**SCO V1.1.0. development Protocol**

**Aim**

To implement the [Sustainability Core Ontology (SCO)](https://github.com/gioUbbiali/Sustainability-Core-Ontology) by establishing an SCO representation that is compliant with 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), two other existing TLOs (Guizzardi *et al.*, 2022). In addition, several ontologies that address domains of primary relevance to sustainability, such as resilience (Barcelos *et al.*, 2024) 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 existing 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 in Protégé. We imported [gUFO.ttl](https://nemo-ufes.github.io/gufo/gufo.ttl) file together with classes and individuals addressing dispositions, modes, and tropes from the [Common Ontology of Value and Risk (COVER)](https://github.com/unibz-core/value-and-risk-ontology), as required to consistently design SCO representation. See the SCO-U COVER import file. UFO theorizes for such entities, but gUFO does not provide related classes. Precisely, imports have been performed in a copy of SCO V1.0.1. where ontology IRIs were revised to correspond to the new ontology version, and in the later development stages, BFO imports and the related axiomatization were deleted. We proceeded as such to limit possible inconsistencies and support the translation process. The final version of the SCO-U segment does not include materials from the SCO-B segment.

Subsequently, we constructed the SCO-U taxonomical hierarchy, extending g[UFO](https://nemo-ufes.github.io/gufo/). We employed the BFO-compliant hierarchy as a starting guiding point, and we referred to the publication listed in the “SCO-U reference file”. We evaluated the SCO is\_A (specialization) hierarchy extending BFO. We identified the adequate and most corresponding position for SCO classes within the gUFO “individual” class hierarchy, and we specialized it accordingly. We further instantiated the “type” class hierarchies for SCO classes ([punning](https://nemo-ufes.github.io/gufo/)). SCO-U and SCO-B hierarchies are in accordance.

Next, we established SCO-U axiomatization. Once more, we employed the BFO-compliant representation of SCO as a starting guiding point, and we referred to the publication listed in the “SCO-U reference file”. We evaluated the SCO axiomatization according to BFO. We constructed adequate and corresponding axioms. When gUFO object properties were sufficient, we employed them. If the need arose, we created new object properties. Similarly, to ensure a satisfactory representation, we also needed to create a few novel classes. For instance, a model of system agency that was compliant with UFO required the inclusion of gUFO “situation” classes. Representing information dependency, instead, required both the creation of novel specific object properties and gUFO “situation” classes. See directly the SCO-U OWL file for details and related comments. SCO-U and SCO-B axiomatizations are in accordance.

We finally created definitions, using SCO-B as a reference point and following Arp et al. (2015) and Smith (2013) recommendations. SCO-U and SCO-B definitions are in accordance. Several comments for implementations have been added to the OWL file. When judged relevant, we reported these considerations in the SCO-B file as well. See directly SCO OWL files for details.

**Validation**

We validated SCO-B and SCO-U. using Protégé automatic reasoners ELK 0.5.0 and HermiT 1.4.3.456. No logic inconsistencies were detected. We further verify SCO-U using [the protégé plugin of UFO validation rules](https://github.com/nemo-ufes/ufo-protege-plugin). See the annotations to SCO-U in the ontology file for details on this point. During the entire process of construction of the SCO-U segment, we also carried out discussions with subject matter experts.

**Mapping between SCO-B and SCO-U**

We constructed the mapping between SCO-U and SCO-B using the [SKOS Vocabulary](https://www.w3.org/2004/02/skos/). We referred to the publication listed in the “SCO-U reference file” to ensure consistency in mapping. We punned SCO-B classes to treat them as individuals, and we instantiated SKOS “concept” class with both SCO-U and SCO-B punned classes. SCO-U already includes classes treated as individuals (see previous paragraphs). We further used SKOS mapping object properties to establish the mapping between the two SCO V1.1.0. segments.

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

**Future Implementations**

We envision the following implementations for SCO V1.1.0. In the near future, SCO V1.1.0. may include additional segments, aligning with other TLOs, such as the [Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)](https://www.loa.istc.cnr.it/dolce/overview.html). Further, we envisage expanding the current SCO representation to cover additional features relating to sustainability and complexity, such as system behaviors, scales and levels of analysis, and change. The works of Calhau *et al.* (2023) and Calhau *et al.* (2024) may be a source of insights to drive these latter implementations.

**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.

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