TrainingManagedDescentModes

Both qualitative and quantitative measures suggest that when conceptual problems with autoflight mode management arise they are most often associated with the descent and approach phases of flight. The following example is representative of what our pilots reported regarding the difficulty they experience in the descent:

P102: a lotta times you'll be sittin' there and // you'll be you'll be high, and you'll be wantin' to get down, and you're in a managed descent, like if-if-if you're flying an arrival and all of a sudden they change an altitude on ya? they want you to get down a little bit sooner? you'll go ahead and say okay well you look at it and see where you're gonna level off and see if-see if that's gonna be enough and if it's not then it's kinda like (1.5) um you know y-you may increase the speed, and all-all this thing does it just (spools) the engines up and not increase the rate of descent. and you're sittin' there going why is it doing that?

To investigate why the descent phase of flight might be problematic for pilots we did a careful analysis of the training materials. These materials included the pilot handbook, CBT, displays guide, lights and switches guide, course syllabi, and IOE training guide. To take an inventory of the auto-flight concepts presented we examined the materials line by line to identify individual concepts, the presentation and descriptions of concepts, and the relations drawn between concepts.

We analyzed the interview data for the conceptual models pilots use to describe aircraft behavior in various auto-flight modes and functioning of the auto-flight system. Pilots appear to use a small set of simple conceptual models to understand how the automation controls aircraft behavior. Some of these models are basic models of airplane control that any instrument-rated pilot would know, such as pitch-to-control-speed, climb-to-slow, and so on. These basic models are not presented to pilots in the training materials at the airline. The data suggest pilots bring these models to the airplane and use them to construct an understanding of how the auto-flight system controls the aircraft's behavior.

Analysis of Training Materials

While performing the concept inventory of the training materials we noticed there are generic concepts any pilot would know, then there are generic automation concepts that any pilot with automation experience should know and be able to adapt to any automated airplane (such as flight guidance and performance targets). Then there are concepts specific to flying the airbus that pilots would need to learn in training such as descent mode functioning.

Considering all of the materials that are provided to the pilots in training, a fairly complete set of concepts is presented, but in considering any one document alone, many concepts may be missing or only partially presented. Many concepts are made implicit in one place and in another place are made explicit. Concepts are introduced in an order that does not support incremental construction of a coherent conceptual model by the pilot.

For example, consider the description given in the pilot handbook of the interactions between autopilot/flight director (AP/FD) and autothrust (A/THR) modes.

Interaction Between AP/FD and A/THR Modes

Speed (or Mach) can be controlled by pitch or thrust, depending on the phase of flight. The AP/FD and A/THR cannot control speed simultaneously. Their interaction is as follows:

- If the AP/FD controls vertical path by pitch – the A/THR system maintains target speed.
- If the AP/FD controls a target speed – the A/THR system controls thrust.
- If no AP/FD mode is engaged the A/THR system controls SPD/MACH mode.

The description of the interaction is presented abstractly, without reference to the flight mode annunciations pilots use to understand automation behavior in flight or the phase of flight when these interactions are likely to occur. This description would be more useful to pilots if it described how these interactions relate to the auto-flight mode functioning.

Of all the training materials in the analysis, the CBT was the most problematic. Furthermore the generic CBT Airbus provides to the airlines also presents pilots with a number of difficulties. Pedagogically it is poorly designed, in that it does not describe how the system actually works when it works properly. It immediately jumps to exception cases disregarding presentation of the concepts necessary for understanding the behavior of the system. No conceptual framework for understanding the system is offered and the presentation assumes knowledge of concepts pilots new to the Airbus are not likely to know. Consider these excerpts from the existing CBT module introducing managed descent:

> **CBT SLIDE 3** "The aircraft is in cruise. The expected approach into Cairo is VOR DME 23L. the FMS has computed a descent profile taking into account all F-PLN data assuming that the aircraft will descent initially with idle thrust and ECON DES speed/MACH and then will follow the descent profile in order to reach 1000ft AGL at VAPP."
>
> **CBT SLIDE 4** "The aircraft has just over flown the Top of Descent, but is still in level flight: The FMA displays the message DECELERATE; this suggests the pilot to select a lower speed since the aircraft will be above the descent profile,
> The aircraft vertical position versus the descent path is indicated by the vertical deviation (VDEV) symbol along the altitude scale. You can read that the aircraft is approximately 300 ft above path."

The above text shown is accompanied in the CBT by illustrations of the primary flight display (PFD), navigation display (ND) and in some cases the multi-control display unit (MCDU). The concepts presented are complex and come early in the unit before any conceptual foundation has been presented. Slide 3 presents a scenario that most of the pilots flying for this particular airline would never encounter given their route structure and approach procedures. Flying a descent to a VOR approach in a non-radar environment would simply not be done in an A320 flying domestically in the US. There is also an immediate shift from describing managed descent mode functioning in normal conditions to an exception case where the aircraft has over flown the top of descent point.

CBT Slide 4 presents an exception case where the airplane has overflown the top of descent point. Pilots must first understand how DES mode works before they can begin to understand the exception cases.

It was obvious to us that the training materials were not giving pilots the conceptual framework they needed to understand how DES mode worked. Our objective was to identify the concepts that pilots need to know to understand DES mode functioning and to develop a CBT module that presented those concepts clearly and so pilots could construct a coherent understanding of the relations and dependencies between concepts.

A New Managed Descent Module

We used the concept inventory, described above in the methods section, as a basis for redesigning the Airbus managed descent module. (The entire module is included as Appendix X of this report.) The conceptual content, representation of concepts, and order of presentation are critical to establishing a solid conceptual understanding of the relations between concepts. Thus in designing the CBT, we adhered to pedagogical principles presented in Table 3. These principles are a compromise between traditional instructional design and newer constructivist approaches. The goal with these principles is to provide pilots in training with a conceptual foundation they can use to discover and construct an understanding of the autoflight system. At present, pilots leave the training center without adequate conceptual knowledge. Armed only with the basic aerodynamic understandings common to all jet pilots, they are unable to construct accurate and reliable models of the behavior of the autoflight system.

Table 3. Pedagogical Principles

Incremental development of conceptual structure by providing component pieces first. Later complexes that make use of relations among the pieces are introduced. For example, the managed descent guidance involves the merging of a path, a speed profile, and idle thrust. These are introduced incrementally.
Place key concepts early. For example, the notion of the descent path is perhaps THE central concept here and is introduced first. The other concepts are organized around this concept.
Key concepts are revisited in the context of newly added concepts as the instruction proceeds. This increases the likelihood that the student understands them.
Present normal operation of the system before dealing with abnormal, unusual, or compensatory behaviors of the system.
Ground the entire presentation in an operational framework that is meaningful to the pilot population. To best be able to use the knowledge in an operational context, it should be acquired in an operational context.
Use consistent terminology throughout. The terminology should be consistent throughout the presentation and consistent with other usage in the instructional and operational environments.

Where explanation of the behavior of the system are provided, ground those explanations in the conceptual models that we observe in interviews with line pilots discussing their understanding of the behavior of the airplane. This assures us that the causal explanations are meaningful to pilots.
Integrate the conceptual exposition with illustrations of the indications that will be present in the cockpit.

In our redesign of the CBT we utilized the concepts and their relations to the conceptual models to build a coherent description of how managed descent mode, DES, controls airplane behavior in the descent phase of flight. We begin by describing how the descent path is computed (Figure 1). We continue with an explanation of how the airplane will fly the computed descent path (Figure 2) and end with exception cases (Figure 3). Thus we integrate the descent concepts with the conceptual models and autoflight functioning to give pilots a conceptual foundation from which they can understand airplane behavior in various descent situations.

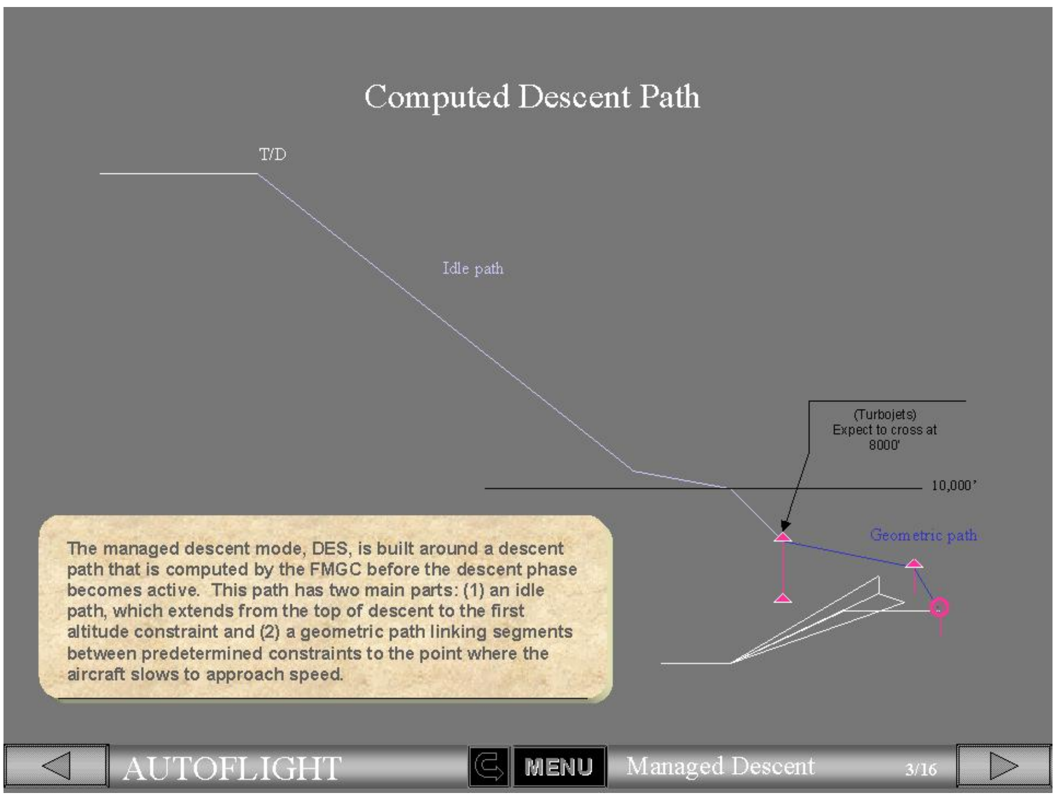

Figure 1. How the Descent Path is Computed

New concepts being introduced are the focus of each slide. Concepts presented in an earlier slide are reinforced before new concepts are introduced. Table X presents the concepts presented in Figure 2 and their order of presentation. Cockpit indications, pilot actions, the relationships between what pilots see, and what pilots do are linked by the underlying conceptual framework of descending an airplane. Our hope is that a strong conceptual understanding of how the automation controls the airplane will reduce mode *surprises* and *confusion* (see Sarter & Woods).

Table X. Referenced Concepts

Text for Computed Descent Path Slide	**References**
The managed descent mode, DES, is built around a descent path that is computed by the FMGS[1] before the descent phase becomes active[2]. This path has two main parts: (1) an idle path, which extends from the top of descent to the first altitude constraint and (2) a geometric path linking segments between predetermined constraints to the point where the aircraft slows to approach speed[3].	1: PH:17-26, **PH:17-29** "The DES mode guides the aircraft along the descent path computed by the FMGS" 2: PH:17-15, **PH:17-17** "The computer calculates the descent profile before the descent phase is initiated…" **3: PH:17-29** Defines the path segments and illustrates them with a diagram similar to the one shown in this slide. That diagram includes an optional 'repressurization segment' which is not mentioned in the training program used by this airline.

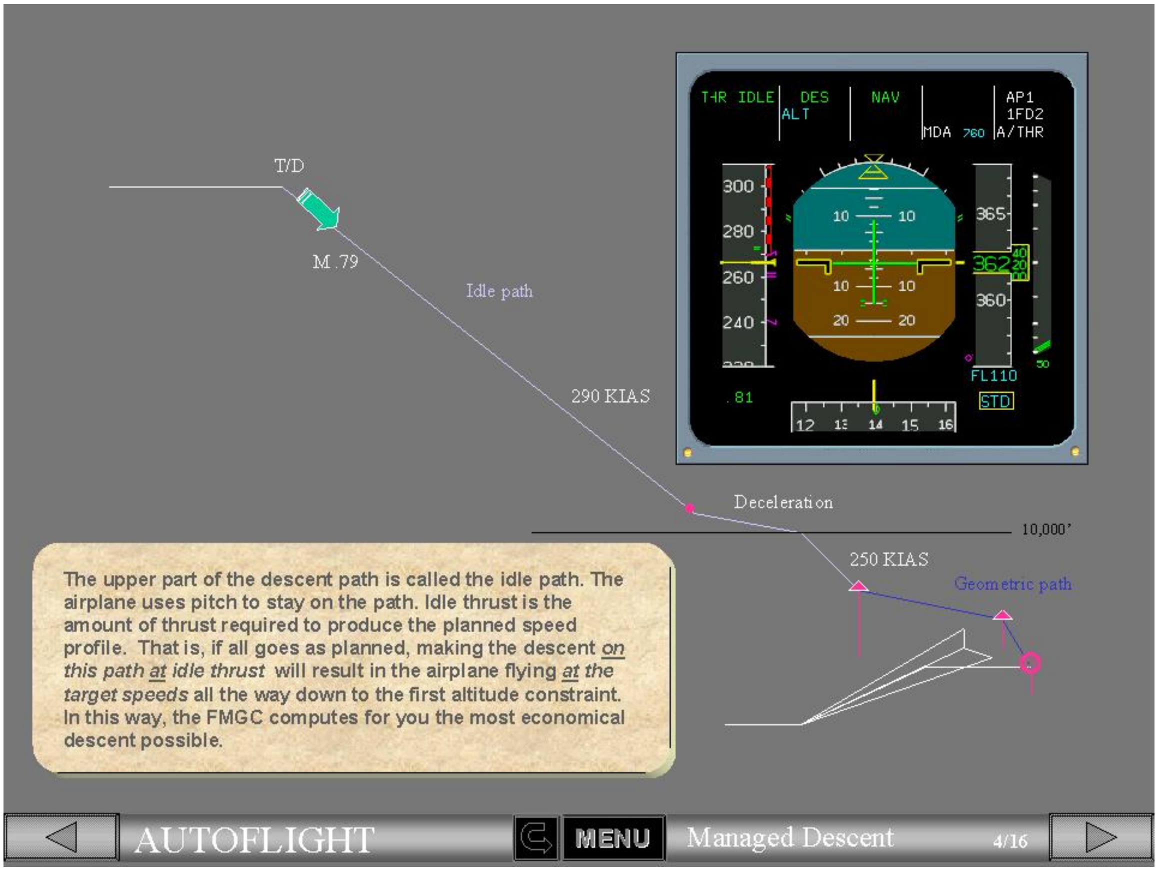

Figure 2. How the Airplane Flies the Idle Path

Figure X. Descent concepts presented in slide 4

New Concepts	**Reinforced Concepts**
	Descent path
	Idle path
Use pitch to maintain path	
Planned speed profile	
Idle thrust produces planned speed profile	
	Speed targets
	Vertical constraint--altitude
	FMGS computations
	Economical descent

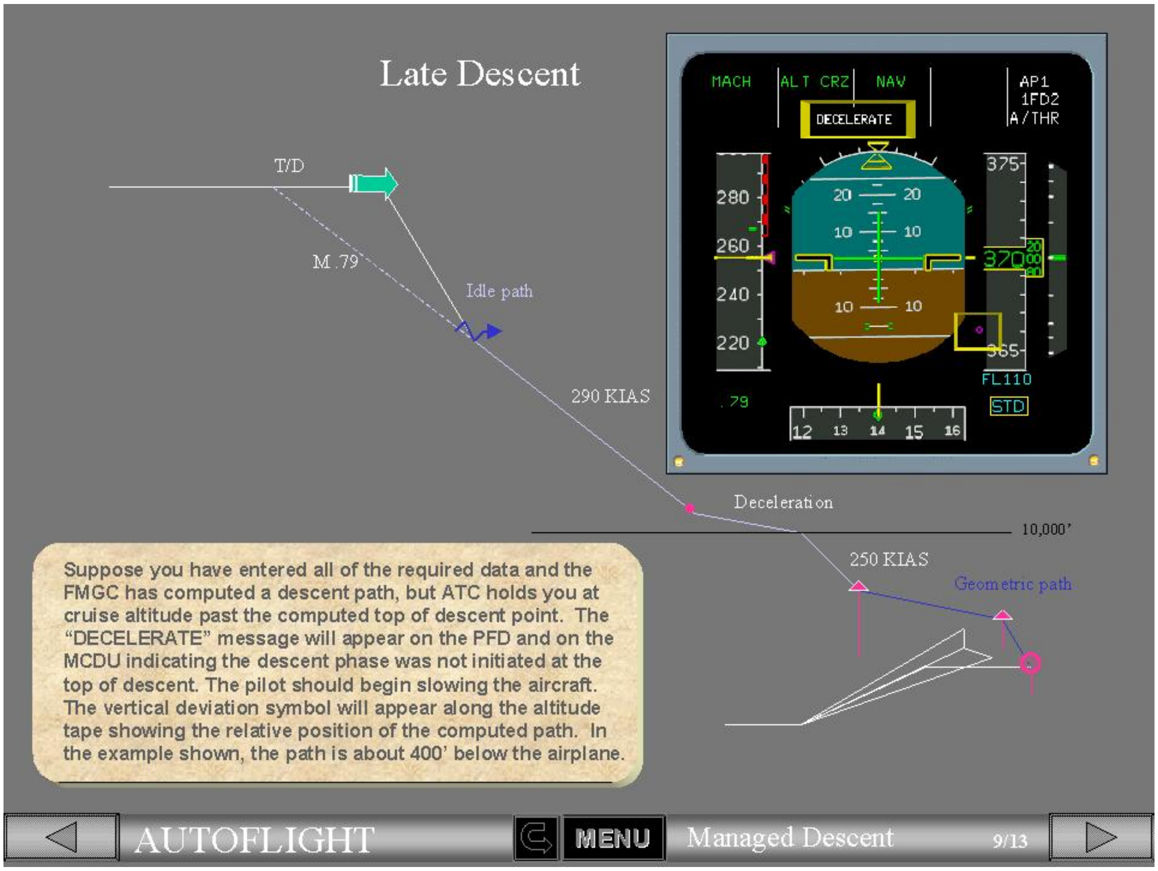

Figure 3. When the Airplane Leaves the Computed Path

Summary

We applied the concept inventory to guide the development of a new CBT module for managed descent. Autoflight training curriculum designers must each determine what concepts to include in the training and what concepts to exclude. The concept inventory helps with that judgment by identifying concepts and their relations that are explicit *and* implicit in the training media which students interact with when they are learning the system. Once identified, core concepts can be made explicit and supporting concepts can be introduced and the important relations between concepts established.

The CBT presents a clear representation and preserves important conceptual components needed to understand how the automation controls the airplane. It is important to note that we did not introduce *our* concepts and conceptual models. The content was derived through a careful analysis of the training materials already in place and in use at the airline[1]. Thus the concepts and representations that appear in the new CBT are the same concepts in place in the existing training materials. We re-represent the conceptual content in such a way to make it easy for pilots to construct a conceptual

[1] The Pilot Handbook (PH) used by the participating airline omits a great deal of material that is present in the manufacturer-supplied Aircraft Flight Manual (AFM). The AFM is supplied as a four volume (four Jeppesen style binders) set. The PH is a single volume. This is not unusual in the industry.

foundation for understanding airplane behavior in one of the most challenging phases of flight.