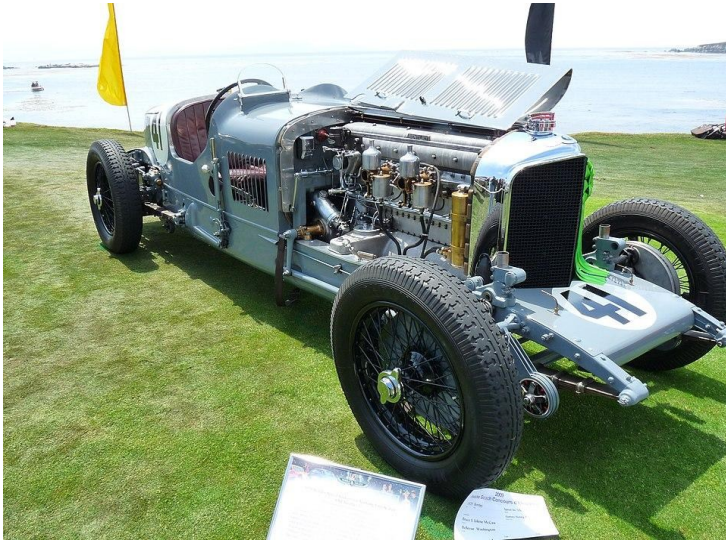


Mixin Things Up!



In the February 2025 edition of the SCSC Newsletter, the Ontology Working Group (OWG) provided an introduction to ontology, explaining how relevant and important the topic was and the OWG's objectives in developing new ontological models.

The OWG aims to make the topic even more accessible through a series of connected articles to be published in serialised form in the coming editions of the newsletter. Each episode will help expand on ontological aspects and by the end, will hopefully provide the reader with enough knowledge to read and contribute to models in the future.

What Is an Ontology? – a Recap

As we mentioned in the Feb'25 SCSC Newsletter article (scsc.uk/scsc-205), an ontology is not some esoteric formalisation, which is nice to have, but is essential to people's day-to-day work on real systems.

When we build a system, we are modelling our world and this involves developing concepts, terms and their relationships – this is called an ontology, or more formally: **“an explicit specification of a conceptualization”** [1].

If not explicitly specified, establishing a shared understanding of interrelated concepts will be much harder and miscommunication may be more common. For the system to operate correctly, any model used to support a part of the lifecycle of a system needs to be correct and consistent. Hopefully the concepts in the model are defined in writing, but at worst, meaning can just be held in the minds of the designers.

Capturing Models

The OWG uses a specialised framework called the Unified Foundation Ontology (UFO) [2]. This is a theoretical framework developed to provide a basis for conceptual modelling and implemented in OntoUML [3] (this is a customisation of the Unified Modelling Language (UML) [4] with associated software support via application plugins).

In the introductory article we modelled two different perspectives of the concept of a Flight of an aircraft; one from the perspective of a small private airfield, and one that considers flights by a commercial transport airline. The two models were quite different but, importantly, neither was incorrect with both reflecting the particular concerns and perspectives relevant to the associated stakeholders.

To recap on the concepts introduced in the previous article:

- We use boxes (more formally **Classes** using the modelling terminology, that are highlighted in this section in **bold**) to represent the concepts that are important to us in our view of the world. For readability, classes mentioned in the text of this article are **bold purple**, for example: **Aircraft**
- Ontological aspects are expressed as **Stereotypes** (the part of the class definition with Guillemets like this: «role»). **Stereotypes** mentioned in the text in this article are **this bold blue colour** for example, **Role**. (Note that in the diagrams, classes have different colours depending on their **Stereotype**, this is determined by the tooling and not to be confused with text colouring)
- Lines between the boxes show their relationships with other things
- Arrows with a ▽ closed white triangle are **Generalizations**, or in other words, one 'thing' subtypes the more general 'thing' that is being pointed to (for example, a **Cessna** is a subtype of **Aircraft** and **Aircraft** is a **Generalization** of **Cessna**)
- An open arrow ➤ relationship shows an **Association** between things. For example, in the phrase "Pilot 'flies' Aircraft", the concept 'flies' would be modelled as an **Association**. Note that **Associations** also have **Stereotypes**.
- **Association ends** are the numerical expressions at the end of each association, such as **0..*** and **1..*** (read as *zero or more* and *one or more* respectively). These show **Multiplicity** – the range of the number of each type of thing that can be related. This is used to help express constraints, such as a **Pilot** can be trained to fly one or more **Aircraft**, but a given **Aircraft** can usually be flown by at most two **Pilots** at any one time.

We also introduced some core UFO concepts, expressed as stereotypes:

- **Kinds** reflect the objects we find around us like **Humans**, **Aircraft** and **Charts**
- **Roles** and **Phases** reflect things that **Kinds** might be during their lifetime. For example, a **Human** may be a **Student Pilot** for some part of their life (a **Role**), but will cease to be a **Student Pilot** when they leave training school. Similarly, an object's failed state is a **Phase** it might go through, which is transitory and only for part of their life (usually the latter part) such as a **Broken Propeller**.

The concept of a **Mixin** was also briefly introduced and that is where our story will soon continue. A **Mixin** is something we use to describe shared properties of objects that do not all belong to the same **Kind** and so can span multiple **Kinds** that do not share the same *identity principles*. Before expanding on **Mixin**, let's explore *identity principles* in more detail.

Identity Principles

If I replace a tyre on my car, I doubt few would dispute that the car is still identifiable as the same car. This might also be safely assumed if I replace the clutch, the drive shaft or even the engine. If, however, I scrap the car so it is just a pile of metal, screws and plastic in a box, we'd likely say it is no longer a car; so where is the line between these extremes? What if *all* the parts in the car were replaced over time? Is it still the same car?

In 1990 there was a dispute around the authenticity of a vintage racing car called "Old Number One". The original, a Bentley Speed Six vehicle, won the Le Mans 24 hours endurance race in 1929 and 1930 and the purchaser, having agreed to buy the car for £10m, researched the vehicle and realised it had been significantly modified since then and disputed its authenticity. In fact, the chassis, front axle, gearbox, differential and, quite possibly, the steering column and engine crankcase had already been replaced between 1929 and 1930 and over the years other modifications and replacements parts where necessary. The case went to court and the outcome was that the car was deemed the "direct descendant" of Old Number One and that *no other car can claim its identity*.



I am Spartacus!

The reason the box of scrap is not my car anymore but Old Number One remains the same vehicle is to do with our common-sense identity principles. These are functions used to distinguish individuals. Unfortunately, there is seldom a single unique function that faithfully distinguishes things and so we need a series of conditions that, in combination, give us the ability to separate one individual from another (*individuate* more formally).



The famous quote "I am Spartacus!" arose from the eponymous 1964 Kirk Douglas film where a number of people stood up claiming they were the individual named Spartacus. This caused a headache for the Romans, but this is fairly straightforward with the right information. Having the birth date, place of birth and birth name is usually sufficient to identify any given person². Only in combination do these conditions

reliably identify and differentiate individuals.

² Unless of course parents give newly born twins the same name, which apparently has happened. Twins are problematic as they pretty much share the same DNA too. It's left to the reader to puzzle over what might be a completely foolproof method of individuating human beings!

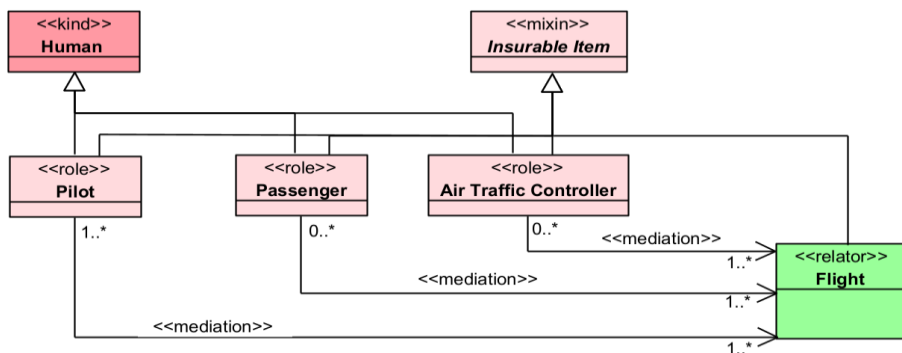
Identity principles are important to us as they help guide us in building type hierarchies by imposing constraints on meaning through abstraction and other techniques in conceptual models. This provides constraints and structure that are a “good thing” as they help us build meaningful and self-consistent models that we can use to reason about our world.

Some stereotypes provide an identity principle and some do not. For example, **Kind**s provide identity principles but a **Mixin** does not. Other classes such as **Role** and **Phase** don’t provide an identity principle themselves but must inherit from a class that does, such as **Kind**. The identity principle allows us to clearly individuate different instances of a class and effectively allows us to do things like count the number of individuals. For example, we can count the number of **Aircraft** (a **Kind**) on the planet, count the number of **Pilots** (a **Role**) employed by an airline and perhaps worry about the number of **Broken Propellers** (a **Phase**) we have on our **Aircraft**.

Mixins

After covering the principles of Identity, we can now return to **Mixins**. These were introduced briefly in the previous introductory article where the **Mixin: Insurable Item** was shown to span different **Kinds**.

We can now show this explicitly on a revised ontology diagram. We can now see that the **Pilot**, the **Passenger** and the **Air Traffic Controller** in their respective roles are insurable. For example, the **Pilot** and **Passenger** might be insured against death and injury and the **Air Traffic Controller** might have professional indemnity insurance. The **Flight** itself might also be insured – compensation might be claimable if the flight doesn’t take place.



There are a lot of lines at the top of the diagram but they are simply saying that:

Pilot, **Passenger** and **Air Traffic Controller** are roles of **Human**
Pilot, **Passenger**, **Air Traffic Controller** and **Flight** are specialisations of the generalization: **Insurable Item**

Importantly though for **Mixins**, things with the **Role** and **Relator** stereotypes are quite different but are still types of **Insurable Item**.

Note that although **Role** and **Relator** follow different identity principles, the **Mixin** cannot therefore provide an overarching identity principle.

By their nature, **Mixins** are a little too flexible so in some cases it helps to be a bit more specific about what is intended. There are therefore stereotypes called **PhaseMixin** and **RoleMixin**. As the names suggest, these apply only to subtypes of **Phases** and **Roles** respectively. For example, An **Individual Customer** and a **Corporate Customer** (both **Roles**) are types of **Customer** (a **RoleMixin**)

Mixins are used in ontologies to reuse patterns of properties and relationships across different concepts, promoting reuse without forcing strict hierarchical inheritance. By defining shared characteristics in a **Mixin**, a concept can "mix in" these properties, leading to more modular, maintainable, and expressive ontologies that can more accurately represent complex domain knowledge.

What We've Learned

In this episode we refreshed our memories on the modelling concepts introduced in the previous article covering:

- **Classes, Stereotypes, Generalizations and Relationships**
- The UFO concepts of **Kind**, **Role** and **Phase**

We then discussed the *Identity Principle* and covered the UFO **Mixin** concept in more detail through the example of an **Insurable Item**

In the next episode we will explore relationship stereotypes in more detail and cover the few remaining class stereotypes we've not mentioned so far. We'll do this by expanding our example to include aspects of flight planning.



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Old Number One: | El Caganer / Craig Howell, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons

Thracian soldiers: AI generated

OntoUML diagram: OWG provided as public domain

American Airlines Flight 965 crash scene: FAA, Public domain, via Wikimedia Commons

The Ontology Working Group (OWG)

The OWG was set up in 2020 to help address issues with the lack of formalisation in terms and conceptual relationships used in standards and guidance documents. In particular, the similar but at times different, interpretations of terms and concepts used between safety and security domains is an ongoing cause of confusion and misunderstandings and presents barriers to more formal integration of these disciplines.

The OWG has its origins in the Data Safety Initiative Working Group (DSIWG), which, between 2016 and 2019, explored the development of an ontology model for the concepts described in the Data Safety Guidance (DSG). However, it was realised that the work couldn't be completed without a wider ontological model for risk, and so the OWG was established and is currently working on developing a clear, systematic terminology, and unambiguous model of risk and value concepts and their relationships.