**Protocol for aligning SCO V1.0.0 to UFO**

**Aim**

To align the [Sustainability Core Ontology (SCO)](https://github.com/gioUbbiali/Sustainability-Core-Ontology) to the [Unified Foundational Ontology (UFO)](https://ontouml.readthedocs.io/en/latest/intro/ufo.html).

**SCO Description**

Sustainability is characterized by three major theoretical challenges (Ubbiali et al., 2024):

1. The polysemy of the term sustainability.
2. The relationship between sustainability and sustainable development.
3. The complexity underlying sustainability.

The Sustainability Core Ontology (SCO) is a middle-level ontology modeling those challenges with the purpose of establishing a core central hub to harmonize ontologies regarding sustainability.

Currently, SCO reuses [Basic Formal Ontology (BFO)](https://basic-formal-ontology.org/), one of the existing Top-level ontologies (TLOs), as the upper-level ontology. In doing so, it aligns with the ontological realism view, according to which BFO has been developed. See Arp et al. (2015) and Smith & Ceusters (2010) for details. Nevertheless, we consider it essential to commit SCO representation to other ontological views. This will assist in addressing sustainability consistently across communities and approaches. No matter which view has been chosen to design sustainability ontologies, a representation of sustainability theoretical challenges according to such a view will be available and developers can use it to support consistency. Further, this will support alignments across SCO-compliant sustainability ontologies that endorse different ontological views. Despite the discrepancies deriving from differences in the chosen ontological views, those ontologies will all account for the sustainability challenges, having a common converging point for integration.

Providing an overarching and domain-neutral representation of reality according to the endorsed ontological view, TLOs incarnate and exemplify such a view. Thus, SCO should align with alternative TLOs other than BFO, to access and leverage the different ontological views proposed by such ontologies. This seems the most coherent way to move toward the establishment of a core ontological hub that can effectively support the integration and interconnection of new and existing ontologies on sustainability.

This document describes the process of alignment of the Sustainability Core Ontology (SCO) to the [Unified Foundational Ontology (UFO)](https://ontouml.readthedocs.io/en/latest/intro/ufo.html), another existent TLO. UFO counts among the major internationally recognized TLOs. UFO has been constructed with reference to the General Formal Ontology (GFO) and the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), other two existing TLOs (Guizzardi et al., 2022). In addition, several ontologies that address domains of primary relevance to sustainability, such as resilience (Barcelos et al., 2025) and risk and value (Sales et al., 2018), employ UFO as the upper-level ontology. Thus, UFO seemed to us the ideal candidate from which to start to expand SCO representation.

The current working-in-progress version of SCO is SCO V1.1.0. SCO V1.1.0. is composed of two segments: SCO-B (B for BFO) and SCO-U (U for UFO). SCO-B aligns the SCO vocabulary with BFO (as SCO V1.0.0.). SCO-U aligns the SCO vocabulary with gUFO ([UFO implementation in the Web Ontology Language (OWL)](https://nemo-ufes.github.io/gufo/)). SCO V1.1.0. is formalized in [OWL](https://www.w3.org/TR/owl2-overview/) and covers three natural languages, English, French, and Italian. SCO V1.1.0. conforms to [OBO-Foundry principles](https://obofoundry.org/principles/fp-000-summary.html).

The most recent version of SCO is available on GitHub at the following link: <https://github.com/gioUbbiali/Sustainability-Core-Ontology.git>. The person responsible for SCO is [Giorgio A. Ubbiali.](mailto:Giorgio.Ubbiali@unimi.it)

**Methods and Materials**

SCO V1.0.0. covers two segments, SCO-B and SCO-U. We constructed these two segments as follows, using [Protégé](https://protege.stanford.edu/) ontology editor. See also the related [slide deck.](https://github.com/gioUbbiali/Sustainability-Core-Ontology/tree/SCO-Alignment-to-UFO/SCO/working%20materials)

**SCO-B**

SCO-B aligns with BFO. We opened a copy of SCO V1.0.1. in protégé, and revised ontology IRIs to correspond to the new ontology version. We also revised a few axioms that showed the need for adjustments, and we added some comments for future implementations. Please see the OWL file for details.

**SCO-U**

SCO-U aligns with UFO. In constructing this segment, we followed a *translation process*, i.e. we employed the existent BFO-compliant representation (SCO-B) as an initial guiding reference point to further design a UFO-compliant representation. We consider it noteworthy to clarify this point as certain advantages and disadvantages ensue. We had a starting account of sustainability challenges that was grounded in an ontologically sound representation of reality thereby supporting a consistent understanding of these challenges. In addition, proceeding as such promoted the exploration and construction of possible alignments between the two TLOs. On the other hand, however, UFO-compliant representation underwent the influence of the BFO-compliant representation, yielding possible slightly different results compared to if it had been started from scratch. Altogether, we decided to proceed as such because, having previously developed a BFO-compliant representation of sustainability challenges, our genuine interpretation of those challenges is filtered through that representation. We considered it more intellectually honest to openly recognize and endorse this standpoint and further deal with deriving benefits and drawbacks. We performed the following passages.

TO REVISE↓

1) in protégé, we imported [gUFO.ttl](https://nemo-ufes.github.io/gufo/gufo.ttl) file and SCO V1.0.0 in a new OWL file. This file contains both gUFO and BFO classes. SCO classes extend BFO classes.

2) We construct SCO hierarchy specializing and instantiating the gUFO “individual” and “type” class hierarchies as follows. We refer to [the gUFO documentation webpage](https://nemo-ufes.github.io/gufo/) and related UFO literature, such as Guizzardi (2005) and Guizzardi et al. (2022), for details regarding individual-type distinction, class specialization and instantiation, and more generally about UFO ontology theory. Here, we use the [SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) as an illustrative example.

1. Background assessment

We Evaluated the position of [the SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) in the BFO hierarchy, using the materials documented in the “references” slide of the [slide deck](https://github.com/gioUbbiali/Sustainability-Core-Ontology/tree/SCO-Alignment-to-UFO/SCO/working%20materials) as a reference point.

[The SCO “complex system” class](http://gioubbiali.github.io/sco/SCO_0000015) is a subclass of the [RO “system” class](http://purl.obolibrary.org/obo/RO_0002577) (subclass of [the BFO“material entity” class](http://purl.obolibrary.org/obo/BFO_0000040)).

1. Exploration of correspondences and construction of SCO-gUFO “individual” class hierarchy

We identified the rough corresponding class position into the gUFO “individual” class hierarchy, using the materials documented in the “references” slide of the [slide deck](https://github.com/gioUbbiali/Sustainability-Core-Ontology/tree/SCO-Alignment-to-UFO/SCO/working%20materials) as a reference point.

The [SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) specializes the ([RO “system” class](http://purl.obolibrary.org/obo/RO_0002577) that specializes the) [gUFO “object” class](http://purl.org/nemo/gufo#Object). In protégé we asserted the [RO “system” class](http://purl.obolibrary.org/obo/RO_0002577) as a subclass of the [gUFO “object” class](http://purl.org/nemo/gufo#Object).

1. Construction of SCO-gUFO “type” class hierarchy

We identified the “type” class that [the SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) instantiates into the gUFO “type” class hierarchy, using the materials documented in the “references” slide of the [slide deck](https://github.com/gioUbbiali/Sustainability-Core-Ontology/tree/SCO-Alignment-to-UFO/SCO/working%20materials) as a reference point.

The [SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) instantiates the [gUFO “subkind” class](http://purl.org/nemo/gufo#SubKind). In Protégé, we instantiated the [gUFO “subkind” class](http://purl.org/nemo/gufo#SubKind) with a [SCO “complex system” individual](http://gioUbbiali.github.io/sco/SCO_0000015) presenting the same URI of the [SCO “complex system” class](http://gioUbbiali.github.io/sco/SCO_0000015) ([Punning](https://nemo-ufes.github.io/gufo/)).

To deepen the representation of perspective, we imported classes and individuals used to represent tropes, modes, and dispositions, from the [Common Ontology of Value and Risk (COVER)](https://github.com/unibz-core/value-and-risk-ontology), as not presented in gUFO. See the [COVER imports](https://github.com/gioUbbiali/Sustainability-Core-Ontology/blob/SCO-Alignment-to-UFO/SCO/src/ontology/imports/SCO-U%20imports/COVER%20imports.owl) file.

To do

Axiomatization

Validation

All through the process of construction of SCO-U segment, we carried out discussions with subject matter experts.

The final release of SCO V1.1.0 can be found here: SCO-B, SCO-U.

**Future Implementations**

To do

**Get In Touch**

Please contact [Giorgio A. Ubbiali](mailto:giorgio.ubbiali@unimi.it) in case you wish to get involved and participate in the development of SCO.

**Bibliography**

* Arp, R., Smith, B., & Spear, A. D. (2015). *Building ontologies with Basic Formal Ontology*. Massachusetts Institute of Technology.
* F. Barcelos, P. P., Calhau, R. F., Oliveira, Í., Prince Sales, T., Gailly, F., Poels, G., & Guizzardi, G. (2025). Ontological Foundations of Resilience. In W. Maass, H. Han, H. Yasar, & N. Multari (A c. Di), *Conceptual Modeling* (Vol. 15238, pp. 396–416). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-75872-0\_21
* Guizzardi, G. (2005). *Ontological Foundations for Structural Conceptual Models*.
* Guizzardi, G., Botti Benevides, A., Fonseca, C. M., Porello, D., Almeida, J. P. A., & Prince Sales, T. (2022). UFO: Unified Foundational Ontology. *Applied Ontology*, *17*(1), 167–210. https://doi.org/10.3233/AO-210256
* Sales, T. P., Baião, F., Guizzardi, G., Almeida, J. P. A., Guarino, N., & Mylopoulos, J. (2018). The Common Ontology of Value and Risk. In J. C. Trujillo, K. C. Davis, X. Du, Z. Li, T. W. Ling, G. Li, & M. L. Lee (A c. Di), *Conceptual Modeling* (Vol. 11157, pp. 121–135). Springer International Publishing. https://doi.org/10.1007/978-3-030-00847-5\_11
* Smith, B., & Ceusters, W. (2010). Ontological realism: A methodology for coordinated evolution of scientific ontologies. *Appl. Ontol.*, *5*(3–4), 139–188.
* Ubbiali, G. A., Borghini, A., & Lange, M. C. (2024). *Ontologies for Sustainability: Theoretical Challenges*.