mode a published procedure without DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-0016

Table 24: EX-SC-DYNCAT-VALP-007

The flight is performed in full vertical managed mode.

4.3.2 DYNCAT flights

The same arrival procedure at Zurich airport is chosen as the reference for the flight plan initialization. This procedure is flown in various ways, with the systems embedding the DYNCAT functionality. This section describes the corresponding scenarios.

- Flights with a heading instruction and with a DTG indication

  During the flight, the controller requests to select a specific heading and provides the indicated track miles to touchdown (also called Distance to Go (DTG)). The pilot shall enter into the system the corresponding data to retrieve an optimized trajectory with associated new cues (cf. Practice #1: Radar vectoring with DTG information sharing). Then a clearance for landing or re-join the FPLN will be given by the controller.

Throughout this exercise, the system proposes to the crew a continuous access to a resumed trajectory from the aircraft with some new cues (optimum distance to land and associated margin, dynamic pseudo DECEL and configuration extension pseudo ("1", "2", "F"), Airbrakes segment, expected modes, etc.) to facilitate the energy management tasks and to better understand the situation.

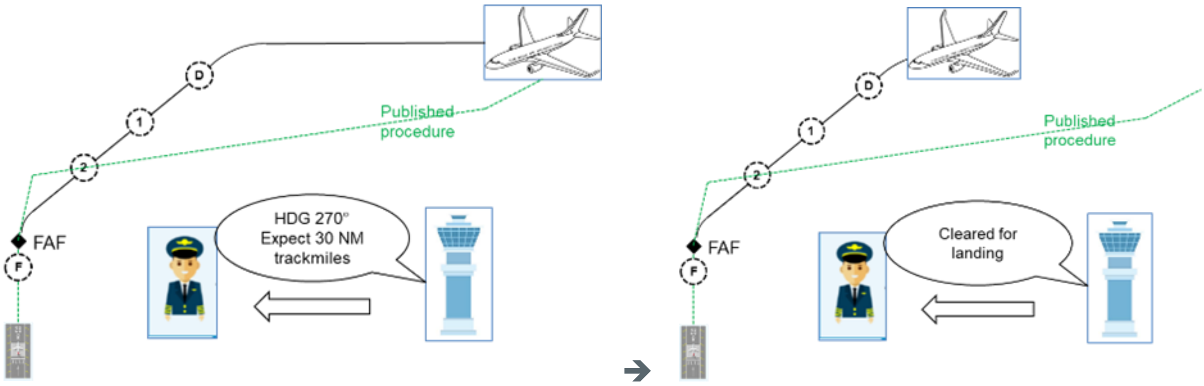

Figure 17: EX-SC-DYNCAT-VALP-002/003 illustration

- In vertical selected mode

Exercise Identifier	EX-SC-DYNCAT-VALP-002
Title	Fly in vertical selected mode with lateral instructions and Indicated Distance to Go with DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-001 OBJ-DYNCAT-VALP-002 OBJ-DYNCAT-VALP-003 OBJ-DYNCAT-VALP-004 OBJ-DYNCAT-VALP-005 OBJ-DYNCAT-VALP-006 OBJ-DYNCAT-VALP-007 OBJ-DYNCAT-VALP-008 OBJ-DYNCAT-VALP-0010 OBJ-DYNCAT-VALP-0011 OBJ-DYNCAT-VALP-0012 OBJ-DYNCAT-VALP-0013 OBJ-DYNCAT-VALP-0014 OBJ-DYNCAT-VALP-0015 OBJ-DYNCAT-VALP-0016

Table 25: EX-SC-DYNCAT-VALP-002

The flight is performed with the vertical axis under crew responsibility, in vertical selected mode.

- Using vertical managed mode when available

Exercise Identifier	EX-SC-DYNCAT-VALP-003
Title	Fly in vertical managed mode with lateral instruction and Indicated Distance to Go with DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-001 OBJ-DYNCAT-VALP-002 OBJ-DYNCAT-VALP-003 OBJ-DYNCAT-VALP-004 OBJ-DYNCAT-VALP-005 OBJ-DYNCAT-VALP-006 OBJ-DYNCAT-VALP-007 OBJ-DYNCAT-VALP-008 OBJ-DYNCAT-VALP-0010 OBJ-DYNCAT-VALP-0011 OBJ-DYNCAT-VALP-0012 OBJ-DYNCAT-VALP-0013 OBJ-DYNCAT-VALP-0014 OBJ-DYNCAT-VALP-0016

Table 26: EX-SC-DYNCAT-VALP-003

The flight is performed in full managed mode (laterally and vertically) as soon as the aircraft is cleared for landing, assuming a PRT clearance.

- Flights with a heading instruction with an ITA indication

During the flight, the controller requests to select a specific heading and provides the indicated time of arrival at a specific point (could be the destination). The pilot shall enter into the system the corresponding data to retrieve an optimized trajectory with associated new cues (cf. Practice #2: Radar vectoring with ITA information sharing). Then a clearance for landing or re-join the FPLN will be given by the controller.

Throughout this exercise, the system proposes to the crew a continuous access to a resumed trajectory from the aircraft with some new cues (optimum distance to land and associated margin, dynamic pseudo DECEL and configuration extension pseudo (“1”, “2”, “F”), Airbrakes segment, expected modes, etc.) to facilitate the energy management tasks and to better understand the situation.

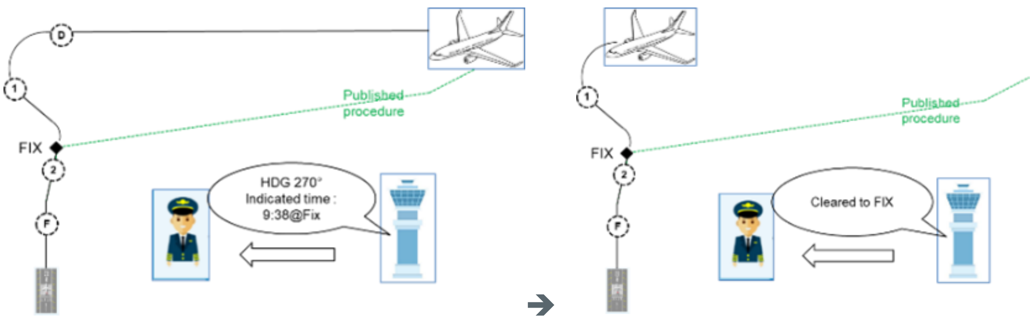

Figure 18: EX-SC-DYNCAT-VALP-004 illustration

- In vertical selected mode

Exercise Identifier	EX-SC-DYNCAT-VALP-004
Title	Fly in vertical selected mode with lateral instruction and Indicated Time of Arrival with DYNCAT.
Exercise Validation objective ID	OBJ-DYNCAT-VALP-001 OBJ-DYNCAT-VALP-002 OBJ-DYNCAT-VALP-003 OBJ-DYNCAT-VALP-004 OBJ-DYNCAT-VALP-005 OBJ-DYNCAT-VALP-006 OBJ-DYNCAT-VALP-007 OBJ-DYNCAT-VALP-009 OBJ-DYNCAT-VALP-0011 OBJ-DYNCAT-VALP-0012 OBJ-DYNCAT-VALP-0013 OBJ-DYNCAT-VALP-0014 OBJ-DYNCAT-VALP-0015 OBJ-DYNCAT-VALP-0016

Table 27: EX-SC-DYNCAT-VALP-004

The flight is performed with the vertical axis under crew responsibility, in vertical selected mode.

Note : the equivalent flight assuming a PRT clearance and performed in full managed mode (laterally and vertically) is not planned as the expected results are exactly the same as for the EX-SC-DYNCAT-VALP-003. Indeed, only the operating methods and air/ground interactions differ but the expected trajectories are the same when flying in full managed modes.

- Flights along published procedure

The published procedure is flown with a shortcut provided as a DIRECT instruction from the controller, in order to create an over-energy situation.

Throughout this exercise, the system proposes to the crew a continuous trajectory from the aircraft with some new cues (optimum distance to land and associated margin, dynamic pseudo DECEL and configuration extension pseudo ("1", "2", "F"), Airbrakes segment, expected modes, etc.) to facilitate the energy management tasks and to better understand the situation.

- <u>In vertical selected mode</u>

The flight is performed with the vertical axis under crew responsibility, in vertical selected mode.

Exercise Identifier	EX-SC-DYNCAT-VALP-006
Title	Fly in vertical selected mode along published procedure with DYNCAT
Exercise Validation objective ID	OBJ-DYNCAT-VALP-001 OBJ-DYNCAT-VALP-002 OBJ-DYNCAT-VALP-003 OBJ-DYNCAT-VALP-004 OBJ-DYNCAT-VALP-005 OBJ-DYNCAT-VALP-006 OBJ-DYNCAT-VALP-007 OBJ-DYNCAT-VALP-0011 OBJ-DYNCAT-VALP-0012 OBJ-DYNCAT-VALP-0013 OBJ-DYNCAT-VALP-0014 OBJ-DYNCAT-VALP-0015 OBJ-DYNCAT-VALP-0016

Table 28: EX-SC-DYNCAT-VALP-006

- Using vertical managed mode

Exercise Identifier	EX-SC-DYNCAT-VALP-008
Title	Fly in vertical managed mode along published procedure with DYNCAT
Exercise Validation objective ID	OBJ-DYNCAT-VALP-001 OBJ-DYNCAT-VALP-002 OBJ-DYNCAT-VALP-003 OBJ-DYNCAT-VALP-004 OBJ-DYNCAT-VALP-005 OBJ-DYNCAT-VALP-006 OBJ-DYNCAT-VALP-007 OBJ-DYNCAT-VALP-0011 OBJ-DYNCAT-VALP-0012 OBJ-DYNCAT-VALP-0013 OBJ-DYNCAT-VALP-0014 OBJ-DYNCAT-VALP-0016

Table 29: EX-SC-DYNCAT-VALP-008

The flight is performed in full managed mode (laterally and vertically)

Through these different scenarios, the DYNCAT prototype will be evaluated:

- Is it consistent with the preliminary high-level specification?
- Does it improve the piloting experience (impact on workload, on awareness, etc.)?
- Does it improve the environmental impact in TMA?

The way to estimate the environmental impact in TMA is described in the next chapter.

4.4 Results analysis specification

During the Real Time Simulation, the flights will be recorded with two different Thales tools.

The first one is called "TOCATA". This tool allows to record and visualize continuously the aircraft state and the trajectory 5D (position, time and fuel) computed by the system. These records allow to analyse the aircraft behaviour and to compare it with the trajectory predicted by the system.

The figure here below presents an example of TOCATA profile visualization means on altitude and speed axis, with in red the simulated flight, and in green the FMS predicted trajectory.

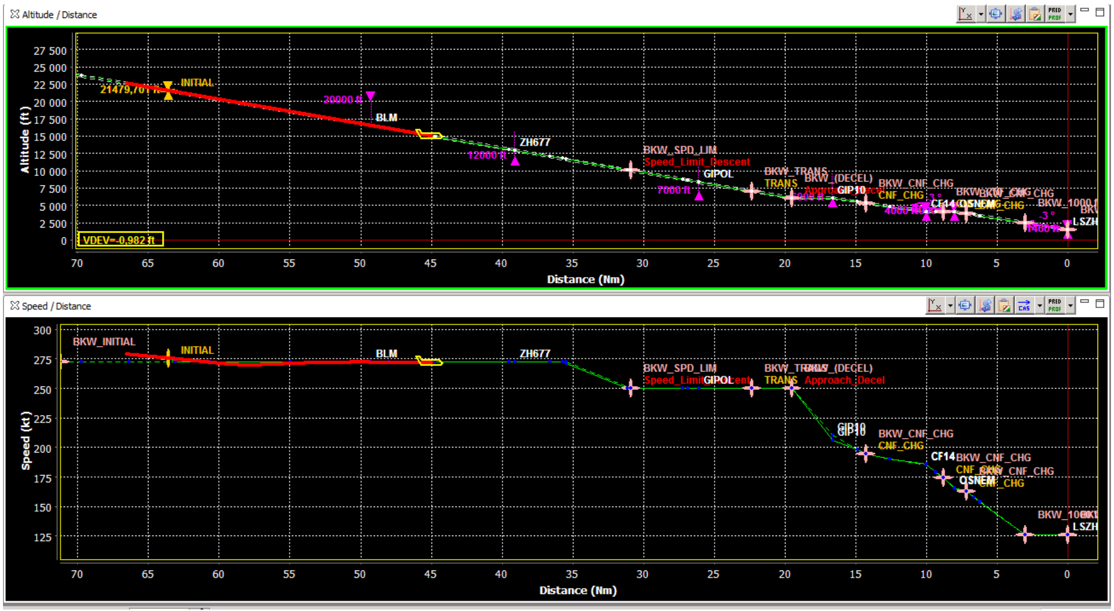

Figure 19: TOCATA tool snapshot

In addition to the fuel and noise analysis as described here after, this tool will support the prototype development phase. Indeed, it is an engineering tool dedicated to the FMS data analysis so that it will permit for instance to:

- Check the construction of the CDA profile
- Correlate the display of the cues on the CDS with the FMS internal computation
- Evaluate and tune the energy dissipation improvement when using speed brakes, when shifting flaps pseudo-waypoints location
- Analyse the pilot practices and behaviour and compare with the FMS assumptions
- Etc.

During the Real Time Simulation, TOCATA will also be useful to validate one of the DYNCAT project objective which is to improve the environmental impact in TMA.

The second tool is simply a recorder of the VSIB simulation and enables to record any signal that transits by the IMB (Integrated Modular Bench), which is the heart of the simulation. This IMB module is a gateway that confers to the bench its modularity by enabling the interconnection of real or simulated products and systems from different generations, different aircrafts. Thus, it permits to record the FMS signals as well as the CDS ones, the AP ones, the environment parameters, etc.

4.4.1 Fuel: data collection & method

As previously explained, the aircraft state and in particular the fuel data, either the Fuel on Board (FOB) or the Gross Weight (GW), will be recorded during the Real Time Simulation. The analysis of these records will allow to compare and quantify the fuel gain provided by DYNCAT in the TMA.

In addition to this benefit directly linked to an efficient management of the aircraft thrust, one expected fuel benefit will not be measurable at this stage of the project: the economy due to an avoidance of the Go-Around procedure activation thanks to the better energy management.

The Figure 20: TOCATA fuel record presents a snapshot of the TOCATA tool, and more precisely of the GW function of the distance to destination, with in red the simulated flight, and in purple the predicted value. This example illustrates the tool potential to correlate the FMS predictions with the Flight Simulation model, but also the possibility to evaluate easily the impact of a flap change on the fuel consumption for a given flight.

Figure 20: TOCATA fuel record

4.4.2 Noise: data collection & method

Empa will assess the impact of the procedural changes based on Real-Time simulations conducted by Thales on noise emissions and sound exposure on ground for varying weather conditions. The simulation results of the test bench in Work Package 4 serve as the basic data for the simulations and investigation of the potential noise reduction.

For noise analysis, two different kind of data are important:

- The aircraft parameters (such as altitude, speed, thrust)
- The atmospheric parameters (such as the wind, temperature, etc.)

The data structure of the Thales test bench and Empa's noise simulation tool sonAIR parameters (for detailed model description see [2]) are different in terms of flight data. Therefore, an interface had to be defined for the transfer of the simulation data. The following table lists the required parameters including description, data format and units.

Parameter	Description	Value Type	Range	Comment
Time	Time [s]	float		Peferably seconds from 00:00:00 of current day / continuous time steps between 0.5 and 2 seconds
X	Longitude [°]	float		
Y	Latitude [°]	float		
Z	GPS Altitude [m]	float		Preferably height above mean sea level (MSL)
V	Ground Speed [m/s]	float		
TAS	True Air Speed [m/s]	float		
TrackAngle	Heading Angle [°]	float		
FlightPathAngle	Flightpath Angle [°]	float		
BankAngle	Bank Angle [°]	float		
AoA	Angle of Attack [°]	float		
p	Atmospheric Pressure [Pa]	float		
T	Air Temperature [°C]	float		
N1	Fan Speed, averaged over all engines [%]	float		
Flaps	Flaps Setting [-]	float or categorical		Preferably categorical values (no angles)
Gears	Gears Setting [-]	float or categorical	[0 1]	Transition phase as float numbers possible
Speed Brakes	Speed Brakes Setting [-]	float or categorical	[0 1]	Transition phase as float numbers possible

Table 30: Interface definition of sonAIR and Thales models

For the Real Time Simulation, the following atmospheric parameters will be defined in order to be as representative as possible from the real use cases:

- the wind velocity and direction for up to 5 altitude levels
- a single delta ISA
- a single pressure offset

Below 1000ft AGL, the aircraft is considered to be stabilized and is no longer part of the DYNCAT investigations. However, the sonAIR propagation model requires accurate meteorological information down to the ground to account for acoustic propagation phenomena such as air absorption, sound diffraction and obstacle shielding effects.

Consequently, physically accurate assumptions for wind, temperature and relative humidity profiles have to be made for altitudes below 1000ft AGL. For that purpose, a meteorological modelling approach as described in [5] will be applied.

For the noise calculations of the flight test bench simulations in the context of the DYNCAT project, the sonAIR model was adapted to determine the noise emissions independently of the sound receiver position on the ground.

For this purpose, a receiver point with fixed distance and angle (θ) relative to the sound source was introduced, whereas both of these two corresponding parameters can be freely selected (see Figure 21). To calculate the atmospheric sound attenuation, a homogeneous atmosphere according to ISO 9613-1 is assumed.

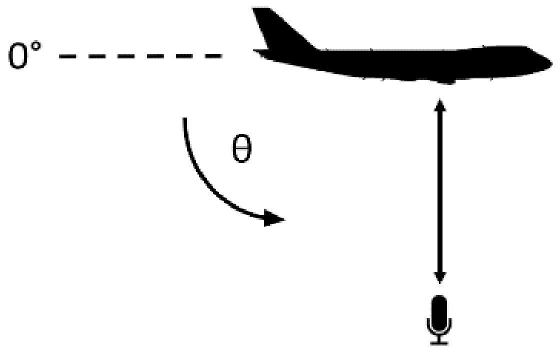

Figure 21: Visualisation of moved along receiver

The introduction of this moved along receiver allows an emission-side analysis of different flight parameter settings during each simulation. Engine and airframe noise level-time-histories can be displayed separately, which allows an isolated analysis especially of the influence of the high-lift system actuation, which is the focus of DYNCAT.

The following graph shows a possible analysis of a single flight, with data evaluation of engine, airframe and total noise, as well as their dependency on Mach number, N1 and configuration.

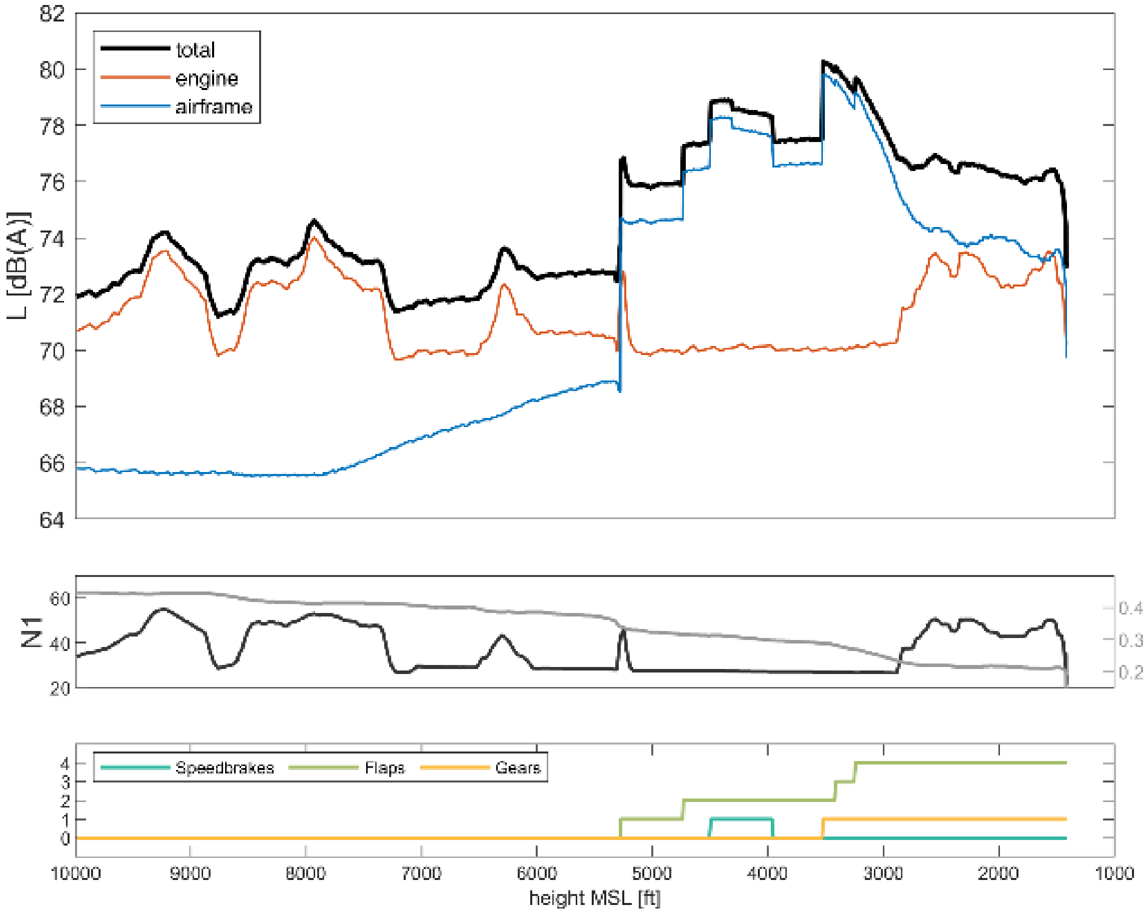

Figure 22: Noise emission and flight data of an A320 during approach, determined by a moved along receiver underneath the aircraft in 1000 ft distance

Another important application of the moved along receiver is the emission-side sensitivity analysis on continuous parameters like Mach number, air density and N1 and also on aircraft configuration changes.

This allows to quantitatively determine the influence of changes of each parameters on the noise emission and deduce its noise reduction potential.

4.5 Exercises planning and management

4.5.1 Activities

The validation activity is spread over time and divided into three phases:

1. **The preparatory phase**
    - CDS and FMS prototypes including DYNCAT have to be integrated into the simulation bench to allow an upstream pre-validation and to prepare the Real Time Simulation in the execution conditions on refined exercises scenarios introduced in this document.
    - Internally in Thales, all the scenarios will be executed by both the engineering team and the test pilots to get more results.
    - The different participants which are mandatory for the Real Time Simulation have to be identified and invited.
    - A preliminary briefing with the participants has to be organized to introduce the DYNCAT prototype and the challenges and expectations of the Real Time Simulation. Following the briefing, the scenarios initially planned might be upgraded to take into account some feedbacks.

2. **The execution of the Real Time Simulation**
    - A briefing with the participants has to be organized to remind the challenges, expectations of the Real Time Simulation and the DYNCAT functionality in the prototypes and to introduce the simulation bench with its specificities (including pilots training to the new generation of Display System and Flight Management System).
    - In order to limit the RTS to an acceptable duration, only the most realistic use cases and the scenarios for which the execution by a pilot brings an added value will be performed. Thus, the scenarios flown in full managed modes are excluded from the RTS and will only be flown by both Thales engineering team and test pilots.

Aircraft Guidance Mode / ATC lateral instructions		Heading (radar vectoring)		DIRECT TO
		+ Distance To Go	+ Time of Arrival	
Full SELECTED	Today **reference** (without DYNCAT nor PRT)	EX-SC-DYNCAT-VAPL-001	Not relevant	Not relevant
	The **pilot** follows the FMS vertical strategy relying on DYNCAT cues	RTS focus EX-SC-DYNCAT-VAPL-002	EX-SC-DYNCAT-VAPL-004 RTS openness	Not relevant
Lateral Managed with Vertical Selected	Today **reference** (without DYNCAT nor PRT)	Not relevant	Not relevant	EX-SC-DYNCAT-VAPL-005
	The **pilot** follows the FMS vertical strategy relying on DYNCAT cues	Not relevant	Not relevant	EX-SC-DYNCAT-VAPL-006
Full MANAGED	Today **reference** (without DYNCAT)	Not relevant	Not relevant	EX-SC-DYNCAT-VAPL-007
	The **system** follows the FMS 4D strategy (with the pilot relying on DYNCAT cues for flaps extension)	EX-SC-DYNCAT-VAPL-003 (assuming PRT « clearance »)	Not tested	EX-SC-DYNCAT-VAPL-008

Table 31: Validation exercises during the RTS day

- These RTS scenarios will be performed by different set of pilots to show that DYNCAT tends to generalize the good practices of the crew.

  Then, a feedback will be collected from all the participants (pilots, controllers, engineers, etc.) and included in the future project deliverables.
- The flights data will be recorded for post-treatments.

3. The analysis phase

- A validation report will be written and will include :
  - The assessment of the operational acceptability and feasibility
  - The assessment of the validation objectives
  - The pilots and controllers feedbacks of DYNCAT new operational overall concept, including their perception of the most valuable items and the most important difficulties to be faced for an implementation into the real operations
- An environmental benefits report will be written to assess the environmental impact of DYNCAT through the analysis of the flight records.
- A DYNCAT function experimental implementation report that will contain the FMS implementation architecture principles of the DYNCAT functionality on Thales industrial test bench will be written.
- The system high level specification document and the operational concept document will be updated to take into account the RTS feedbacks that will support the maturation of the concept.

The following Figure provides the expected number of results for each scenarios, considering a maximum number of five flight crews, representing up to ten pilots. For more details, refer to section 4.5.3.

Aircraft Guidance Mode \ ATC lateral instructions		Heading (radar vectoring)		DIRECT TO
		+ Distance To Go	+ Time of Arrival	
Full SELECTED	Today <u>**reference**</u> (without DYNCAT nor PRT)	**x20** from RTS (10 pilots 2 times) **x2** from Thales (engineers + pilot)	*Not relevant*	*Not relevant*
	The <u>**pilot**</u> follows the FMS vertical strategy relying on DYNCAT cues	**x20** from RTS (10 pilots 2 times) **x2** from Thales (engineers + pilot)	**x5** from RTS (5 flight crew) **x2** from Thales (engineers + pilot)	*Not relevant*
Lateral Managed with Vertical Selected	Today <u>**reference**</u> (without DYNCAT nor PRT)	*Not relevant*	*Not relevant*	**x2** from Thales (engineers + pilot)
	The <u>**pilot**</u> follows the FMS vertical strategy relying on DYNCAT cues	*Not relevant*	*Not relevant*	**x2** from Thales (engineers + pilot)
Full MANAGED	Today <u>**reference**</u> (without DYNCAT)	*Not relevant*	*Not relevant*	**x2** from Thales (engineers + pilot)
	The <u>**system**</u> follows the FMS 4D strategy (with the pilot relying on DYNCAT cues for flaps extension)	**x2** from Thales (engineers + pilot)	*Not tested*	**x2** from Thales (engineers + pilot)

Table 32: Expected results and associated producers

4.5.2 Roles & responsibilities

To realize the activities described in the previous paragraph, each participant has a key role:

- **DLR** will act as the coordinator of the DYNCAT project as a whole and contribute to the evaluation of the Real Time Simulation study both from operational and from environmental point of view, including the definition of further steps to mature the concept.
  It includes the final update of the Operational Concept Document (deliverable D2.5) that will describe how the DYNCAT function will be used in real operations and the expected benefits.

- **Empa** will be responsible for the adaptations of the noise simulation tool and will contribute to study the environmental impact of the simulated real-time trajectories produced by Thales, in particular the noise analysis. Empa is also in charge of the Environmental Benefits Report (deliverable D4.2) that quantifies the environmental benefits obtainable with the DYNCAT solution regarding fuel consumption and CO_2 emission reduction.

- **SkyLab** will be responsible in providing experts for the Real-Time Simulation, in contracting airline pilots from SWISS (or other airlines) and air traffic controllers from SkyGuide. It will contribute to assess the operational acceptability and feasibility as well as the impact on ATM procedures. SkyLab will also summarize the recommendations for the next step of DYNCAT's life.

- **SWISS** will give an evaluation of flyability of the procedures which includes pilots' assessment of workload and situational awareness (may be completed by the feedback from pilots coming from other airlines).

- **Thales** leads the Real-Time Simulation, ensuring the prototype realization and integration on the flight test bench in Toulouse, preparing the scenarios, leading the briefing meeting with the participants and the organization of the Real-Time Simulation execution. Thales is responsible for the flight simulation records during the session and will provide the expected data to Empa for noise exposure analysis.
  Thales will also deliver the DYNCAT Function Experimental Implementation Report (Deliverable D3.3) and the Prototype Validation Report (Deliverable D4.1). These documents will assess the new operational concept from pilots' perspective regarding the operational feasibility and acceptability.
  Thales will finally provide the Final System High-Level Specification (Deliverable D3.4) based on the initial one after conduction and evaluation of the Real-Time Simulation exercise by the operational experts.

4.5.3 Time planning

The Table 33: Detailed time planning for implementation & validation activities provides the detailed time planning for the implementation and validation activities, from the incremental prototyping until the real time simulation execution, with the link to the expected project deliverables that will benefit from the results analysis and participants feedbacks.

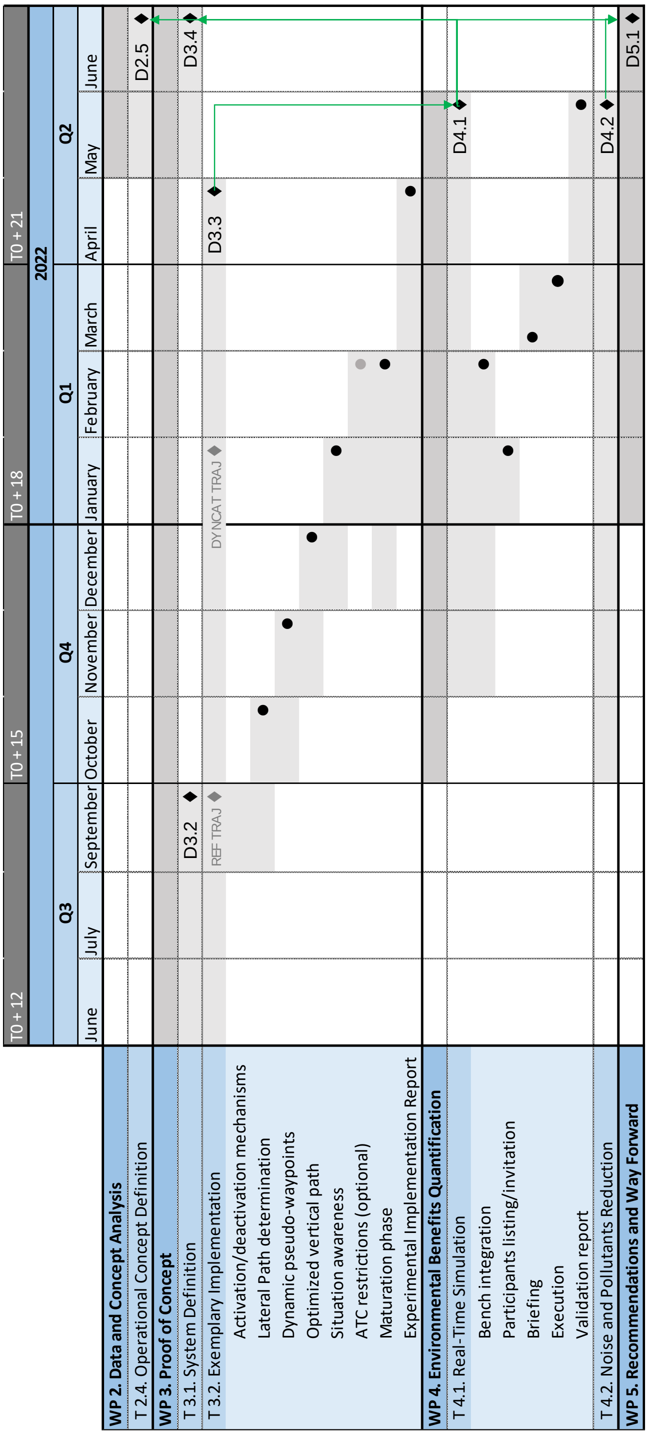

Table 33: Detailed time planning for implementation & validation activities

Depending on the crew participants, the RTS has been defined to last several days in March 2022.

The detailed provisional agenda for the RTS is the following for a typical day that can be repeated up to five times, considering up to five flight crews, thus representing up to ten pilots. One unique ATCO is needed as keeping the same way of working will be preferable to avoid multiplying the variables.

- **A few days before Day#X : Virtual briefing session**
  - XXhXX (2h00) : Concept and evaluations presentation
- **Day#X : Flights with crew #X + controller**
  - ***Welcome session (1h30)***
    - 09h00 (0h30) : Welcome coffee / roundtable
    - 09h30 (1h00) : Free flight for test bench familiarization
  - ***Batch of reference flights in full selected mode with DTG (2h)***
    - 10h30 (0h30) : EX-SC-DYNCAT-VAPL-001 (00h20 of flight + 00h10 of debriefing) → Pilot X.1
    - 11h00 (0h30) : EX-SC-DYNCAT-VAPL-001 (00h20 of flight + 00h10 of debriefing) → Pilot X.2
    - 11h30 (0h30) : EX-SC-DYNCAT-VAPL-001 (00h20 of flight + 00h10 of debriefing) → Pilot X.1
    - 12h00 (0h30) : EX-SC-DYNCAT-VAPL-001 (00h20 of flight + 00h10 of debriefing) → Pilot X.2
  - ***12h30 (1h30) : Lunch***
  - ***Batch of DYNCAT flights in full selected mode with DTG (2h)***
    - 14h00 (0h30) : EX-SC-DYNCAT-VAPL-002 (00h20 of flight + 00h10 of debriefing) → Pilot X.1
    - 14h30 (0h30) : EX-SC-DYNCAT-VAPL-002 (00h20 of flight + 00h10 of debriefing) → Pilot X.2
    - 15h00 (0h30) : EX-SC-DYNCAT-VAPL-002 (00h20 of flight + 00h10 of debriefing) → Pilot X.1
    - 15h30 (0h30) : EX-SC-DYNCAT-VAPL-002 (00h20 of flight + 00h10 of debriefing) → Pilot X.2
  - ***DYNCAT flight with ITA (for brainstorming about ways of working only)***
    - 16h00 (0h30) : EX-SC-DYNCAT-VAPL-004 (00h20 of flight + 00h10 of debriefing) → Both Pilots X.1/2 + Pilot X.2
  - ***Closing session (1h30)***
    - 16h30 (0h15) : Coffee break
    - 16h45 (0h45) : Day debriefing
    - 17h30 : End of the day
- **A few days after the last RTS Day : Virtual wrap-up session**
  - XXhXX (2h00) : Final wrap-up
  - XXhXX (1h00) : Way-forward for DYNCAT project

4.6 Risks and issues associated to the validation activities

The risks and issues identified for the Validation activities are the ones described in Stellar, and recalled in the Table here below.

Stellar Risk ID	Stellar Risk description
1698	Unavailability of sufficient number of pilots and ATCos for system evaluation due to higher priority of productive assignment by their employers (low)
1700	Unavailability of FMS test bench for implementation and test (low)

Table 34: Risks and issues associated to the validation activities

They are associated to the mitigation plan here below.

Stellar Risk ID	Mitigation measures
1698	Pilots and ATCO are contracted on a freelancing basis via SkyLab. This approach has been successfully employed in other projects. It is currently in progress and should be finalized in December In addition, even if in the best configuration 10 pilots will be contracted, the evaluation plan has been designed to be scalable and offers some flexibility regarding the number of flight crews involved, and their availability (day to day evaluation).
1700	Careful task/time planning and monitoring. Flight test bench will be booked early enough to ensure availability in March 2022. The risk is minor not to have the bench available.

Table 35: Mitigation measures

As a conclusion, there is no major risk identified that could compromise the planned validation activities as it defined.

5 Summary

The implementation validation plan is a key document in the DYNCAT project since it describes the method used to validate the concept. If it is not adapted, the results of the Real Time Simulation exercise will be irrelevant and as a consequence, the conclusion on the concept itself may be distorted.

This document establishes a validation plan of the DYNCAT concept though the validation of the prototype which implements the DYNCAT capability in the avionics systems Flight Management System (FMS) and Cockpit Display System (CDS). The formal validation will be performed during a Real Time Simulation exercise that will take place on a Thales research simulation bench in 2022.

The preliminary high-level system requirements (Deliverable D3.1) and the initial operational concept document (Deliverable D2.4) previously delivered detail the main objective of the DYNCAT concept which is to ease the energy management for the crew in particular with a better understanding of the situation. Relying on these documents, this one provides the precise objectives of the validation and the expectations for the different stakeholders. The different retained scenarios and the associated objectives are described. These scenarios are representative for an operational execution in the TMA and will be relevant to assess the added value of DYNCAT both from operational and from environmental point of view.

The way to evaluate the environmental positive impact in the TMA from the results in terms of fuel and noise is also described, with the engineering tools that will be used.

The flight test simulation bench description is part of the document to understand the required update added for DYNCAT. This overview will serve to provide the RTS participants with a virtual view of the flight test environment before the D-Day.

Finally, this document refines the roadmap of DYNCAT project, from the prototyping activities until the validations exercises progress, with the link on the impacted deliverables. It includes, of course, a description of the activities performed during the Real Time Simulation execution but also during preparatory and post-execution phases.

6 References

[1] DYNCAT Deliverable D2.1, "Description of acoustical and weather data measurements", 17th November 2020, Edition 00.02.00

[2] DYNCAT Deliverable D2.3, "Critical Analysis of Current Operations", 31th March 2021, Edition 00.01.00

[3] DYNCAT Deliverable D2.4, "Initial Concept Document", 23th April 2021, Edition 00.01.00

[4] DYNCAT Deliverable D3.1, "DYNCAT D3.1 - Preliminary System High-Level Specification", 30th June 2021, Edition 00.01.00

[5] Wunderli, J. M. and M. W. Rotach (2011). "Application of statistical weather data from the numerical weather prediction model COSMO-2 for noise mapping purposes." Acta Acustica United with Acustica 97: 403-415.

7 Appendix

SPECIFICATION		Is Validated By		Is Exercised By
Identifier	Title	Validation objective ID	Success criteria ID	ID of the scenario
REQ-DYNCAT-FMS-001	DECEL, "1", "2" and "F" dynamic positions computation	OBJ-DYNCAT-VALP-001	CRT-DYNCAT-VALP-001	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-002	"F" final pseudo-waypoint definition	OBJ-DYNCAT-VALP-002	CRT-DYNCAT-VALP-002	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-003	Configuration pseudo-waypoints operational limitations	OBJ-DYNCAT-VALP-003	CRT-DYNCAT-VALP-003	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-004	Approach pseudo-waypoints anticipation	OBJ-DYNCAT-VALP-004	CRT-DYNCAT-VALP-004	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-005	Configuration pseudo-waypoints position stabilization	OBJ-DYNCAT-VALP-005	CRT-DYNCAT-VALP-005	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-006	Vertical mode for deceleration segment in approach	OBJ-DYNCAT-VALP-006	CRT-DYNCAT-VALP-006	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-007	Vertical mode for constant speed segment in approach	OBJ-DYNCAT-VALP-007	CRT-DYNCAT-VALP-007	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-008	Distance-To-Go (DTG) information retrieval	OBJ-DYNCAT-VALP-008	CRT-DYNCAT-VALP-008	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003
REQ-DYNCAT-FMS-009	Indicated Time of Arrival (ITA) information retrieval	OBJ-DYNCAT-VALP-009	CRT-DYNCAT-VALP-009	EX-SC-DYNCAT-VALP-004
REQ-DYNCAT-FMS-010	Lateral path length	OBJ-DYNCAT-VALP-008 OBJ-DYNCAT-VALP-009	CRT-DYNCAT-VALP-008 CRT-DYNCAT-VALP-009	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004
REQ-DYNCAT-FMS-011	Flight plan lateral capture	OBJ-DYNCAT-VALP-010	CRT-DYNCAT-VALP-010	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003
REQ-DYNCAT-FMS-012	ATC speed restriction	OBJ-DYNCAT-VALP-011	CRT-DYNCAT-VALP-011	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-FMS-013	ATC altitude constraint	OBJ-DYNCAT-VALP-012	CRT-DYNCAT-VALP-012	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008

REQ-DYNCAT-CDS-001	Distance To Go (DTG) entry	OBJ-DYNCAT-VALP-008	CRT-DYNCAT-VALP-008	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003
REQ-DYNCAT-CDS-002	Capture point entry	OBJ-DYNCAT-VALP-010	CRT-DYNCAT-VALP-010	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003
REQ-DYNCAT-CDS-003	Indicated Time of Arrival (ITA) entry	OBJ-DYNCAT-VALP-009	CRT-DYNCAT-VALP-009	EX-SC-DYNCAT-VALP-004
REQ-DYNCAT-CDS-004	Optimum distance to land display	OBJ-DYNCAT-VALP-013 OBJ-DYNCAT-VALP-014	CRT-DYNCAT-VALP-013 CRT-DYNCAT-VALP-014	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-CDS-005	Optimum distance to land margin display	OBJ-DYNCAT-VALP-013 OBJ-DYNCAT-VALP-014	CRT-DYNCAT-VALP-013 CRT-DYNCAT-VALP-014	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-CDS-006	Approach pseudo-waypoints display on ND	OBJ-DYNCAT-VALP-001	CRT-DYNCAT-VALP-001	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-CDS-007	Vertical pseudo-waypoints display on ND	OBJ-DYNCAT-VALP-015	CRT-DYNCAT-VALP-015	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006
REQ-DYNCAT-CDS-008	Energy awareness cues	OBJ-DYNCAT-VALP-001	CRT-DYNCAT-VALP-001	EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-008
REQ-DYNCAT-CDS-009	DYNCAT option activation	OBJ-DYNCAT-VALP-016	CRT-DYNCAT-VALP-016	EX-SC-DYNCAT-VALP-001 EX-SC-DYNCAT-VALP-002 EX-SC-DYNCAT-VALP-003 EX-SC-DYNCAT-VALP-004 EX-SC-DYNCAT-VALP-005 EX-SC-DYNCAT-VALP-006 EX-SC-DYNCAT-VALP-007 EX-SC-DYNCAT-VALP-008

Table 36: Traceability matrix between requirements and validation objectives/scenarios

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