Natural language specification of BFO 2020

Buffalo Developers Group

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1. Introduction

This clause documents the signature of BFO 2020, satisfying requirement ISO/IEC 21838-1:2020, 4.1. This signature shall be used in determining conformance to BFO 2020 in the sense defined in Clause 4. Primitive terms and primitive relational expressions in this signature are marked by the fact that they are provided with <u>elucidations</u>.

BFO 2020 is the version of Basic Formal Ontology that has been created to conform to the requirements in ISO/IEC 21838-1.

1.1 Syntax

— 'a', '*b*', '*c*', 'etc., for particulars

— '*t*,' '*t*'', etc., for temporal regions; expressions such as 'for all times' should be interpreted as meaning 'for all temporal regions'

— '*r*,' '*r*'', '*s*,' '*s*'', etc., for spatial and spatiotemporal regions

— 'A', 'B', '*C*', '*P*', etc. for universals or types ('type' and 'universal' are treated as synonyms)

— '*R*', *R*'', etc. for relations.

1.2 Relations and relational expressions

All relational expressions defined in BFO 2020 have a binary core; some have in addition a third relatum, which is in every case an **instance of** *temporal region* and which is marked syntactically by use of '**at**'. Three types of binary core are distinguished, as follows:

— connecting a particular to a particular, expressed using **bold face**;

— connecting a particular to a universal, expressed using **bold face**;

— connecting a universal to a universal, expressed using *italics*.

In some definitions, relational expressions are divided into separate strings for the sake of readability, as in: '**spatial region** *r* which *b* **occupies at** *t*', which includes the relational expression '**occupies spatial region at**'.

1.3 Primitive and defined terms

For both terms and relational expressions in BFO, there is a distinction between *primitive* and *defined*. 'Entity' is an example of a primitive term. Primitive terms in a top-level ontology such as BFO are

terms that are so basic to our understanding of reality that there is no way of defining them in a non-circular fashion.

By 'definitional content' is meant, in the terminology of ISO/IEC 21838-1:2020, 4.1.1, a set of both primitive and non-primitive definitions. The former are referred to here as 'elucidations', the latter as 'definitions'. An elucidation thus corresponds to a definition that is marked as primitive in the sense of ISO/IEC 21838-1:2020, 4.1.1. Both definitions and elucidations are supplemented by examples.

In ISO/IEC documents, the definition (definiens) of a term is a text string or formula that can replace the defined term (definiendum) in its original context. As understood in the BFO context, however, a definiens shall in addition satisfy the conditions.

1. that it is built out of terms and relational expressions that are logically more primitive than the definiendum, and either:

   a) that it provides a statement of individually necessary and jointly sufficient conditions for an entity to fall under the universal or defined class to which the definiendum refers (in the case where the definiendum is a term), or

   b) that it provides a statement of individually necessary and jointly sufficient conditions for a relation to hold (in the case where the definiendum is a relational expression).

An elucidation, in contrast, provides a statement of necessary conditions only.

Those parts of the document which belong to the definitional content are indicated by special formatting, following the patterns:

— Definition: X =Def. Y [000-BFO]

— Elucidation: an X is a Y (or some similar expression) [000-BFO]

where the three digits in '[000-BFO]' serve to identify the salient definition or elucidation.

1.4 Domain and range

All relations in the signature of BFO 2020 are binary or ternary. Domain and range are used to describe the types instantiated by the first and second relata of each relation, respectively. If the relation holds, then it follows that the first and second relata are instances of one of the types specified under domain and range. The third relatum, if present, is always an instance of *temporal region*. Binary versions of all ternary relations are provided for use in OWL.

1.5 Binaryized versions of ternary relational expressions for use in BFO 2020-OWL

The relational expressions in A.1.3 are provided as binary counterparts of the corresponding BFO 2020 relational expressions for use in OWL, which requires that all relations be binary. Domain and range are in every case the same as for the ternary counterpart. All binaryized versions have definitions, even where the base relation receives only an elucidation in A.1.2, because this base relation is used to build the corresponding definitions.

2 BFO 2020 terms, definitions and elucidations

2.1 entity

Elucidation: An *entity* is anything that exists or has existed or will exist [001-BFO]

EXAMPLES   Julius Caesar, the Second World War, your body mass index, Verdi's *Requiem*.

2.2 *is a*

Definition: *A **is a** B* =Def. for all *x*, *t*, if *x* is an **instance of** *A* **at** *t* then *x* is an **instance of** *B* **at** *t* [140-BFO]

Domain: universal

Range: universal

EXAMPLES   House is a building, symphony is a musical work of art, promenade is a dance step, promise is a speech act, cell division is a biological process.

2.3 instance of at

Synonym: **instantiates**

Elucidation: *relation* (3.2) that holds between a *particular* (3.5) and a *universal* (3.6) at a time [200-BFO]

Domain: *particular*

Range: *universal*

EXAMPLES   John instance of human, this laptop instance of laptop; the year 2012 instance of temporal region; John's birth instance of process, all at time: now.

NOTE   Instantiation relations for occurrents hold trivially at every time at which the occurrent exists.

2.4 exists at

Elucidation: **exists at** is a relation between a particular and some *temporal region* **at** which the particular **exists** [118-BFO]

Domain: *entity*

Range: *temporal region*

EXAMPLES   First World War exists at 1914-1916, Mexico exists at January 1, 2000.

2.5 continuant part of at

Elucidation: *b* **continuant part of** *c* **at** *t* means: *b* and *c* are *continuants* & *b* is a part of *c* at *t* [002-BFO]

Domain: *continuant*

Range: *continuant*

EXAMPLES   Mary's arm continuant part of Mary in the time of her life prior to her operation; the Northern hemisphere of the planet Earth is a continuant part of the planet Earth at all times at which the planet Earth exists.

NOTE   For A.1.2.5 (and also A.1.2.6) elucidations are provided because the informal expression 'part' is used in both definiens and definiendum.

2.6 has continuant part at

Definition: *b* **has continuant part** *c* **at** *t* =Def. *b* and *c* are *continuants* & *b* is a **continuant part of** *c* **at** *t* [201-BFO]

Domain: *continuant*

Range: *continuant*

EXAMPLES   Planet Earth has continuant part Equator.

2.7 occurrent part of

Elucidation: *b* **occurrent part of** *c* means: *b* is a part of *c* & *b* and *c* are *occurrents* [003-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   Mary's 5th birthday is an occurrent part of Mary's life; the first set of the tennis match is an occurrent part of the tennis match.

2.8 has occurrent part

Definition: *b* **has occurrent part** *c* =Def. *c* is a **occurrent part of** *b* & *b* and *c* are *occurrents* [202-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   Mary's life has occurrent part Mary's 5th birthday.

2.9 proper continuant part of at

Definition: *b* **proper continuant part of** *c* **at** *t* =Def. *b* **continuant part of** *c* **at** *t* & not (*c* **continuant part of** *b* **at** *t*) [004-BFO]

Domain: *continuant*

Range: *continuant*

EXAMPLES   As for A.1.2.5.

2.10 has proper continuant part at

Definition: *b* **has proper continuant part** *c* **at** *t* =Def. *c* **proper continuant part of** *b* **at** *t* [203-BFO]

Domain: *continuant*

Range: *continuant*

EXAMPLES   As for A.1.2.6.

2.11 proper occurrent part of

Definition: *b* **proper occurrent part of** *c* =Def. *b* **occurrent part of** *c* & *b* and *c* are not identical [005-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   As for A.1.2.7.

2.12 has proper occurrent part

Definition: *b* **has proper occurrent part** *c* =Def. *b* **has occurrent part** *c* & *b* and *c* are not identical [154-BFO]

Domain: *continuant*

Range: *continuant*

EXAMPLES   As for A.1.2.8.

2.13 continuant

Elucidation: A *continuant* is an *entity* that persists, endures, or continues to exist through time while maintaining its identity [008-BFO]

EXAMPLES   A human being, a tennis ball, a cave, a region of space, someone's temperature.

2.14 specifically depends on

Synonym: **s-depends on**

Elucidation: *b* **specifically depends on** *c* means:

b and *c* do not share common parts

& *b* is of a nature such that at all times *t* it cannot **exist at** *t* unless *c* **exists at** *t* & *b* is not a boundary of *c* [012-BFO]

Domain: *specifically dependent continuant*

Range: *independent continuant* that is not a *spatial region; specifically dependent continuant*

EXAMPLES   A shape s-depends on the shaped object, hue, saturation and brightness of a colour sample s-depend on each other.

NOTE   The analogue of **s-dependence** for *occurrents* is **has participant**.

2.15 specifically depended on by

Synonym: **s-depended on by**

Definition: *b* **s-depended on by** *c* =Def. *c* **specifically depends on** *b* [260-BFO]

Domain: *independent continuant* that is not a *spatial region; specifically dependent continuant*

Range: *specifically dependent continuant*

EXAMPLES   Coloured object s-depended on by colour.

2.16 independent continuant

Definition: *b* is an *independent continuant* =Def. *b* is a *continuant* which is such that there is no *c* such that *b* **s-depends on** *c* and no *c* such that *b* **g-depends on** *c* [017-BFO]

EXAMPLES   An atom, a molecule, an organism, a heart, a chair, the bottom right portion of a human torso, a leg; the interior of your mouth; a spatial region; an orchestra.

2.17 material entity

Elucidation: A *material entity* is an *independent continuant* that at all *times* **at** which it **exists** has some portion of matter as **continuant part** [019-BFO]

EXAMPLES   A human being, the undetached arm of a human being, an aggregate of human beings.

2.18 object

Elucidation: an *object* is a *material entity* which manifests causal unity & is of a *type* **instances of** which are maximal relative to the sort of causal unity manifested [024-BFO]

EXAMPLES   An organism, a fish tank, a planet, a laptop, a valve, a block of marble, an ice cube.

NOTE   A description of three primary sorts of causal unity is provided in Reference [6].

2.19 member part of at

Definition: *b* **member part of** *c* **at** *t* =Def. *b* is an *object*

& *c* is an *object aggregate*

& there is **at** *t* a mutually exhaustive and pairwise disjoint partition of *c* into *objects* $x_1, ..., x_n$ (for some $n \geq 1$) with $b = x_i$ (for some $1 \leq i \leq n$) [026-BFO]

Domain: *object*

Range: *object aggregate*

EXAMPLES   Each tree in a forest is a member part of the forest; each piece in a chess set is a member part of the chess set; each Beatle in the collection called *The Beatles* is a member part of *The Beatles*; each human being is a member part of the population *homo sapiens*; employee of an industrial company.

2.20 has member part at

Definition: *b* **has member part** *c* **at** *t* =Def. *c* **member part** *b* **at** *t* [204-BFO]

Domain: *object aggregate*

Range: *object*

EXAMPLES   As for A.1.2.19.

2.21 object aggregate

Elucidation: an *object aggregate* is a *material entity* consisting exactly of a plurality (≥1) of *objects* as **member parts** which together form a unit [025-BFO]

EXAMPLES   A symphony orchestra, the aggregate of bearings in a constant velocity axle joint, the nitrogen atoms in the atmosphere, a collection of cells in a blood biobank.

NOTE 1   'Exactly' means that there are no parts of the object aggregate other than its member parts.

NOTE 2   The unit can, at certain times, consist of exactly one object, for example, when a fire brigade loses all but one of its members, but it must at some time have a plurality of member parts.

2.22 fiat object part

Elucidation: a *fiat object part b* is a *material entity* which is such that

for all times *t*, if *b* **exists at** *t* then

there is some object *c* such that *b* is a **proper continuant part** of *c* **at** *t* and *b* is demarcated from the remainder of *c* by one or more fiat surfaces [027-BFO]

EXAMPLES   The upper and lower lobes of the left lung, the dorsal and ventral surfaces of the body, the Western hemisphere of the Earth, the FMA:*regional parts* of an intact human body.

2.23 immaterial entity

Definition: *a* is an *immaterial entity* =Def. *a* is an *independent continuant* which is such that there is no time *t* when it has a *material entity* as **continuant part at** *t* [028-BFO]

EXAMPLES   As for A.1.2.25 through A.1.2.28.

2.24 continuant fiat boundary

Elucidation: *b* is a *continuant fiat boundary* means: *b* is an *immaterial entity* that is of zero, one or two dimensions, which is such that there is no time *t* when *b* has a *spatial region* as **continuant part at** *t*, and whose location is determined in relation to some *material entity* [029-BFO]

EXAMPLES   As for A.1.2.25 through A.1.2.27.

2.25 fiat point

Elucidation: a *fiat point* is a zero-dimensional *continuant fiat boundary* that consists of a single point [031-BFO]

EXAMPLES   The geographic North Pole; the quadripoint where the boundaries of Colorado, Utah, New Mexico and Arizona meet, the point of origin of some spatial coordinate system.

2.26 fiat line

Elucidation: a *fiat line* is a one-dimensional *continuant fiat boundary* that is continuous [032-BFO]

EXAMPLES   The Equator, all geopolitical boundaries, all lines of latitude and longitude, the median sulcus of your tongue, the line separating the outer surface of the mucosa of the lower lip from the outer surface of the skin of the chin.

2.27 fiat surface

Elucidation: a *fiat surface* is a two-dimensional *continuant fiat boundary* that is self-connected [033-BFO]

EXAMPLES   The surface of the Earth, the plane separating the smoking from the non-smoking zone in a restaurant, the surface of the moon, the boundary between the upper and lower hemisphere of the moon, the surface of a tennis ball, the surface of a tabletop.

2.28 site

Elucidation: *b* is a *site* means: *b* is a three-dimensional *immaterial entity* whose boundaries either (1) (partially or wholly) coincide with the boundaries of one or more *material entities* or (2) have locations determined in relation to some *material entity* [034-BFO]

EXAMPLES 1 A hole in a portion of cheese, a rabbit hole, the Grand Canyon, the Piazza San Marco, the kangaroo-joey-containing hole of a kangaroo pouch, your left nostril (a fiat part – the opening – of your left nasal cavity), the lumen of your gut, the hold of a ship, the interior of the trunk of your car, a hole in an engineered floor joist.

EXAMPLES 2 An air traffic control region of type A is determined in terms of elevation above mean sea level of lower and upper boundaries.

2.29 spatial region

Elucidation: A *spatial region* is a *continuant entity* that is a **continuant part of** the spatial projection of a portion of spacetime at a given time [035-BFO]

EXAMPLES   As for A.1.2.30 through A.1.2.33.

2.30 zero-dimensional spatial region

Elucidation: A *zero-dimensional spatial region* is one or a collection of more than one spatially disjoint points in space [037-BFO]

EXAMPLES   The spatial region occupied at some time instant by the North Pole.

2.31 one-dimensional spatial region

Elucidation: A *one-dimensional spatial region* is a whole consisting of a line together with zero or more lines and/or points as parts [038-BFO]

EXAMPLES   An edge of a cube-shaped portion of space, a line connecting two points, two parallel lines extended in space.

2.32 two-dimensional spatial region

Elucidation: A *two-dimensional spatial region* is a *spatial region* that is a whole consisting of a surface together with zero or more surfaces and/or *spatial regions* of lower dimension as parts [039-BFO]

EXAMPLES   The surface of a sphere-shaped part of space, an infinitely thin plane in space.

2.33 three-dimensional spatial region

Elucidation: A *three-dimensional spatial region* is a whole consisting of a spatial volume together with zero or more spatial volumes and/or *spatial regions* of lower dimension as parts [040-BFO]

EXAMPLES   A cube-shaped region of space, a sphere-shaped region of space, the region of space occupied by all and only the planets in the solar system at some point in time.

2.34 occupies spatial region at

Elucidation: an *independent continuant c* that is not a *spatial region* **occupies spatial region** *r* **at** *t* means: every **continuant part of** *c* **occupies** some **continuant part of** *r* **at** *t* and no **continuant part of** *c* **occupies** any *spatial region* that is not a **continuant part of** *r* **at** *t* [041-BFO]

Domain: *independent continuant* that is not a *spatial region*

Range: *spatial region*

EXAMPLES   Part of Amundsen's foot occupies the spatial region that is the South Pole at (some temporal instant in the temporal region) December 14, 1911.

NOTE   'Occupies' here means: exact occupation.

2.35 located in at

Definition: *b* **located in** *c* **at** *t* =Def. *b* and *c* are *independent continuants* and not *spatial regions*, and the *spatial region* which *b* **occupies at** *t* is a (proper or improper) **continuant part of** the *spatial region* which *c* **occupies at** *t* [045-BFO]

Domain: *independent continuant* that is not a *spatial region*

Range: *independent continuant* that is not a *spatial region*

EXAMPLES   Your arm is located in your body; this stem cell is located in this portion of bone marrow; this portion of cocaine is located in this portion of blood; Mary is located in Salzburg; the Empire State Building is located in New York.

2.36 location of at

Definition: *b* **location of** *c* **at** *t* =Def. *c* ***located in*** *b* ***at*** *t* [*205*-BFO]

Domain: *independent continuant* that is not a *spatial region*

Range: *independent continuant* that is not a *spatial region*

EXAMPLES   Manhattan location of Mary during the time of her wedding.

2.37 specifically dependent continuant

Definition: *b* is a *specifically dependent continuant* =Def. *b* is a *continuant*

& there is some *independent continuant c*

which is not a *spatial region*

& which is such that *b* **s-depends on** *c* [050-BFO]

EXAMPLES   (with one bearer) The mass of this tomato, the pink colour of a medium rare piece of grilled filet mignon at its centre, the smell of this portion of mozzarella, the disposition of this fish to decay, the role of being a doctor, the function of this heart: to pump blood, the shape of this hole; (with multiple bearers:) John's love for Mary, the ownership relation between John and this statue, the relation of authority between John and his subordinates.

NOTE   On the multiple bearers case, see A.1.2.41.

2.38 inheres in

Definition: *b* **inheres in** *c* =Def. *b* is a *specifically dependent continuant* & *c* is an *independent continuant* that is not a *spatial region* & *b* **s-depends on** *c* [051-BFO]

Domain: *specifically dependent continuant*

Range: *independent continuant* that is not a *spatial region*

EXAMPLES   A shape inheres in a shaped object; a mass inheres in a material entity.

2.39 bearer of

Definition: *b* **bearer of** *c* =Def. *c* **inheres in** *b* [053-BFO]

Domain: *independent continuant* that is not a *spatial region*

Range: *specifically dependent continuant*

EXAMPLES   A patch of ink is the bearer of a colour quality; an organism is the bearer of a temperature quality.

2.40 quality

Elucidation: a *quality* is a *specifically dependent continuant* that, in contrast to *roles* and *dispositions*, does not require any further *process* in order to be realized [055-BFO]

EXAMPLES   The colour of a tomato, the ambient temperature of this portion of air, the length of the circumference of your waist, the shape of your nose, the shape of your nostril, the mass of this piece of gold.

2.41 relational quality

Definition: *b* is a *relational quality* =Def. *b* is a *quality* and there exists *c* and *d* such that *b* and *c* are not identical, & *b* **s-depends on** *c* & *b* **s-depends on** *d* [057-BFO]

EXAMPLES   A marriage bond, an instance of love, an obligation between one person and another.

2.42 realizable entity

Elucidation: *b* is a *realizable entity* means: *b* is a *specifically dependent continuant* that **inheres** in some *independent continuant* which is not a *spatial region* and is of a *type* some instances of which are **realized** in *processes* of a correlated *type* [058-BFO]

EXAMPLES   The role of being a doctor, the role of this boundary to delineate where Utah and Colorado meet, the function of your reproductive organs, the disposition of your blood to coagulate, the disposition of this piece of metal to conduct electricity.

2.43 realizes

Elucidation: *b* **realizes** *c* means:

there is some *material or immaterial entity d*

& *c* is a *realizable entity* that **inheres** in *d*

& for all *t*, if *b* **has participant** *d* **at** *t* then *c* **exists at** *t*

& the type **instantiated by** *b* is correlated with the type **instantiated by** *c* [059-BFO]

Domain: *process*

Range: *realizable entity*

EXAMPLES   A disposition to go bald is realized in a balding process; a role of student is realized in studying processes; the pumping function of a heart is realized in processes of pumping.

2.44 has realization

Definition: *b* **has realization** *c* =Def. *c* **realizes** *b* [206-BFO]

Domain: *realizable entity*

Range: *process*

EXAMPLES   As for A.1.2.43.

2.45 role

Synonym: externally-grounded realizable entity

Elucidation: *b* is a *role* means:

b is a *realizable entity*

& *b* exists because there is some single bearer that is in some special physical, social, or institutional set of circumstances in which this bearer does not have to be

& *b* is not such that, if it ceases to exist, then the physical make-up of the bearer is thereby changed [061-BFO]

EXAMPLES   The priest role, the student role, the role of subject in a clinical trial, the role of a stone in marking a property boundary, the role of a boundary to demarcate two neighbouring administrative territories, the role of a building in serving as a military target.

2.46 disposition

Synonym: internally-grounded realizable entity

Elucidation: *b* is a *disposition* means:

b is a *realizable entity*

& *b*'s bearer is some *material* or *immaterial entity*

& *b* is such that if it ceases to exist, then its bearer is physically changed,

& *b*'s realization occurs when and because this bearer is in some special physical circumstances,

& this realization occurs in virtue of the bearer's physical make-up [062-BFO]

EXAMPLES   An atom of element X has the disposition to decay to an atom of element Y; the cell wall is disposed to transport cellular material through endocytosis and exocytosis; certain people have a predisposition to colon cancer; children are innately disposed to categorize objects in certain ways.

2.47 function

Elucidation: A *function* is a *disposition* that exists in virtue of the bearer's physical make-up and this physical make-up is something the bearer possesses because it came into being, either through evolution (in the case of natural biological entities) or through intentional design (in the case of artefacts), in order to realize processes of a certain sort [064-BFO]

EXAMPLES   The function of a hammer to drive in nails, the function of a heart pacemaker to regulate the beating of a heart through electricity.

2.48 has material basis at

Elucidation: *b* **has material basis** *c* **at** *t* means:

b is a *disposition*

& *c* is a *material entity*

& there is some *d* **bearer of** *b*

& *c* **continuant part of** *d* **at** *t*

& *d* **bearer of** *b* because *c* **continuant part of** *d* **at** *t* [071-BFO]

Domain: *disposition*

Range: *material entity*

EXAMPLES   The disposition of a portion of saliva to break down starch has material basis portion of amylase; the disposition of the suspension system of my car to squeak has material basis bushings in the system's joints.

2.49 material basis of at

Definition: *b* **material basis of** *c* **at** *t* =Def. *c* **has material basis** *b* [214-BFO]

Domain: *independent continuant* that is not a *spatial region*

Range: *disposition*

EXAMPLES   The material basis of the disposition of the rocket to move is its engine and the fuel supply,

2.50 generically dependent continuant

Synonym: **g-dependent continuant**

Elucidation: a *generically dependent continuant* is an *entity* that exists in virtue of the fact that there is at least one of what may be multiple copies; it is the content or the pattern that the multiple copies share [074-BFO]

EXAMPLES   The pdf file on your laptop, the pdf file that is a copy thereof on my laptop; the sequence of this protein molecule; the sequence that is a copy thereof in that protein molecule; the content that is shared by a string of dots and dashes written on a page and the transmitted Morse code signal; the content of a sentence; an engineering blueprint.

2.51 generically depends on at

Synonym: **g-depends on**

Elucidation: a *g-dependent continuant b* **g-depends on** an *independent continuant c* **at** *t* means: there **inheres** in *c* an *s-dependent continuant* which **concretizes** *b* **at** *t* [072-BFO]

Domain: *generically dependent continuant*

Range: *independent continuant* that is not a *spatial region*

EXAMPLES   The pattern shared by chess boards g-depends on any chess board; the score of a symphony g-depends on a copy of the score, the novel *War and Peace* generically depends on this copy of the novel; this pdf file generically depends on this server.

2.52 is carrier of at

Elucidation: *b* **is carrier of** *c* **at** *t* means: *c* ***g-depends*** **on** *b* **at** *t* [262-BFO]

Domain: *independent continuant* that is not a spatial region

Range: *generically dependent continuant*

EXAMPLES   This hard drive is carrier of these data items; this copy of *War and Peace* is carrier of the novel written by Tolstoy; molecules of DNA are carriers of genetic information.

2.53 concretizes at

Elucidation: an *s-dependent continuant* or *process b* **concretizes** a *g-dependent continuant c* **at** *t* when *c* is the pattern or content which *b* shares with actual or potential copies [207-BFO]

Domain: *specifically dependent continuant, process*

Range: *generically dependent continuant*

EXAMPLES   The sum of patterns of ink on the pages of this copy of *War and Peace* concretizes the novel written by Tolstoy.

2.54 is concretized by at

Elucidation: a *g-dependent continuant c* **at** *t* **is concretized by** an *s-dependent continuant* or *process b* when *b* **concretizes** *c* [208-BFO]

Domain: *generically dependent continuant*

Range: *specifically dependent continuant, process*

EXAMPLES   This set of dots and dashes concretizes this Morse code message.

2.55 occurrent

Elucidation: An *occurrent* is an *entity* that unfolds itself in time or it is the start or end of such an *entity* or it is a *temporal* or *spatiotemporal region* [077-BFO]

EXAMPLES   As for A.1.2.66, A.1.2.67, A.1.2.70, A.1.2.73, A.1.2.75 through A.1.2.78.

2.56 temporal part of

Definition: *b* **temporal part of** *c* =Def. *b* **occurrent part of** *c*

& either

b and *c* are *temporal regions*

or

b and *c* are *spatiotemporal regions* & *b* **temporally projects onto** an **occurrent part of** *the temporal region* that *c* **temporally projects onto**

or

b and *c* are *processes* or *process boundaries* & *b* **occupies** a **temporal region** that is an **occurrent part of** the *temporal region* that *c* **occupies** [078-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   Your heart beating from 4pm to 5pm today is a temporal part of the *process* of your heart beating; the 4th year of your life is a temporal part of your life, as is the process boundary which separates the 3rd and 4th years of your life; the first quarter of a game of football is a temporal part of the whole game.

2.57 has temporal part

Definition: *b* **has temporal part** *c* =Def. *c* **temporal part of** *b* [211-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   Your life has temporal part the first year of your life.

2.58 proper temporal part of

Definition: *b* **proper temporal part of** *c* =Def. *b* **temporal part of** *c* & not (*b* = *c*) [116-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   As for A.1.2.56.

2.59 has proper temporal part

Definition: *b* **has proper temporal part** *c* =Def. *c* **proper temporal part of** *b* [212-BFO]

Domain: *occurrent*

Range: *occurrent*

EXAMPLES   As for A.1.2.57.

2.60 temporally projects onto

Elucidation: **temporally projects onto** is a relation between a *spatiotemporal region s* and some *temporal region* which is the temporal extent of *s* [080-BFO]

Domain: *spatiotemporal region*

Range: *temporal region*

EXAMPLES   The world line of a particle temporally projects onto the temporal region extending from the beginning to the end of the existence of the particle.

2.61 spatially projects onto at

Elucidation: *b* **spatially projects onto** *c* **at** *t* means: *b* is a *spatiotemporal region* and *c* is a *spatial region* and *c* is the spatial extent of *b* at *t*) [081-BFO]

Domain: *spatiotemporal region*

Range: *spatial region*

EXAMPLES   The world line of a particle spatially projects at *t* onto the spatial region occupied by the particle at *t.*

2.62 occupies spatiotemporal region

Elucidation: *p* **occupies spatiotemporal region** *s* is a relation between an *occurrent p* and the *spatiotemporal region s* which is its spatiotemporal extent [082-BFO]

Domain: *process or process boundary*

Range: *spatiotemporal region*

EXAMPLES   A particle emitted by a nuclear reactor occupies the spatiotemporal region which is its trajectory.

2.63 occupies temporal region

Definition: *p* **occupies temporal region** *t* =Def. the *spatiotemporal region* occupied by *p* **temporally projects onto** *t* [132-BFO]

Domain: *process* or *process boundary*

Range: *temporal region*

EXAMPLE   The Second World War occupies the temporal region September 1, 1939 – September 2, 1945.

2.64 occurs in

Definition: *b* **occurs in** *c* =Def. *b* is a *process* or a *process boundary* and *c* is a *material entity or immaterial entity*

& there exists a *spatiotemporal region r* and *b* **occupies spatiotemporal region** *r*

& for all *t*, if *b* **exists at** *t* then *c* **exists at** *t*

& there exist *spatial regions s* and *s'* where

b **spatially projects onto** *s* **at** *t*

& *c* **occupies spatial region** *s'* **at** *t*

& *s* is a **continuant part of** *s'* **at** *t* [143-BFO]

Domain: *process or process boundary*

Range: *material entity* or *immaterial entity* but not *spatial region*

EXAMPLES   A process of digestion occurs in the interior of an organism, a process of loading artillery rounds into a tank cannon occurs in the interior of the tank.

2.65 environs

Definition: *b* **environs** *c* =Def. *c* **occurs in** *b* [267-BFO]

Domain: *material entity* or *immaterial entity* but not *spatial region*

Range: *process* or *process boundary*

EXAMPLES   Mouth environs process of mastication, city environs traffic.

2.66 process

Elucidation: *p* is a *process* =Def. *p* is an *occurrent* that **has** some **temporal proper part** and for some time *t*, *p* **has** some *material entity* as **participant** [083-BFO]

EXAMPLES   An act of selling, the life of an organism, a process of sleeping, a process of cell-division, a beating of the heart, a process of meiosis, the taxiing of an aircraft, the programming of a computer.

2.67 history

Elucidation: A *history* is a *process* that is the sum of the totality of *processes* taking place in the *spatiotemporal region* occupied by the material part of a *material entity* [138-BFO]

EXAMPLE   The life of an organism from the beginning to the end of its existence.

2.68 history of

Elucidation: *b* **history of** *c* if *c* is a *material entity* and *b* is a *history* that is the unique *history* of *c* [144-BFO]

Domain: *history*

Range: *material entity*

EXAMPLE   This life is the history of this organism.

2.69 has history

Definition: *b* **has history** *c* =Def. *c* **history of** *b* [145-BFO]

Domain: *material entity*

Range: *history*

EXAMPLE   This organism has history this life.

2.70 process boundary

Definition: *p* is a *process boundary* =Def. *p* is a **temporal part** of a *process* & *p* **has** no **proper temporal parts** [084-BFO]

EXAMPLE   The boundary between the 2nd and 3rd year of your life.

2.71 has participant at

Elucidation**:** *p* h*as* **participant** *c* **at** *t* means: *b* is a *process*, *c* is a *continuant*, and *c* **participates in** *p* some way **at** *t* [086-BFO]

Domain**:** *process*

Range**:** *continuant* that is not a *spatial region*

EXAMPLES   Cruise has participant ship, Second World War has participant Germany, data transformation has participant body of data.

2.72 participates in at

Definition: *b* **participates in** *p* **at** *t* =Def. *p* **has participant** *b* **at** *t* [210-BFO]

Domain: *continuant* that is not a *spatial region*

Range: *process*

EXAMPLES   Field participates in soil erosion, student participates in studying.

2.73 spatiotemporal region

Elucidation: A *spatiotemporal region* is an *occurrent* that is an **occurrent part** of spacetime [095-BFO]

NOTE   'Spacetime' here refers to the maximal instance of the universal *spatiotemporal region.*

EXAMPLES   The spatiotemporal region occupied by the development of a cancer tumour, the spatiotemporal region occupied by an orbiting satellite.

2.74 temporal region

Elucidation: A *temporal region* is an *occurrent* over which processes can unfold [100-BFO]

EXAMPLES   As for A.1.2.75 and A.1.2.76.

2.75 zero-dimensional temporal region

Elucidation: A *zero-dimensional temporal region* is a *temporal region* that is a whole consisting of one or more separated *temporal instants* as parts [102-BFO]

EXAMPLES   A temporal region that is occupied by a process boundary; the moment at which a finger is detached in an industrial accident.

2.76 one-dimensional temporal region

Elucidation: A *one-dimensional temporal region* is a *temporal region* is a whole that has a *temporal interval* and zero or more *temporal intervals* and *temporal instants* as parts [103-BFO]

EXAMPLE   The temporal region during which a process occurs.

2.77 temporal interval

Elucidation: a *temporal interval* is a *one-dimensional temporal region* that is continuous, thus without gaps or breaks [155-BFO]

EXAMPLE   The year 2018.

NOTE   A one-dimensional temporal region can include as parts not only temporal intervals but also temporal instants separated from other parts by gaps.

2.78 temporal instant

Elucidation: a *temporal instant* is a *zero-dimensional temporal region* that **has** no **proper temporal part** [209-BFO]

EXAMPLE   The millennium.

2.79 first instant of

Definition: *temporal instant t* **first instant of** *temporal region t′* =Def. *t* **precedes** all **temporal parts of** *t′* other than *t* [268-BFO]

Domain**:** *temporal instant*

Range**:** *temporal region*

EXAMPLE   An hour starting at midnight yesterday has first instant midnight yesterday.

2.80 has first instant

Definition: *t* **has first instant** *t′* =Def. *t′* **first instant of** *t* [261-BFO]

Domain**:** *temporal region*

Range**:** *temporal instant*

EXAMPLE   The first hour of a year has first instant midnight on December 31.

2.81 last instant of

Definition: *temporal instant t* **last instant of** *temporal region t′* =Def. all **temporal parts of** *t′* other than *t* **precede** *t* [269-BFO]

Domain**:** *temporal instant*

Range**:** *temporal region*

EXAMPLE   Last midnight is the last instant of yesterday.

2.82 has last instant

Definition: *t* **has last instant** *t′* =Def. *t′* **last instant of** *t* [215-BFO]

Domain**:** *temporal region*

Range**:** *temporal instant*

EXAMPLE   The last hour of a year has last instant midnight December 31.

2.83 precedes

Elucidation: If *o, o′* are *occurrents* and *t* is the temporal extent of *o* and *t′* is the temporal extent of *o′* then *o* **precedes** *o′* means**:**

either **last instant of** *o* is before **first instant** of *o'*

or **last instant of** *o* = **first instant of** *o'* and neither *o* nor *o'* are *temporal instants* [270-BFO]

Domain**:** *occurrent*

Range**:** *occurrent*

EXAMPLE   The temporal region occupied by Mary's birth precedes the temporal region occupied by Mary's death.

NOTE 1   Each *temporal region* is its own temporal extent. The temporal extent of a *spatiotemporal region* is the *temporal region* it **temporally projects onto**. The temporal extent of a *process* or *process boundary* that **occupies temporal region** *t* is *t*.

NOTE 2   Precedes defines a strict partial order on occurrents.

2.84 preceded by

Definition: *b* **preceded by** *c* =*Def. b* **precedes** *c* [213-BFO]

Domain**:** *occurrent*

Range**:** *occurrent*

EXAMPLE   The temporal region occupied by the second half of the match is preceded by the temporal region occupied by the first half of the match.

3. Binary counterparts of BFO 2020 ternary relations for use in BFO 2020-OWL

3.1 continuant part of at some time

Definition: *b* **continuant part of** *c* **at some time** =Def. for some time *t* (*b* **exists at** *t* and *c* **exists at** t and *b* **continuant part of** *c* **at** *t* & *t* is a *temporal region* & *b* and *c* are *continuants*) [221-BFO]

EXAMPLES   Milk teeth continuant part of human at some time; surgically removed tumour continuant part of organism at some time.

3.2 continuant part of at all times

Definition: *b* **continuant part of** *c* **at all times** =Def. for all times *t* (*b* **exists at** *t*, implies *b* **continuant part of** *c* **at** *t* & *t* is a *temporal region* & *b* and *c* are *continuants*) [222-BFO]

EXAMPLES   Centre of mass of a material entity continuant part of material entity at all times; continuant fiat external boundary of an object continuant part of object at all times.

3.3 has continuant part at some time

Definition: *b* **has continuant part** *c* **at some time** =Def. for some time *t* (*b* and *c* are *continuants* & *b* is a **part of** *c* **at** *t*) [271-BFO]

3.4 has continuant part at all times

Definition: *b* **has continuant part** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*b* and *c* are *continuants* & *b* is a **part of** *c* **at** *t*) [223-BFO]

3.5 proper continuant part of at some time

Definition: *b* **proper continuant part of** *c* **at some time** =Def. for some time *t* (*b* **continuant part of** *c* **at** *t* & not (*c* **continuant part of** *b* **at** *t*) [224-BFO]

3.6 proper continuant part of at all times

Definition: *b* **proper continuant part of** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*b* **continuant part of** *c* **at** *t* & not (*c* **proper continuant part of** *b* **at** *t*)) [225-BFO]

3.7 has proper continuant part at some time

19

Definition: *b* **has proper continuant part** *c* **at some time** =Def. *c* **proper continuant part of** *b* **at some time** [226-BFO]

3.8 has proper continuant part at all times

Definition: *b* **has proper continuant part** *c* **at all times** =Def. *c* **proper continuant part of** *b* **at all times** [227-BFO]

3.9 member part of at some time

Definition: *b* **member part of** *c* **at some time** =Def. for some time *t* (*b* is an *object*

& there is **at** *t* a mutually exhaustive and pairwise disjoint partition of *c* into *objects* x_1, ..., x_n (for some $n \geq 1$) with $b = x_i$ (for some $1 \leq i \leq n$)) [228-BFO]

3.10 member part of at all times

Definition: *b* **member part of** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies

(*b* is an *object* & *c* is an object aggregate

& there is **at** *t* a mutually exhaustive and pairwise disjoint partition of *c* into *objects* x_1, ..., x_n (for some $n \geq 1$) with $b = x_i$ (for some $1 \leq i \leq n$)) [229-BFO]

3.11 has member part at some time

Definition: *b* **has member part** *c* **at some time** =Def. for some time *t* (*c* **member part of** *b* **at** *t*) [230-BFO]

3.12 has member part at all times

Definition: *b* **has member part** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*c* **member part** *b* **at** *t*) [231-BFO]

3.13 occupies spatial region at some time

Definition: an *independent continuant c* that is not a *spatial region* **occupies spatial region** *r* **at some time** =Def. for some time *t* (every **continuant part of** *c* **occupies** some **continuant part of** *r* **at** *t* and no **continuant part of** *c* **occupies** any **spatial region** that is not a **continuant part of** *r* **at** *t*) [232-BFO]

3.14 occupies spatial region at all times

Definition: an *independent continuant c* that is not a *spatial region* **occupies spatial region** *r* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (every continuant part of *c* **occupies** some continuant part of *r* **at** *t* and no continuant part of *c* **occupies** any **spatial region** that is not a continuant part of *r* **at** *t*) [233-BFO]

3.15 located in at some time

Definition: *b* **located in** *c* **at some time** =Def. *for some* time *t* (*b* and *c* are *independent continuants* and not *spatial regions,* and the *spatial region* which *b* **occupies at** *t* is a (proper or improper) **continuant part of** the **spatial region** which *c* **occupies at** *t*) [234-BFO]

3.16 located in at all times

Definition: *b* **located in** *c* **at all times** =Def. *for all* times *t*, *b* **exists at** *t* implies (*b and c* are *independent continuants* and not *spatial regions,* and the **spatial region** which *b* **occupies** at *t* is a (proper or improper) continuant part of *the spatial region* which *c* **occupies at** *t*) [235-BFO]

3.17 location of at some time

Definition: *b* **location of** *c* **at some time** =Def. for some time *t* (*c* **located in** *b* **at** *t*) [236-BFO]

3.18 location of at all times

Definition: *b* **location of** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*c* **located in** *b* **at** *t*) [237-BFO]

3.19 has material basis at some time

Definition: *b* **has material basis** *c* **at some time** =Def.

for some time *t* (*b* is a *disposition*

& *c* is a *material entity*

& there is some *d* **bearer of** *b*

& *c* **continuant part of** *d* **at** *t*

& *d* **bearer of** *b* because *c* **continuant part of** *d* **at** *t*) [242-BFO]

3.20 has material basis at all times

Definition: *b* **has material basis** *c* **at all times** =Def.

For all times *t*, *b* **exists at** *t* implies (*b* is a *disposition*

& *c* is a *material entity*

& there is some *d* **bearer of** *b*

& *c* **continuant part of** *d* **at** *t*

& *d* **bearer of** *b* because *c* **continuant part of** *d* **at** *t*) [243-BFO]

3.21 material basis of at some time

Definition: *b* **material basis of** *c* **at some time** =Def. at some time *t* (*c* **has material basis** *b* **at** *t*) [244-BFO]

3.22 material basis of at all times

Definition: *b* **material basis of** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*c* **has material basis** *b* **at** *t*) [245-BFO]

3.23 spatially projects onto at some time

Definition: *b* **spatially projects onto** *c* **at some time** =Def. for some time *t* (*b* is a *spatiotemporal region* and *c* is a *spatial region* and *c* is the spatial extent of *b* **at** *t*) [246-BFO]

3.24 spatially projects onto at all times

Definition: *b* **spatially projects onto** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*b* is a *spatiotemporal region* and *c* is a *spatial region* and *c* is the spatial extent of *b* **at** *t*) [247-BFO]

3.25 has participant at some time

Definition**:** *p* h**as participant** *c* **at some time** =Def. for some time *t* (*b* is a *process*, *c* is a *continuant*, and *c* **participates in** *p* some way at *t* [248-BFO]

3.26 has participant at all times

Definition**:** *p* h**as participant** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*b* is a *process*, *c* is a *continuant*, and *c* **participates in** *p* some way at *t*) [249-BFO]

3.27 participates in at some time

Definition**:** *b* **participates in** *p* **at some time** =Def. for some time *t* (*p* **has participant** *b* **at** *t***)** [250-BFO]

3.28 participates in at all times

Definition**:** *b* **participates in** *p* **at all times =Def. for all** times *t*, *b* **exists at** *t* implies (*p* **has participant** *b* **at** *t*) [251-BFO]

3.29 generically depends on at some time

Synonym: **g-depends on at some time**

Definition: a *g-dependent continuant b* **g-depends on** an *independent continuant c* **at some time** =Def. for some time *t* (there **inheres** in *c* an *s-dependent continuant* which **concretizes** *b* at *t*) [252-BFO]

3.30 generically depends on at all times

Synonym: **g-depends on all times**

Definition: a *g-dependent continuant b* **g-depends on** an *independent continuant c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (there **inheres** in *c* an *s-dependent continuant* which **concretizes** *b* at *t*) [253-BFO]

3.31 is carrier of at some time

Definition: *b* **is carrier of** *c* **at some time** =Def. for some time *t* (*c* ***g-depends*** **on** *b* at *t*) [254-BFO]

3.32 is carrier of at all times

Definition: *b* **is carrier of** *c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*c* ***g-depends*** **on** *b* at *t*) [255-BFO]

3.33 concretizes at some time

Definition: an *s-dependent continuant b* **concretizes** a *g-dependent continuant c* **at some time** =Def. for some time *t* (*c* is the pattern or content which *b* shares at *t* with actual or potential copies) [256-BFO]

3.34 concretizes at all times

Definition: an *s-dependent continuant b* **concretizes** a *g-dependent continuant c* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*c* is the pattern or content which *b* shares at *t* with actual or potential copies) [257-BFO]

3.35 is concretized by at some time

Definition: a *g-dependent continuant c* **is concretized at some time by** an *s-dependent continuant* or *process b* =Def. for some time *t*, *b* **concretizes** *c* **at** *t*) [258-BFO]

3.36 is concretized by at all times

Definition: a *g-dependent continuant c* **is concretized by** an *s-dependent continuant* or *process b* **at all times** =Def. for all times *t*, *b* **exists at** *t* implies (*b* **concretizes** *c* **at** *t*) [259-BFO]