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Tools Output Integration Framework (TOIF)

Version 1.3

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Normative Machine Consumable files:

http://www.omg.org/spec/TOIF/20180901/toif.emof

http://www.omg.org/spec/TOIF/20180901/toif.xsd

Non-normative Machine Consumable files:

http://www.omg.org/spec/TOIF/20180901/toif.ecore

http://www.omg.org/spec/TOIF/20180901/toif.mdxml

http://www.omg.org/spec/TOIF/20180901/toif_clean_uml.xmi

OMG's Issue Reporting Procedure

Table of Contents

Table of Figures

Preface

OMG

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Specifications within the Catalog are organized by the following categories:

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- MOF
- XMI
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- Profile specifications

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- Specialized CORBA specifications
- CORBA Component Model (CCM)

Platform Specific Model and Interface Specifications

- CORBAservices
- CORBAfacilities
- OMG Domain specifications
- OMG Embedded Intelligence specifications
- OMG Security specifications

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OMG Headquarters
140 Kendrick Street
Building A, Suite 300
Needham, MA 02494
USA
Tel: +1-781-444-0404
Fax: +1-781-444-0320
Email: *pubs@omg.org*

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Typographical Conventions

The type styles shown below are used in this document to distinguish programming statements from ordinary English. However, these conventions are not used in tables or section headings where no distinction is necessary.

Times/Times New Roman - 10 pt.: Standard body text

Helvetica/Arial - 10 pt. Bold: OMG Interface Definition Language (OMG IDL) and syntax elements.

`Courier - 10 pt. Bold:` Programming language elements.

Helvetica/Arial - 10 pt: Exceptions

NOTE: Terms that appear in italics are defined in the glossary. Italic text also represents the name of a document, specification, or other publication.

1 Specification Specific Material

1.1 Specification Preface

TOIF XML (XMI) is a common normalized format for representing the findings of static code analysis tools for the purpose of integrating multiple facts related to a single system under assessment. This format is described in this specification first as a conceptual model in SBVR Structured English, focusing at the key noun and verb concepts, then by a more specific logical model in MOF/UML which determines the TOIF XML schema. The MOF metamodel is consistent with the SBVR Structured English representation (and can in principle, be systematically derived from it). The key to the TOIF MOF metamodel is that each verb concept is represented by an association class in such a way that the resulting XML has a “triple flavor”. SBVR stands for Semantic for Business Vocabulary and Rules. MOF stands for Meta Object Facility. XML stands for eXtended Markup Language. The acronym XMI stands for XML Metadata Interchange format. XMI is a specific form of XML that is associated with the Model Driven Development approach. XMI has been developed for the purpose of exchanging metadata such as models. XMI is standardized by OMG (current specification is identified as MOF 2.0 / XMI Mapping Specification, v2.1.1, document formal/07-12-01) and ISO (19503:2005).

1.2 Copyright Waivers

1.3 IPR Mode

The IPR Mode for this specification is: Non-Assertion Covenant

1.4 Submitter Representatives

Dr. Nikolai Mansourov, KDM Analytics, Inc., nick@kdmanalytics.com
Dr. Ben A. Calloni, Lockheed Martin Corporation, ben.a.calloni@lmco.com
Robert A. Martin, The MITRE Corporation, ramartin@mitre.org
Cory Casanave, Model Driven Solutions, cory-c@modeldriven.com
Gary Duncanson, NoMagic, Inc., gary@nomagic.com
Manfred Koethe, 88solutions Corp,. koethe@88solutions.com

1.5 Author Team

Dr. Nikolai Mansourov, KDM Analytics Inc., nick@kdmanalytics.com

Dr. Ben A. Calloni, Lockheed Martin Corporation, ben.a.calloni@lmco.com

Manfred Koethe, 88solutions Corp,. koethe@88solutions.com

Robert A. Martin, The MITRE Corporation, ramartin@mitre.org

Cory Casanave, Model Driven Solutions, cory-c@modeldriven.com

2 Scope

This document provides specification of the Tools Output Integration Framework (TOIF) XMI schema – the common reporting format of source/machine code weaknesses. TOIF XMI is the core part of a protocol that integrates weakness findings, from multiple static code analysis tools, related to a single system under assessment.
This specification describes TOIF schema at three different levels of abstraction.
First, the specification describes the **conceptual schema of the TOIF** as SBVR Structured English focusing at a technology-independent description of the key noun and verb concepts involved in reporting weakness findings. This conceptual schema defines a common vendor-neutral vocabulary for the TOIF Ecosystem. The conceptual schema addresses the following concerns:

- Defining TOIF basic facts and entities
- Defining TOIF housekeeping concepts
- Presenting TOIF fact-oriented organization (emphasizing the noun and verb organization of TOIF facts which gives it a characteristic "triple flavor")

Second, the TOIF specification then describes the **MOF/UML metamodel of the TOIF**. This metamodel is consistent with the Structured English representation and can be, in principle, produced by a systematic transformation from the conceptual schema. The MOF metamodel determines the **TOIF XML/XMI schema** which can be derived from the UML model as described in the MOF and XMI specifications.
Third, the specification illustrates the usage of the TOIF XMI schema by providing **examples of the TOIF XMI data** that uses the TOIF XMI schema.

TOIF addresses two types of normalization of weakness reporting. First, **syntactic** normalization addresses the differences in reporting formats of various static code analysis tools. This is addressed by the common TOIF XML schema. Second, the **semantic** normalization addresses the nomenclature of the findings by the static analysis tools. This is addressed by a mapping from proprietary nomenclature to a common nomenclature. The common nomenclature of weaknesses in TOIF is based on the Software Fault Pattern (SFP) catalog of clusters and patterns, that are further linked to a catalog known as the Common Weakness Enumeration (CWE). The vendor-neutral common nomenclature of weakness types consisting of SFP and CWE is an integral part of the TOIF approach. Both the syntactic and the logical mapping from a proprietary reporting format of a given static analysis tool to TOIF is assumed to be implemented by an non-intrusive Adaptor to the static code analysis tool.

3 Conformance

The principle goal of TOIF is the common normalized format for representing the findings of multiple static code analysis (SCA) tools for the purpose of integrating multiple findings related to a single system under assessment and managing collections of findings in an enterprise context.

To be TOIF compliant as a **TOIF generator**, an implementation shall fully support TOIF as one compliance point. An implementation shall:

1. Provide the capability to generate XMI documents based on the TOIF XMI schema capturing findings from the internal proprietary model of the tool.
2. Generate "housekeeping" facts according to the TOIF schemaProvide the mapping from each proprietary weakness type to common TOIF vendor-neutral weakness type based on SFP and CWE when capturing findings.

   This compliance point is formally defined as follows. Let's assume an SCA tool TOOLA is capable of producing proprietary weakness findings of types WDi where i=1..k. This means that given a set of input files F1,..,Fn the tool TOOLA may produce a set of findings, described by proprietary set report items RWD1,..,RWDm such that each RWDj refers to a certain weakness type RWDi. The number of findings, m, depends on the presence of weaknesses in the input files {Fi}, as well as on the capability of the tool TOOLA to identify a finding (true positive) and the capability of the tool TOOLA to avoid reporting a false positive.
   The TOIF mapping is a set of k tuples (where k is the number of all distinct proprietary weakness types for tool TOOLA), {WDi, {CWEi, SFPi, SFP Cluster-i }} where

   WDi is the proprietary description of the weakness type by tool TOOLA

CWEi is the CWE identifier aligned with the SFPi and SFP Cluster-i that provides the most specific description of the weakness.

SFPi is the SFP identifier that provides the most specific description of the weakness; the SFP catalog provides mappings from each SFP to a set of relevant CWE. SFP identifiers are defined as part of the SFP Catalog.

SFP Cluster-i is the SFP Cluster that describes the broad and non-overlapping set of faults to which the weakness type belongs. SFP Clusters are defined in the SFP Catalog.

According to the TOIF specification, each individual finding RWDj refers only to the CWEj, while the relations between CWEi, SFPi and SFP Cluster-i are defined once at the weakness type level rather than at the finding level.

TOIF mapping constitutes the semantic specification of a **TOIF Adaptor** for tool TOOLA. The other part of the specification of the Adaptor is the syntactic specification related to transforming the proprietary syntax of report items RWDj from TOOLA into TOIF data conforming to the TOIF XMI schema.

To be TOIF compliant as a **TOIF consumer**, an implementation shall fully support TOIF as one compliance point. The implementation shall:

1. Provide the capability to import the facts described by the TOIF XMI schema and to map the facts into the internal proprietary model of the tool.

In contrast to a TOIF Generator, a TOIF Analytics tool does not produce new findings, but can filter the original findings and produce additional information, for example, compute ranks, citings, etc. To be TOIF compliant as a **TOIF analytics tool**, an implementation shall fully support TOIF as one compliance point. The implementation shall:

1. Provide the capability to import the facts described by the TOIF XMI schema
2. To generate XMI documents based on the TOIF XMI schema that are based on the original findings and include some added value facts

4 References

4.1 Normative References

The following normative documents contain provisions which, through reference in this text, provide normative context for material in this specification.

[kdm]	Knowledge Discovery Metamodel (KDM), v1.4, http://www.omg.org/spec/KDM/1.4
[sbvr]	Semantics for Business Vocabulary and Rules (SBVR), v1.4, http://www.omg.org/spec/SBVR/1.4/
[uml]	Unified Modeling Language (UML), v2.5, http://www.omg.org/spec/UML/2.5
[xmi]	XML Metadata Interchange (XMI), v2.5.1, http://www.omg.org/spec/XMI/2.5.1
[xml]	Extensible Markup Language, v1.1, http:// http://www.w3.org/TR/xml11
[xsd-1]	XML Schema Definition Language (XSD) v1.1 Part 1: Structures, http://www.w3.org/TR/xmlschema11-1
[xsd-2]	XML Schema Definition Language (XSD) v1.1 Part 2: Datatypes, http://www.w3.org/TR/xmlschema11-2

4.2 Informative References

The following non-normative documents contain provisions which, through reference in this text, provide informative context for material in this specification.

- [cwe] Common Weakness Enumeration (CWE) –
  - a repository maintained by MITRE Corporation of known weaknesses in software that can be exploited to modify data, read data, create a denial-of-service that results in unreliable execution, create a denial-of-service that results in resource consumption, execute unauthorized code or commands, gain privileges /

assume identity, bypass protection mechanism, and/or hide their activities[1]. <https://cwe.mitre.org>

- also, ITU standard: ITU X.1524 Common Weakness Enumeration

  < http://www.itu.int/rec/T-REC-X.1524-201203-I/en >

- Software Fault Patterns (SFP) Catalog –
  - AFRL-RY-WP-TR-2012-0111, V2 - DoD document approved for public release, distribution unlimited;
  - Software Fault Pattern Clusters - a repository maintained by MITRE Corporation of links connecting SFPs and CWEs <https://cwe.mitre.org/data/definitions/888.html> ;

5 Terms and Definitions

For the purposes of this specification, the most of applicable terms and definitions are provided in Section 9 TOIF Conceptual Model.

6 Symbols

List of symbols/abbreviations:

CWE	Common Weakness Enumeration
KDM	Knowledge Discovery Metamodel
SCA	Static Code Analysis
SFP	Software Fault Patterns
TOIF	Tools Output Integration Framework
XMI	XML Metadata Interchange

7 Additional Information

7.1 How to Read this Specification

TOIF Exchange Format is a common normalized format for representing the findings of static code analysis (SCA) tools for the purpose of integrating multiple facts related to a single system under assessment.

This specification has the following structure.

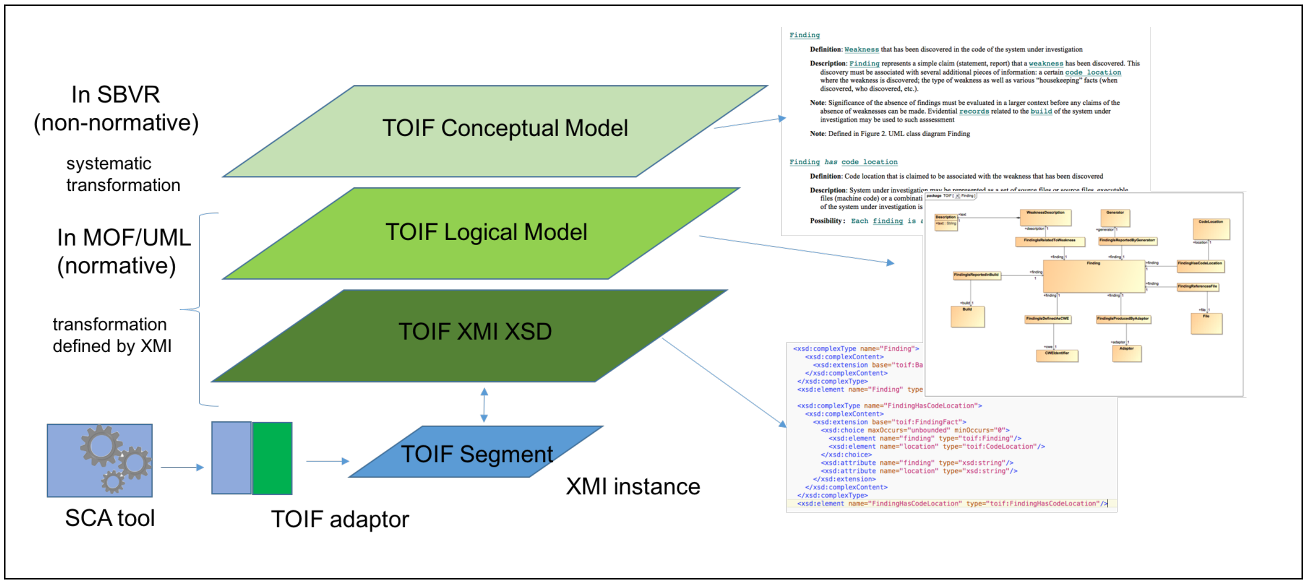
Section 8.1 “Objectives” summarizes the key design ***objectives*** for the TOIF XML format and its role in the TOIF Ecosystem

Section 9 “TOIF Conceptual Model” presents the ***conceptual schema*** for TOIF XMI described in SBVR Structured English as a set of definitions of noun and verb concepts. This section defines a vendor-neutral vocabulary for the entire TOIF Ecosystem. TOIF Conceptual Model provides a technology-neutral vocabulary for TOIF which is then

[1] CWE technical impact enumeration <https://cwe.mitre.org/cwraf/enum_of_ti.html>

systematically implemented as a MOF/UML metamodel for the purpose of specifying a concrete XML/XMI schema for the TOIF data (the TOIF Exchange Format).
Section 9.1. describes the basic common facts related to ***weakness findings***.
Section 9.2 "Housekeeping considerations for TOIF XMI" describes several "***housekeeping***" facts that facilitate management of multiple TOIF XMI files during the entire life cycle of the operation of the TOIF framework. The "housekeeping" facts define various meta-data to the basic TOIF facts, mainly related to multiple builds of the system, and versions of the tools used, etc. Such additional information is important to manage TOIF data over the entire life-cycle of the system under assessment as well as in an enterprise context where multiple systems are assessed by multiple teams.
Section 9.3 "Fact-oriented organization of TOIF XMI" elaborates the conceptual model and describes the organization of the TOIF XMI as ***triples*** built around the verb concepts with noun concepts as the endpoints.

Section 10 "TOIF Logical Model" presents the ***MOF/UML metamodel for TOIF*** which is systematically developed based on the TOIF Conceptual Model as an intermediate step towards the TOIF XMI schema. Both the TOIF Conceptual Model as well as the TOIF Logical Model provide an adequate description of the TOIF XMI schema, so either (or both) can be used to understand TOIF. However it is the TOIF Logical Model that determines the exact structure of the TOIF XMI schema through the rules described in MOF and XMI specifications. Section 10 provides multiple examples of the TOIF XMI data compliant to the TOIF XMI schema. Section 10 has the following organization.
Section 10.1 describes the basic concepts of TOIF represented as MOF/UML metamodel.
Section 10.2 describes the MOF/UML representation pf the house-keeping concepts of TOIF.
Section 10.3 describes the fact-oriented structure of TOIF XML.
Section 10.4 describes evidential records in TOIF XML.



Finding

Definition: Weakness that has been discovered in the code of the system under investigation

Description: Finding represents a simple claim (statement, report) that a weakness has been discovered. This discovery must be associated with several additional pieces of information: a certain code location where the weakness is discovered; the type of weakness as well as various "housekeeping" facts (when discovered, who discovered, etc.).

Note: Significance of the absence of findings must be evaluated in a larger context before any claims of the absence of weaknesses can be made. Evidential records related to the build of the system under investigation may be used to such asssessment

Note: Defined in Figure 2. UML class diagram Finding

Finding *has* code location

Definition: Code location that is claimed to be associated with the weakness that has been discovered

Description: System under investigation may be represented as a set of source files or source files, executable files (machine code) or a combinati
of the system under investigation is

Possibility: Each finding is a

```
<xsd:complexType name="Finding">
  <xsd:complexContent>
    <xsd:extension base="toif:Ba
  </xsd:complexContent>
</xsd:complexType>
<xsd:element name="Finding" type

<xsd:complexType name="FindingHasCodeLocation">
  <xsd:complexContent>
    <xsd:extension base="toif:FindingFact">
      <xsd:choice maxOccurs="unbounded" minOccurs="0">
        <xsd:element name="finding" type="toif:Finding"/>
        <xsd:element name="location" type="toif:CodeLocation"/>
      </xsd:choice>
      <xsd:attribute name="finding" type="xsd:string"/>
      <xsd:attribute name="location" type="xsd:string"/>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
<xsd:element name="FindingHasCodeLocation" type="toif:FindingHasCodeLocation"/>
```

Figure 1. Organization of the TOIF specification

7.2 Acknowledgements

The following companies submitted this specification:

- KDM Analytics Inc
- Lockheed Martin Corporation
- The MITRE Corporation
- Model Driven Solutions
- 88solutions Corp
- NoMagic Inc

8 TOIF Exchange Format

8.1 Objectives

- Define a standard vendor-neutral protocol that facilitates information flow from multiple proprietary static code analysis tools as producers to various consumer tools that can integrate, collate, store, rank, measure, transform and present findings from multiple sources for a single system under assessment.
- Establish a uniform, vendor-neutral, normalized environment for processing findings from multiple SCA tools for a single system under assessment.
- Define standard semantic for weakness findings, focusing at the standard nomenclature of weakness findings to collate findings by multiple tools and identify weaknesses reported by more than one tool
- Facilitate managing findings from multiple SCA tools over the life-cycle of a system under assessment.
- Facilitate managing findings in enterprise environments (multiple tools, multiple builds, multiple systems, multiple consumers).
- Be a common normalized schema for integrating findings from multiple static code analysis tools and developing vendor-neutral "big data" analytics.
- Define a standard syntax – based on MOF XML – to represent results of SCA tools to be consumed by third-party tools, including the analytics environment
- Align with the standard Knowledge Discovery Metamodel (KDM) protocol describing basic facts about the system under assessment
- Align with risk analysis interchange protocol, and Software Fault Pattern (SFP) catalog as well as other protocols of the OMG System Assurance Ecosystem to link findings as evidence to risks
- Facilitate systematic evaluation and measurement of existing static code analysis tools.
- Be a non-intrusive format that requires no modification of the source code of a static analysis tool to adopt such that TOIF adapters can be developed independently of an SCA tool

The key requirement for the TOIF protocol is that no modifications to the source code of the original static code analysis tools be made, in other words, the TOIF protocol assumes an explicit **adaptation step** that is performed outside of an off-the-shelf proprietary static code analysis tool (non-intrusive), and that transforms the original report from such tool into a normalized TOIF report. The open description of the normalized TOIF XMI format will encourage the vendors of the commercial SCA tools to support TOIF natively, however regardless of the adoption by the tool vendors of the original tools, their outputs can still be integrated into the framework by the adaptors implemented by the third parties. The adaptation step performs both **syntactic normalization** (normalizing the differences in the output reporting formats of proprietary SCA tools) as well as **semantic normalization** (normalizing the meaning of the findings and the location of the findings).

The semantic normalization maps the nomenclature of the findings used in a proprietary static analysis tool into a common vendor-neutral nomenclature. The "mapping" artifact is formally described in the Conformance Section, clause 3. The common nomenclature of weaknesses in TOIF is based on the Software Fault Pattern (SFP) system of clusters and individual patterns, and the further mapping to a catalog known as the Common Weakness Enumeration (CWE). The

vendor-neutral common nomenclature of weakness types consisting of SFP and CWE is an integral part of the TOIF approach.
In addition, TOIF extends finding reports from proprietary SCA tools with normalized vendor-neutral meta-information (further referred to as the housekeeping information), facilitating management of facts, their provenance and attribution over larger life-cycles, independent on any of the SCA tools in an enterprise environment.

TOIF data are organized as triples, following the verb and noun phrases in the TOIF Structured English Vocabulary. While the specific embodiment of the TOIF Exchange Format is specified in this document as a TOIF XMI schema (through a MOF/UML metamodel and the MOF/XMI rules that determine the XML/XMI schema) the "triple flavor" of the TOIF data is designed to support additional formats and technology spaces, including, for example, reasoning tools.

8.2 TOIF Ecosystem

The TOIF exchange protocol assumes several specific capabilities with regards to how TOIF information can be produced and consumed. Thus the TOIF protocol determines a certain ecosystem where there can exist multiple implementations of the TOIF capabilities that satisfy the interfaces defined by the TOIF protocol and that address the different roles within the TOIF protocol.
The operation of the TOIF Ecosystem involves three distinct phases. Phase 1 involves application of one or more static code analysis tools to the system under assessment. Phase 1 also may involve application of a Knowledge Discovery Metamodel (KDM) extractor tool to the same system under assessment in order to generate the basic KDM facts about the system. Within the Phase 1, TOIF Adaptor tools process the proprietary finding reports from each SCA tool, and normalize these reports (both syntactically and semantically) into the TOIF format. Since weakness finding reports are produced by multiple off-the-shelf static code analysis tools, phase 1 shall perform normalization of the original reports by tool-specific TOIF Adaptors so that the rest of capabilities in the TOIF Ecosystem can successfully consume reports from multiple TOIF producers.
Phase 1 is often performed as part of the regular build of the system under investigation, in which case this phase would also involve running code compilers and linkers. Regular builds are usually orchestrated by build tools. Extending the orchestration to correctly include SCA tools and TOIF adaptors into the build process is one of the key success factors for running static code analysis and software assurance.
In Phase 2, normalized weakness reports from various tools are integrated into a single, comprehensive report. As the result, an integrated repository of the TOIF facts can be populated.
Phase 3 involves consuming the integrated TOIF weakness finding facts for the purposes of presenting them to human analysts (browsing), analyzing them as evidence for software assurance, entering them as evidence for risk assessment or Risk Management Framework (RMF) security control assessment, as well as any other purposes.

The TOIF Ecosystem assumes the following roles:

- SCA tool – provides capability to scan source or machine code of the system under investigation and generate weakness finding reports. An SCA tool usually involves components that perform scanning and parsing of source code, or perform disassembling of the machine code, implement optimized control and data flow analysis algorithms, often incorporate extensive information about standard software libraries and components, operating systems and compilers, as well as a certain knowledge base of what they consider as weaknesses and the corresponding patterns that can be used to discover at least some of these weaknesses in the code. Effectiveness of an SCA tool is determined by multiple factors. An SCA tool will be also referred to as a TOIF Generator.

- TOIF Adaptor tool – provides capability to transform the proprietary weakness finding report from a particular SCA tool into a normalized representation determined by the TOIF specification. The most challenging part of implementing a TOIF adaptor is to provide a mapping from proprietary weakness type system used by a particular SCA tool into a normalized system of weakness types in a justifiable and unambiguous way that facilitates further semantic integration of the TOIF finding facts. The TOIF specification uses a formalized 3-level hierarchical system of weakness types that involve a combination of the Software Fault Patterns (SFP) catalog and the Common Weakness Enumeration (CWE). The "mapping" artifact is formally defined in Compliance Section of this document, clause 3.

- TOIF producer – a generic term to describe any capability that produces output conformant with the TOIF specification. For example, a combination of an SCA tool (a TOIF Generator) and the corresponding TOIF Adaptor can play a role of a TOIF Producer

- KDM tool – provides the capability to scan source or machine code of the system under investigation and produce normalized description of this system conformant to the Knowledge Discovery Metamodel (KDM) specification. KDM facts, as we will refer to such normalized description provide a vendor-neutral general-purpose representation of the semantic structure, behavior, and datatype organization of the system under investigation. KDM facts are a form of intermediate representation of the system under assessment. A KDM tool usually involves components that perform scanning and parsing of source code, or perform disassembling of the machine code, may incorporate information about standard software libraries and components, and operating systems. KDM facts may be generated by a Code Complier. KDM facts can be integrated with the TOIF facts for more powerful analysis of the weakness findings.

- Code Compiler – provides capability to scan source code of the system under investigation and produce linkable object code or excitable machine code for the selected platform. A Code Compiler involves a proprietary intermediate representation of each module of the system under assessment from the syntax viewpoint, and from the semantic viewpoint. A Code Compiler usually involves components that perform scanning and parsing of source code, build the intermediate representation(s) of the code, analyze the intermediate representation and generate the machine code. The last component is often called the BackEnd, while the first two components are often referred to as the FrontEnd. The intermediate representation constructed by a code compiler provides valuable information about the system under investigation that may be useful for the purposes of software assurance, however this information is seldom exposed by code compilers and when it is, it is often difficult to utilize it because of its proprietary nature, technology dependencies, and low level. Some compilers may choose to transform their high-fidelity intermediate representation into KDM facts, thus removing the barriers for using this information by other consumers

- Code Linker – provides capability to combine one or more linkable object code files into machine code for the selected execution platform. Code Linker is used in system builds because the executable machine code of the system usually involves a mix of application modules and various third-party libraries, already precompiled for the selected platform.

- Build Tool – provides capability to orchestrate the process of running Code Compilers, with desired options, inputs and outputs, running Code Linkers, packaging the outputs, and performing other desired steps to transform input source files, precompiled object files and libraries into the output artifacts. Usually a Build Tool is general-purpose, driven by a Build Script that describes the build steps.

- Build Script – description of the build steps to be performed by a Build Tool to perform a build of the system under investigation

- TOIF Orchestration tool – provides capability to orchestrate the process of running SCA tools and their corresponding TOIF Adaptors in alignment with the regular build, i.e. such that each source file is processed by selected SCA tools with desired options, aligned with the options used during the regular build, that an appropriate TOIF Adaptor is called for each SCA tool, that all TOIF output files are appropriately managed; Similarly for machine code analysis, the TOIF Orchestration tool aligns the process of running the selected SCA tools and their TOIF Adaptors on all desired machine code files. From the software assurance evidence perspective, the TOIF Orchestration tool generates the key piece of evidence regarding the coverage of the source and machine code files, correctness of the SCA findings, etc.

- TOIF repository – provides capability to store, manage and query TOIF facts.

- TOIF browser – provides capability to view TOIF related entities and relationships by human analysts in a visual environment.

- TOIF consumer - a generic term to describe any capability that consumes input conformant with the TOIF specification

- TOIF Analytics tool – a generic term to describe any capability that consumes one or more TOIF segments and produces one or more TOIF segments. This may include, for example, a TOIF Integration tool, that consumes partial TOIF segments and produces a single integrated segment, or a TOIF Citing tool that consumes TOIF integrated segment and augments it with some elements, or a TOIF ranking tool that consumes TOIF integrated segment possibly with some original measurements captured by the SCA tools and evaluates a normalized ranking. A TOIF Analytics tool is both a TOIF consumer and a TOIF producer.

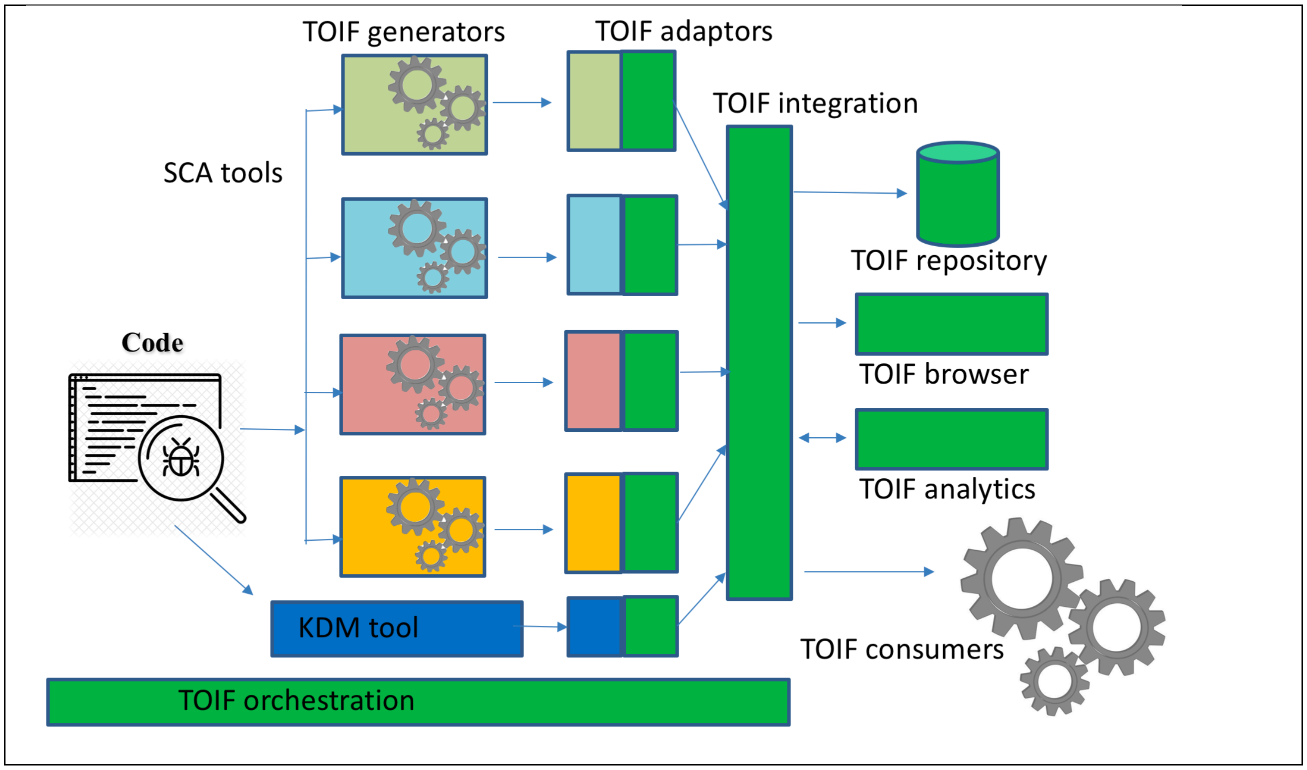


Figure 2. The Flow of the TOIF Protocol and the TOIF Ecosystem

9 TOIF Conceptual Model

This section describes TOIF Exchange Format in SBVR Structured English by focusing at a set of vendor-neutral noun and verb phrases that provide the foundation for the TOIF Ecosystem as its technology neutral vocabulary. The actual TOIF XMI schema is consistently derived from this conceptual model by representing each verb concept as a triple. However the precise details of the TOIF XMI schema are provided by the TOIF MOF/UML metamodel defined in Section 10 together with multiple examples of TOIF XMI data compliant with the TOIF XMI schema. The TOIF MOF/UML metamodel determines the TOIF XMI schema through a set of rules described in MOF and XMI specifications.

9.1 Basic Entities and Facts

The conceptual model of the TOIF protocol describes the characteristics of the weakness findings, as they are reported by SCA tools. We also defined the facts where the original weakness findings can be merged with the basic facts about the system under investigation, as defined by the standard Knowledge Discovery Metamodel (KDM).

`Weakness`

Definition: characteristic or property of software that, in proper conditions, could contribute to the introduction of vulnerabilities within that software

Synonym: `weakness` of software

Note: Each weakness is categorized by a weakness type. Some weaknesses can be characterized by a certain location in the code of the system under assessment.

Note: A claim of a weakness (of a certain weakness type at a certain code location) can be supported by by one or more findings as well as additional citings.

`Vulnerability`

Definition: `weakness` of software, hardware, or online service that can be exploited by a threat

Description: Examples of weaknesses in a system are software and hardware design flaws, poor administrative processes, lack of awareness and education, and advancements in the state of the art or improvements to current practices. Regardless of cause, an exploitation of such vulnerabilities may result in real threats to mission-critical information systems.

Note: Vulnerabilities can be architecture flaws, coding errors, or other implementation errors, or insecure configuration. Vulnerabilities can also result from insufficient or incorrect security documentation, security awareness, or communication.

`Finding`

Definition: `Weakness` that has been discovered in the code of the system under investigation

Description: `Finding` represents a simple claim (statement, report) that a `weakness` has been discovered. This discovery shall be associated with several additional pieces of information: a certain `code location` where the weakness is discovered; the type of weakness as well as various "housekeeping" facts (when discovered, who discovered, etc.).

Note: Significance of the absence of findings should be evaluated in a larger context before any claims of the absence of weaknesses can be made. Evidential `records` related to the `build` of the system under investigation may be used for such assessment.

Note: Defined in Figure 3. UML class diagram Finding.

Finding *has* code location

Definition: Code location that is claimed to be associated with the weakness that has been discovered

Description: System under investigation may be represented as one or more source files, executable files (machine code) or a combination of both. The mechanism to uniquely identify a location within the code of the system under investigation is the foundation for reporting weaknesses.

Possibility: Each finding is associated with one or more code location.

Finding *is defined as* CWE

Definition: Normalized identifier of the weakness type that is claimed to be associated with the finding.

Possibility: a finding may *have* many CWE identifier

Note: CWE identifier shall be added during the adaptation phase.

Note: In the situation when there is an ambiguity in a mapping of a particular finding (type) of a static analysis tool to CWE, multiple CWE identifier will be associated with the corresponding finding.

Note: the TOIF Analyzer may split finding with multiple CWE identifier into several findings with a single CWE identifier

Finding *is reported as* Weakness Description

Definition: Description of the weakness type other than the normalized identifier associated with the finding.

Description: Weakness description is associated with the finding by the generator. Usually this description represents a proprietary message generated by the static code analysis tool (either specific to the weakness type, or specific to the finding).

Finding *references* File

Finding *is produced by* Adaptor

Finding *is reported by* Generator

Finding *is reported in* Build

Finding *has* Criticality

Definition: Claim that a finding has certain criticality.

Description: Generator tools may capture criticality of an individual finding to facilitate ranking of the findings.

Finding *has* Confidence

Definition: Claim that a finding has certain confidence.

Description: Generator tools may associate confidence with a finding to facilitate analysis of the findings and ranking of the findings.

Criticality

Definition: A measure of impact that a certain weakness may cause.

General concept: `Percent`

Description: 0% - means that a weakness does not cause any impact, while 100% means that the weakness corresponds to a critical vulnerability. Criticality is a natural number from 0 to 100 interpreted as percent.

Note: Original SCA tools may use proprietary methodology to calculate criticality of a finding.

`Confidence`

Definition: a measure of confidence of an agent making a claim that the statement is actually true.

General concept: `Percent`

Description: 0% means that an agent is not confident (the evidence is slim, yet there is something that caused the agent to make the claim). 100% means that the agent is very confident (there is strong evidence supporting the claim). Confidence is a natural number from 0 to 100 interpreted as percent.

Note: Original SCA tools may use proprietary methodology to calculate confidence of a finding.

`Weakness` *`is defined as`* `CWE`

`Weakness` *`has`* `Code Location`

`Code location`

Definition: Location in the code of a system under investigation.

Description: This element is a statement of a location within a system under investigation. The system under investigation may be represented as one or more source files, executable files (machine code) or a combination of both. Location in the code of the system under investigation is defined as a combination of a file and a location within the file. Location in a source file is given as a line number and optionally a position within the line. Location within an executable file is defined as an offset. Multiple Code Location elements may refer to the same logical location, for example when the same set of files is analyzed independently by multiple static code analysis tools and several reports are produced.

Note: In some cases, Code location may refer to the entire file (including situations when the file is empty). In this case, the Code location involves only the reference to a File. In other cases, Code location shall involve either a Line number or an Offset. When a Code location involves a Line number, it may additionally involve a position.

Note: this provides a unique reference schema for findings. The corresponding concept in KDM is SourceRef

Note: Defined in Figure 7. UML class diagram Code Location

`Code location` *`references`* `file`

Definition: Code location is uniquely described as a location within a certain file.

Description: Code location element refers to a location in the code of the system under investigation by describing a combination of a file and a location within the file.

Possibility: `Code location` *`references`* `exactly one` `file`

`Code location` *`has`* `line number`

Definition: Line number that describes a location within a source file.

Description: for locations in source files; this attribute is optional

Possibility: `code location` `may` *`have`* `line number`

`Code location` *`has`* `position`

Definition: Position of a character within a line number that uniquely describes a location within a source file.

Description: for locations in source files; this attribute is optional

Possibility: `code location` `may` *`have`* `position`

`Code location` *`has`* `offset`

Definition: Number of a byte in a binary file that uniquely describes a location within an executable file.

Description: for locations in binary files. Code locations in executable files are identified in binary image, therefore offset is the same as the virtual address of a byte in the image. Offset does not represent the offset in the executable file itself.

Possibility: `code location` `may` *`have`* `offset`

`Line number`

Definition: Line number that uniquely describes a location within a file.

General concept: `Natural number`

Description: A source file is assumed to be a text file that consists of a sequence of one or more lines, marked by an end-of-line characters. Lines are enumerated from 1. Line number in case of an empty file is not applicable.

`Position`

Definition: Number of a character within a line (identified by a line number) that uniquely describes a location within a file.

General concept: `Nonnegative integer number`

Description: A line of a source file is assumed to be a sequence of one or more characters different from an end-of-line character. Characters are enumerated from 1. Position in in case of an empty line is not applicable.

`Offset`

Definition: Offset of a byte that uniquely describes a location within a binary image.

General concept: `Nonnegative integer number`

Description: A binary file is assumed to be a sequence of one or more bytes. Bytes are enumerated from 1. Offset in in case of an empty binary file is not applicable. Offset is the same as the virtual address of a byte in the image. Offset does not represent the offset in the executable file itself.

`Weakness Type Identifier`

Definition: A category of weakness.

Note: This is not a designation, but the actual category. The suffix Identifier is added for consistency with "CWE Identifier" and SFP Identifier", to avoid possible confusion between "CWE" as the entire catalog, "CWE" as a specific category of weakness in the CWE catalog.

Synonym: Weakness Type

Note: Defined in Figure 4. UML class diagram WeaknessType

Weakness Type Identifier *has* name

Definition: A unique name provided to a weakness type defined by the Common Weakness Enumeration (CWE).

Description: Common Weakness Enumeration (CWE) is a standard that provides a list of weakness types, each identified by a CWE name, for example, "CWE-561".

Weakness Type Identifier *has* description

Definition: Description of a Weakness Type Identifier is an informal description of the corresponding weakness type

CWE identifier

Definition: A weakness type defined by the Common Weakness Enumeration (CWE).

Description: Common Weakness Enumeration (CWE) is a catalog that describes a collection of weakness types, each identified by a CWE identifier, for example, "CWE-121". CWE associates several information blocks with each weakness type, including a long name, an informal description, examples, references to other standards, such as CVE, etc.

Note: The `CWE Identifier` represents an individual weakness type. The suffix "Identifier" is added to avoid possible confusion between "CWE" as the entire catalog, "CWE" as a specific category of weakness in the CWE catalog. The "Name" attribute corresponds to the CWE identifier.

Note: Since the original CWE catalog provides only an informal description of each weakness type, TOIF uses the more formal approach aligned with the SFP catalog, which involves several adjustments to the original CWE types to achieve an unambiguous identification scheme.

Note: Defined in Figure 4. UML class diagram WeaknessType

SFP Identifier

Definition: A weakness type defined by the Software Fault Patterns (SFP) catalog.

Note: This is not a designation, but the actual category. The suffix Identifier is added to avoid possible confusion between "SFP" as the entire catalog, "SFP" as a specific category of weakness in the SFP catalog.

Description: Software Fault Patterns (SFP) is a standard that provides a list of weakness types, each identified by a SFP identifier, for example, "SFP-8". Each SFP weakness type is further linked to one or more individual CWE weakness types, possibly with some adjustments to the original CWE types in order to achieve an unambiguous identification scheme. Each SFP weakness type is part of one SFP Cluster.

SFP Cluster

Definition: A weakness category provided by the Software Fault Patterns (SFP) catalog.

Description: Software Fault Patterns (SFP) is a standard that provides a list of weakness clusters, each identified by a unique name, for example, "Authentication".

Note: Defined in Figure 4. UML class diagram WeaknessType

Weakness Description

Definition: Description of the weakness type other than the normalized identifier associated with the finding.

Description: Weakness description is associated with the finding. Usually this description represents a proprietary report generated by the static code analysis tool (either specific to the weakness type, or specific to the finding).

Note: Weakness Description is a proprietary Weakness Type Identifier. Because it is proprietary, and also because it is defined operationally (by an SCA tool), it is difficult to reason about the exact extent of this Weakness Type.

`Weakness description` *`has`* `description`

Definition: Text of the weakness description

`Description`

General concept: `Text`

`File`

Definition: A computer resource for recording a collection of related data or program records stored as a unit with a single name.

Description: File in TOIF corresponds to the InventoryItem concept in KDM. In TOIF a File is assumed to represent code of the system under investigation and is usually either a source file (KDM SourceFile) or an executable file (KDM ExecutableFile).

Note : Defined in Figure 8. UML class diagram File.

`File` *`has`* `name`

Definition: Name of the file

`Name`

General concept: `Text`

`File` *`has`* `checksum`

Definition: Checksum of the file

Note: the ability to compute the checksum of a file that is the source for the particular weakness report depends on the access to this file. In general, the application of the generator is done at a separate phase, therefore the adaptor may not be able to compute this information. However, availability of the checksum will facilitate management of multiple TOIF segments and reduce errors caused by merging unrelated TOIF segments.

Note: The Inventory Model of the KDM Model includes the checksum of each file in the system under assessment.

`Checksum`

General concept: `Integer`

Definition: Checksum is a small-sized datum derived from a block of digital data for the purpose of detecting errors which may have been introduced during its transmission or storage or to identify duplicate blocks.

`File` *`has`* `version`

Note: the ability to compute the version of a file that is the source for the particular weakness report depends on the access to this file. In general, the application of the generator tool is done at a separate phase; therefore the adaptor may not be able to compute this information. However, availability of the version will facilitate management of multiple TOIF segments and reduce errors caused by merging unrelated TOIF segments.

Note: the Inventory Model of the KDM Model includes the version of each file in the system under assessment.

Version

Definition: A unique identifiable state of something.

General concept: State

Note: Version of the subject is designated by a string

File *is contained in* Directory

File *belongs to* Project

Directory

Definition: An organizational unit or container, used to organize directories and files into a hierarchical structure.

Note: Defined in Figure 9. UML class diagram Directory

Directory *is contained in* Directory

Directory *has* name

Directory *belongs to* Project

Statement

Definition: An basic identifiable unit of behavior in software such as a source code statement, a basic block, a operator.

Note: this corresponds to KDM ActionElement class

Note: Defined in Figure 10. UML class diagram Semantic Statement

Statement *has* code location

Statement *is involved in* Finding

Synonym: Finding *is associated with* statement

Possibility: each Finding may *be associated with* many statement

Statement *is part of sink of* Finding

Note: This is a stronger form of the fact type Statement *is involved in* Finding where the role of Statement is known to be a sink, i.e. a statement that corresponds to the discernable necessary condition of the weakness. For example, a statement that performs access to a buffer is the necessary condition to a buffer overflow weakness, since without an access there is no overflow. Sink is a concept use in the Software Fault Patterns (SFP). Many software faults have discernable Sink and Source statements and a data flow path between them.

Statement *is part of source of* Finding

Note: This is a stronger form of the fact type Statement *is involved in* Finding where the role of Statement is known to be a source, i.e. a statement that corresponds to the discernable sufficient condition of the weakness. For example, a statement that sets the pointer outside of the available space in a buffer is the sufficient condition to a buffer overflow weakness, provided that there also exists a data flow path to a sink which performs access to the buffer using the same pointer, and the value of the pointer is unchanged along the path. Source is a concept use in the Software Fault Patterns (SFP). A weakness finding may have multiple sources. Many software faults have discernable Sink and Source statements and a data flow path between them.

Statement *is preceded by* Statement

Data element

Definition: An basic identifiable data item is software such as global and local variables, records, formal parameters and constants.

Note: This corresponds to the KDM DataElement class
Note: Defined in Figure 11. UML class diagram Semantic Data

Data element *is defined at* Code Location

Data element *is involved in* Finding
Note: This fact type establishes an association between a Data element and a Finding, but does not provide any further detail regarding the role of the Data Element.

Data element *has* name

Data element *is involved in* Statement
Note: This fact type establishes an association between a Data element and a Statement, where a Statement can be further identified as either the Source or the Sink of the Finding. In this case, the Data element is passed along the data flow path from the Statement is known to be a Source, i.e. a statement that corresponds to the discernable sufficient condition of the weakness, to the Sink of the finding, i.e. a statement that corresponds to the necessary condition of the weakness. For example, a statement that sets the pointer outside of the available space in a buffer is the sufficient condition to a buffer overflow weakness, if there also exists a data flow path to a sink which performs access to the buffer using the same pointer, and the value of the pointer is unchanged along the path. The pointer is then the Data element involved in the Source statement. Data element, Source and Sink are concepts used in the Software Fault Patterns (SFP). A weakness finding may have multiple data elements involved in the data flow path between Source and Sink.

Citing
Definition: An observation related to a weakness that may supply additional information to the weakness and a verdict which is a claim that a weakness is valid or is not valid.

Note: Some citings may be performed by analysts, while other citings may be performed by Analytics Tools, for example based on pattern matching and/or machine learning

Note: Defined in Figure 6. UML class diagram Citing

Citing *references* Weakness

Citing *has* Description

Citing *has* Confidence

Citing *is generated at* Date

Citing *is generated by* Citing Agent

Citing *has* Verdict

Verdict

Definition: An evaluation of the findings and code facts for a particular weakness as represented by one or more findings, CWE Identifier and code location into Code Artifacts. Verdict represents a claim that a weakness is a valid finding (true) or not a valid finding (false)

Citing Agent

Definition: An Person or an Analytics Tool that has provided the Citing.

Note: Some citings may be performed by analysts, while other citings may be performed by Analytics Tools, for example based on pattern matching and/or machine learning

9.2 "Housekeeping" Entities and Facts

This section describes several "housekeeping" facts that facilitate management of multiple TOIF facts during the entire life cycle of the system under investigation, or multiple systems under investigation within an enterprise.
The key objectives are

- to facilitate management of multiple TOIF Segment generated during the course of the TOIF project
- to reduce the possibility of errors caused by merging unrelated TOIF Segments
- to reduce the possibility of errors caused by merging a TOIF Segment with an unrelated KDM model

The housekeeping information includes the following:

- project identifier (unique project name that corresponds to the system under investigation)
- build identifier
- name of the generator tool
- vendor name of the generator tool
- generator tool identifier (unique version of the generator tool)
- adaptor identifier (unique name and version of the adaptor tool)
- person name responsible to the TOIF Segment
- organization responsible for the TOIF Segment
- date when the TOIF Segment was produced

Tool

Definition: Any software that can be used to develop, test, analyze, or maintain a computer program or its documentation.

Note: Defined in Figure 15. UML class diagram Tools

Tool *has* Description

Tool *has* name

Tool *has* version

Generator

Definition: Any capability to scan source or machine code of the system under investigation and generate weakness finding reports.

Description: Generator tool usually involves components that perform scanning and parsing of source code, or perform disassembling of the machine code, implement optimized control and data flow analysis algorithms, often incorporate extensive information about standard software libraries and components, operating systems and compilers, as well as a certain knowledge base of what they consider as weaknesses and the corresponding patterns that can be used to discover at least some of these weaknesses in the code. Effectiveness of Generator tool is determined by multiple factors.

Synonym: SCA tool

Note: Defined in Figure 15. UML class diagram Tools

`Adaptor`

Definition: Any capability to transform the proprietary weakness finding report from a particular Generator tool into a normalized representation determined by the TOIF specification.

Description: The most challenging part of implementing a TOIF adaptor is to provide a mapping from proprietary weakness type system used by a particular Generator tool into a normalized system of weakness types in a justifiable and unambiguous way that facilitates further semantic integration of the TOIF finding facts. TOIF specification uses a formalized 3-level hierarchical system of weakness types that involve a combination of the Software Fault Patterns (SFP) catalog and the Common Weakness Enumeration (CWE)

Note: Defined in Figure 15. UML class diagram Tools

`Adaptor` *`supports`* `Generator`

Synonym: `Generator` *`requires`* `Adaptor`

`Adaptor` *`is capable of finding`* `CWE`

Synonym: `CWE` *`can be reported by`* `Adaptor`

`Orchestration tool`

Definition: Any capability to perform the process of running Generator tools and their corresponding TOIF Adaptors in alignment with the regular build

Description: The responsibility of the Orchestration tool is to make sure that each source file is processed by selected Generator tools with desired options, aligned with the options used during the regular build, that an appropriate TOIF Adaptor is called for each Generator tool, that all TOIF output files are appropriately managed; Similarly for machine code analysis, the TOIF Orchestration tool aligns the process of running the selected Generator tools and their TOIF Adaptors on all desired machine code files. From the software assurance evidence perspective, the TOIF Orchestration tool generates the key piece of evidence regarding the coverage of the source and machine code files, correctness of the weakness findings, etc.

Note: Defined in Figure 15. UML class diagram Tools

`Analytics tool`

Definition: Any capability to consume one or more TOIF segments and produce one or more TOIF segments.

Description: Analytics tools may include, for example, a TOIF Integration tool, that consumes partial TOIF segments and produces a single integrated segment, or a TOIF Citing tool that consumes TOIF integrated segment and augments it with some elements.

Note: Defined in Figure 15. UML class diagram Tools

`Vendor`

Definition: An organization that supplies a Tool used in project

General concept: `Organization`

Note: Defined in Figure 16. UML class diagram Organization

`Tool` *`is supplied by`* `Vendor`

Synonym: `Vendor` *`supplies`* `Tool`

`Person`

Synonym: Individual, human

Note: Defined in Figure 17. UML class diagram Person

`Person` *`has`* `name`

`Person` *`has`* `email address`

`Person` *`has`* `phone number`

`Email address`

`Phone number`

`Address`

`Person` *`is employed by`* `Organization` *`as`* `Role`

Note: it is assumed that the dynamics of this relationship is not relevant to the TOIF. So this relationship means that the Person was employed by Organization for the duration of the project.

`Organization`

Description: An entity comprising multiple persons that have a shared goal and is linked to an external environment

Description: `an Organization involved in project`

Note: Defined in Figure 16. UML class diagram Organization

`Organization` *`has`* `name`

`Organization` *`has`* `Description`

`Organization` *`has`* `address`

`Organization` *`has`* `email address`

`Organization` *`has`* `phone number`

Organization$_1$ *`is part of`* Organization$_2$ *`as`* `Role`

`Role`

Definition: The position or purpose that someone or something has in a situation, organization, society, or relationship. Role usually defines a function or part performed in a particular operation or process. In TOIF, this element describes the nature of involvement of a Person in an Organization, or of one Organization in another, or Person/Organization in a Project.

Note: Defined in Figure 18. UML class diagram Role

`Role` *`has`* `name`

`Role` *`has`* `Description`

`Project`

Description: a TOIF project related to a specific system under investigation. This element is part of TOIF "housekeeping" elements that describe metadata for managing findings in an enterprise environment.

Note: Defined in Figure 14. UML class diagram Project

`Project` *`has`* `name`

`Project` *`has`* `Description`

Note: a separate TOIF Segment may be used to own all "housekeeping" elements and their descriptions

`Person` *`is involved in`* `Project` *`as`* `Role`

`Organization` *`is involved in`* `Project` *`as`* `Role`

`Build`

Definition: An engineering activity that involves a series of transformations of the "source code" artifacts into "executables" that can run on a selected computer platform. Build is performed in the context of the system under investigation. Build is a specific event and the corresponding set of artifacts.

Synonym: `TOIFBuild`

Note: Defined in Figure 12. UML class diagram Build and in Figure 13. UML class diagram Housekeeping

`Build` *`has`* `name`

`Build` *`has`* `description`

Definition: Text that provides a description of the build

`Build` *`is related to`* `Project`

`Build` *`is generated by`* `Person`

`Build` *`is supervised by`* `Person`

Synonym: `Person` *`is responsible for`* `TOIF Segment`

`Build` *`is produced by`* `Organization`

`Build` *`is owned by`* `Organization`

`Build` *`is created at`* `Date`

`Date`

Definition: Time stated in terms of year, month, day and possibly also hour, minute

Note: Date may include a Time Zone.

Synonym: `Timestamp`

`Build` *`is orchestrated by`* `Orchestration tool`

Synonym: `Orchestration tool` *`generated`* `Build`

9.3 Fact-oriented organization of TOIF XMI

This section elaborates the conceptual model and describes the fact-oriented organization of the TOIF XMI. More specifically, this section describes a certain abstract structure of the TOIF concepts, by observing that all above concepts of TOIF are either noun concepts (such as Finding), or verb concepts (such as Finding is reported in Build), or take a specific form of an owned attribute (such as File has Name). Noun concepts will be further referred to as Entities (or TOIF Entities). Verb concepts will be further referred to as Facts, or Clauses (or TOIF Facts). Few special purpose verb concepts will be referred to as TOIF Records (or Evidential Records). Finally, Attributes are special verb concepts in the form of TOIF Entity *has* something.
Collectively, TOIF Entities and TOIF Facts/Clauses will be referred as TOIF Elements.

The physical structure of the TOIF XMI shall be based on the abstract structure of the TOIF, i.e. shall be structured as a collection of instances of TOIF Entities, together with their owned Attributes, and instances of TOIF Facts/Clauses and Records. A TOIFSegment is a physical container for a collection of the instances of TOIF Entities together with their owned/unique Attributes, and instances of TOIF Facts/Clauses and TOIF Records. When this does not lead to confusion, the content of a TOIFSegment will be also referred to as "TOIF facts", meaning the individual noun and verb concepts that are instances of the TOIF concepts from the TOIF specification, taken as the truth.

First, a Segment is the root element for the TOIF XMI file and the container of the TOIF facts and the corresponding entities. TOIF segment is be the main unit of information exchange within the TOIF framework. The TOIF Segment *owns* the corresponding entities and facts. The concept of element ownership is important from the design perspective of the XML/XMI. Eventually, ownership corresponds to the nested XMI tags. It is assumed that every TOIF entity and every TOIF fact is defined by a unique pair of XMI tags. Facts and entities in a TOIF Segment are flat, i.e a TOIF Segment is an ordered list of TOIF entities and facts. The following logical constraints apply:

C1: TOIF Segment shall own all TOIF entities that are objects of the TOIF facts owned by that Segment
C2: TOIF entity that is the object of a TOIF fact shall precede that fact in the TOIF Segment.
C3: TOIF Entity owns all its attributes

The physical organization of the TOIF facts is defined by the following conceptual schema:

`Fact`

Definition: A general category that includes all verb concepts defined in TOIF, that represent general statements (assertions) about TOIF entities, except the verb concepts that define owned attributes of TOIF Entities.

Synonym: TOIF Fact

Synonym: Clause

Synonym: TOIF Clause

Description: a TOIFSegment describes instances of TOIF Facts. TOIF distinguishes Facts and Evidential Records where a Fact provides a statement related to both basic and housekeeping TOIF Entities, and Evidential Record provides a statement related to the build (orchestration) environment.

Note: Defined in Figure 19. UML class diagram Abstract Structure

Note: Concrete facts are enumerated in Figure 22. UML class diagram Basic Facts 1, Figure 23. UML class diagram Basic Facts 2, Figure 24. UML class diagram Basic Facts 3, Figure 25. UML class diagram Basic Facts 4 and Figure 28. UML class diagram Housekeeping Facts 1, Figure 29. UML class diagram Housekeeping Facts 2, Figure 30. UML class diagram Housekeeping Facts 3

`Entity`

Definition: A general category that includes all noun concepts defined in TOIF, except ones that define owned attributes of TOIF Entities.

Synonym: a TOIF entity

Description: a TOIFSegment describes instances of TOIF Facts that reference TOIF Entities

Note: TOIF specification describes a number of noun concepts referred to as Entity. TOIF segment enumerates instances of Entity as individual noun concept. Introduction of an individual Entity is considered as the so-called existential fact

Note: Concrete noun concepts that correspond to Entity in TOIF specification are enumerated in Figure 21. UML class diagram Basic entities and Figure 27. UML class diagram Housekeeping entities

`Entity` *`is subject of`* `Fact`

Synonym: `Fact` *`adds information about`* `Entity`

`Entity` *`is object of`* `Fact`

Synonym: `Fact` *`references`* `Entity`

`Attribute`

Definition: A general category of noun concepts and the corresponding role concepts in the form of X has Y that describe owned attributes of TOIF Entities

Description: a TOIF attribute

General concept: `Fact`

Possibility: `an Attribute is owned by exactly one Entity`

Note: Defined in Figure 26. UML class diagram Basic Attributes and Figure 31. UML class diagram Housekeeping Attributes

`Attribute` *`is an attribute of`* `Entity`

Synonym: `Entity` *`owns`* `Attribute`

`Evidential Record`

Definition: A general category of verb concepts that represent evidential record related to the build (orchestration) environment of the system under assessment rather that generic statements about TOIF Basic or Housekeeping Entities

Description: A general category that includes few verb concepts defined in TOIF that have a form of a TOIF fact with one or more additional attributes.

Synonym: TOIF Record

Synonym: Record

Note: Defined in Figure 19. UML class diagram Abstract Structure

Note: Concrete record are enumerated in Figure 32 UML class diagram EvidentialRecord

Example: BuildRecord, CompileRecord, GeneratorRecord

`Build Record`

Definition: An evidential record that captures the total number of findings by a given SCA tool in a given file in a given build. Build Record is part of the mechanism that supports “negative claims” – understanding what weaknesses are absent in the system under assessment (or in one of its components). The other part of this mechanism is the access to full list of weaknesses that a given SCA tool is capable of finding (the so-called adaptor api).

General concept: Evidential Record

Compile Record

Definition: An evidential record that captures the options used to compile a given file in a given build. Compile Record together with Generator Record can be used to validate the orchestration of multiple tools for a given build.

General concept: Evidential Record

Generator Record

Definition: An evidential record that captures the options of a given SCA tool used to analyze a given file in a given build. Generator Record together with Compile Record can be used to validate the orchestration of multiple tools for a given build. Generator Record also has a role in “negative claims” as the options used to analyze a given file by a given SCA tool may limit the types of weaknesses being reported for that file

General concept: Evidential Record

TOIF Segment

Synonym: Segment

Definition: A container for one or more instances of TOIF elements with a shared purpose

Note: TOIF describes a logical model – a network of entities linked by named relationships. Segment is a physical unit of exchange for some cohesive collection of elements and corresponding relationships.

TOIF Segment *has* name

TOIF Segment *has* Description

Note: Defined in Figure 19. UML class diagram Abstract Structure

TOIF Segment *owns* Fact

TOIF Segment *owns* Entity

Necessity: TOIF Segment *owns* each Entity that is *referenced by* Fact that is *owned by* the TOIF Segment

10 TOIF Logical model

This section describes the MOF/UML metamodel for TOIF XMI which is developed as an intermediate step from the TOIF Conceptual Model defined in SBVR Structured English as a technology-independent vocabulary for the TOIF Ecosystem towards the TOIF XMI schema. The TOIF MOF/UML metamodel is consistent with the TOIF Conceptual Model. The TOIF XMI schema is derived from the TOIF MOF/UML model by applying the MOF/XMI rules.
The TOIF UML model consists of a single UML package and includes 30 class diagrams to represent the following:

- TOIF basic elements
- TOIF housekeeping elements
- TOIF fact-oriented structure

The TOIF UML model is structured as an explicit set of classes corresponding to the conceptual schema, where each verb concept is represented as a UML association class, and each TOIF attribute is implemented as an owned class, rather than a UML attribute. This determines a certain “triple flavor” of the TOIF XMI data, and facilitates the potential use of other technology spaces, including reasoning tools to handle TOIF data.
The rest of this section has the following organization. Section 10.1 presents 7 UML class diagrams that describe the basic elements of the TOIF XMI, the logical entities and fact types. Section 10.2 presents 8 UML class diagrams that describe the housekeeping elements of the TOIF XML. Section 10.3 presents 8 UML class diagram that describes the physical structure of the TOIF XMI.

10.1 The basic elements of the TOIF XML

This section presents 9 UML class diagrams that represent the basic entities and facts of the TOIF XMI: Finding, Weakness Type Identifier, Code Location, File, Directory, Semantic Statement and Semantic Data.

10.1.1 Finding Class Diagram

This section describes the UML representation of the Finding concept and the corresponding facts that fully describe the finding through several clauses where the finding is the subject and other concepts of TOIF are objects of the clause.

10.1.1.1 Finding Class

The Finding class is the key class of TOIF. Instances of this class represent individual weakness findings reported by static analysis tools for the code of the system under investigation. The Finding class only has a unique id, it does not own any attributes, and is defined through connections to other instances of TOIF through association classes, such as, for example, FindingIdefinedAsCWE, which represents a verb concept “Finding is represented as CWE” and associated the instance of Finding to an instance of a class CWEIdentifier. An instance of Finding is essentially a “hub” that joins multiple related clauses, each providing a facet of information about the finding.
The superclass BasicEntity is defined in Section 10.3.3 Basic Entities Class Diagram

Superclass
BasicEntity

Associations

criticality:Criticality[0..1]	Owned attribute that specifies criticality of the finding in terms of the impact that it may cause.
confidence:Confidence[0..1]	Owned attribute that specifices the confidence in this finding claim.

Constraints

1. Each Finding instance shall be the subject of at least one FindingIsReportedAsType clause
2. Each Finding instance shall be the subject of at least one FindingIsReportedByGenerator clause
3. Each Finding instance shall be the subject of exactly one FindingIsDefinedAsCWE clause
4. Each Finding instance shall be the subject of at least one FindingIsProducedByAdaptor clause
5. Each Finding instance shall be the subject of at least one FindingHasCodeLocation clause
6. Each Finding instance shall be the subject of at least one FindingIsProducedInBuild clause

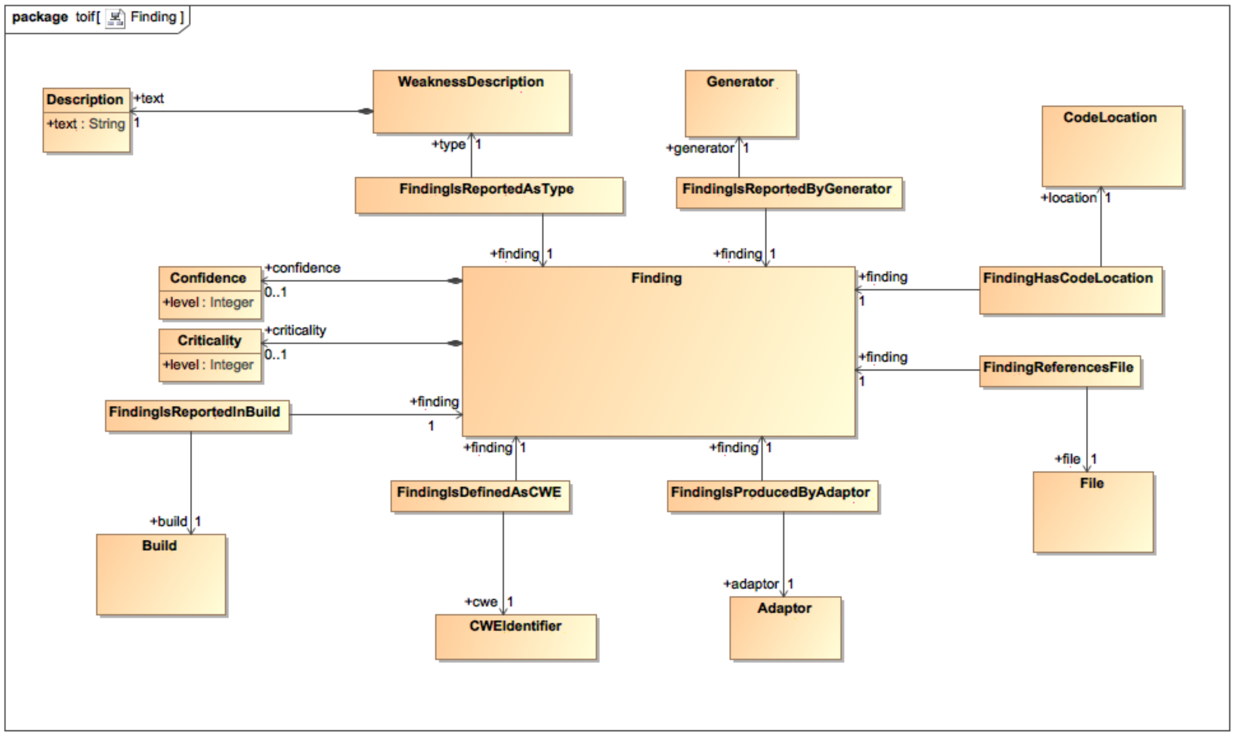


Figure 3. UML class diagram Finding

Example

This example illustrates a single Finding and a complete set of related clauses. Note, that all finding-related clauses are mandatory, except for the FindingReferencesFile. This clause is optional, since the same information is provided by the pair of mandatory clauses FindingHasCodeLocation and CodeLocationReferencesFile.

```
<fact xmi:type=”toif:Finding” xmi:id=”f0001”/>

<fact xmi:type=”toif:CodeLocation” xmi:id=”loc10”>
    <linenumber linenumber=”1856”/>
</fact>

  <fact xmi:type=”toif:FindingIsReportedAsType”
     finding=”f0001” type=”wd_t1_1”/>
  <fact xmi:type=”toif:FindingIsReportedByGenerator”
     finding=”f0001” generator=”rats_2.3”/>
```

```
   <fact xmi:type=”toif:FindingIsDefinedAsCWE”
      finding=”f0001” cwe=”CWE-561”/>
   <fact xmi:type=”toif:FindingIsProducedByAdaptor”
      finding=”f0001” adaptor=”rats_toif_adaptor_1.1”/>
   <fact xmi:type=”toif:FindingIsRelatedToBuild”
      finding=”f0001” build=”b1020171330”/>
   <fact xmi:type=”toif:FindingReferencesFile”
      finding=”f0001” file=”f10”/>
   <fact xmi:type=”toif:FindingHasCodeLocation”
      finding=”f0001” location=”loc10”/>

<fact xmi:type=”toif:WeaknessDescription” xmi:id=”wd_t1_1”>
    <description text=”Weakness that may lead to severe exposure”/>
</fact>
<fact xmi:type=”toif:CWEIdentifier” xmi:id=”CWE-561”>
    <description text=”xxxxxx”/>
</fact>
<fact xmi:type=”toif:Generator” xmi:id=”rats_2.3”>
    <name name=”RATS”/>
    <description text=”xxxxxx”/>
    <version version=”2.3”/>
</fact>
<fact xmi:type=”toif:Adaptor” xmi:id=”rats-toif-adaptor_1.1”>
    <name name=”RATS-TOIF”/>
    <description text=”xxxxxx”/>
    <version version=”1.1”/>
</fact>
<fact xmi:type=”toif:Build” xmi:id=”b1020171330”>
    <description text=”xxxxxx”/>
</fact>
   <fact xmi:type=”toif:CodeLocationReferencesFile”
      finding=”loc10” file=”f10”/>

<fact xmi:type=”toif:File” xmi:id=”f10”>
    <name name=”main.c”/>
</fact>
```

Example

This example illustrates a single Finding with attributes. Other clauses are assumed to be refer to the previous example.

```
<fact xmi:type=”toif:Finding” xmi:id=”f0001”>
      <confidence xmi:type=”toif:Confidence” xmi:id=”co_f0001” level=90/>
      <criticality xmi:type=”toif:Criticality” xmi:id=”cr_f0001” level=50/>
</fact>
```

10.1.1.2 FindingIsReportedAsType Class

The FindingIsReportedAsType class represents a verb concept “Finding is reported as Weakness Description”. This is an important clause that associates an instance of a Finding class to an instance of WeaknessDescription, which is a proprietary weakness type provided by a static code analysis tool.

When one instance of Finding is a subject of more than one FindingIsReportedAsType clauses, all corresponding descriptions are assumed to be jointly describing the finding, however no particular order is assumed. This may be utilized by some Adaptor tools to split proprietary reports into parts, some of which may be shared across findings, while others are specific to an individual finding.

Superclass

FindingFact

Associations

type:WeaknessDescription[1]	represents a proprietary weakness type reported by a static code analysis tool (either specific to the weakness type, or specific to the finding)
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

For the basic example, see 10.1.1.1

The following example illustrates multiple FindingIsReportedAsType clauses for the same subject, described below as xmi:id “f0001”. Note, that several mandatory clauses for the finding are not shown. Note, that the generic WeaknessDescription is shared by two findings “f0001” and “f0002”.

```
<fact xmi:type=”toif:Finding” xmi:id=”f0001”/>

  <fact xmi:type=”toif:FindingIsReportedAsType”
     finding=”f0001” type=”wd_t1_1_generic”/>

  <fact xmi:type=”toif:FindingIsReportedAsType”
     finding=”f0001” type=”wd_t1_1_concrete”/>

<fact xmi:type=”toif:WeaknessDescription” xmi:id=”wd_t1_1_generic”>
    <description text=”Unprotected global may lead to severe exposure”/>
</fact>

<fact xmi:type=”toif:WeaknessDescription” xmi:id=”wd_t1_1_concrete”>
    <description text=”unprotected global X”/>
</fact>


<fact xmi:type=”toif:Finding” xmi:id=”f0002”/>
  <fact xmi:type=”toif:FindingIsReportedAsType”
     finding=”f0002” type=”wd_t1_1_generic”/>
```

10.1.1.3 FindingIsReportedByGenerator Class

The FindingIsReportedByGenerator class represents a verb concept “Finding is reported by Generator”. This clause provides an association between a weakness finding and the static code analysis tool that has reported this finding. The Generator is represented as an instance of the Generator class, including specific version of the Generator used in the current Build. The clauses represented by TOIF can address situations where multiple versions of Generator were used in the same build, processing same or different files, and in these situations each instance of Finding is associated with a specific instance of Generator, where some of these instances will have the same name, and possibly description, but different version numbers. For more details, see the description of the Generator class.

Situations where one instance of Finding is a subject of more than one FindingIsReportedByGenerator clauses, may occur after merging multiple TOIFSegment in a TOIF repository in which case it may be beneficial to further normalize similar findings reported by multiple version of the same Generator tool by merging them into a single Finding instance.

Superclass

FindingFact

Associations

generator:Generator[1]	Generator tool that discovered weakness
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

See 10.1.1.1

10.1.1.4 FindingIsDefinedAsCWE Class

The FindingIsDefinedAsCWE class represents a verb concept "Finding is defined as CWE". This clause provides an association between a weakness finding and the normalized weakness type identifier for the weakness – a Common Weakness Enumerated identifier, represented by an instance of CWEIdentifier class.

Superclass

FindingFact

Associations

cwe:CWEIdentifier[1]	A weakness type defined by the Common Weakness Enumeration (CWE).
Finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Constraints

1. Each Finding shall be the subject of exactly one FindingIsDefinedAsCWE clause

Example

See 10.1.1.1

10.1.1.5 FindingIsProducedByAdaptor Class

The FindingIsProducedByAdaptor class represents a verb concept "Finding is produced by Adaptor". This clause provides a direct association between a weakness finding and the Adaptor tool that transformed the original proprietary finding reported by the Generator into a normalized format and a normalized weakness type identifier. For more details, see description of the Adaptor class.

Situations where one instance of Finding is a subject of more than one FindingIsProducedByAdaptor clauses, may occur after merging multiple TOIFSegment in a TOIF repository in which case it may be beneficial to further normalize similar findings reported by multiple version of the same Generator tool and/or multiple versions of the Adaptor tools for the Generator tool by merging them into a single Finding instance.

In a situation when some static analysis tool provides full native support to TOIF, an Adaptor element is still required.

Superclass

FindingFact

Associations

adaptor:Adaptor[1]	Instance of the Adaptor tool that performed normalization of the original proprietary tool weakness report
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

See 10.1.1.1

10.1.1.6 FindingHasCodeLocation Class

The FindingHasCodeLocation class represents a verb concept "Finding has Code Location". This clause provides an association between a weakness finding and the specific location in the code of the system under investigation, where the original finding was reported by some Generator tool. For more details, see description of the CodeLocation class.

When one instance of Finding is a subject of more than one FindingHasCodeLocation clauses, all corresponding locations are assumed to be jointly describing the finding, however no particular order is assumed. This may be utilized by some Adaptor tools to split proprietary reports involves multiple code locations. For a more semantically accurate descriptions, see descriptions of semantic facts (Semantic Statement and Semantic Data class diagrams).

Superclass

FindingFact

Associations

location:CodeLocation[1]	Location in the code of a system under investigation where weakness is discovered
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

See 10.1.1.1

10.1.1.7 FindingReferencesFile Class

The FindingReferencesFile class represents a verb concept "Finding references File". This clause provides a direct association between a weakness finding and the specific file of the system under investigation, where the original finding was reported by the Generator. For more details, see description of the CodeLocation and File classes.

This is an optional clause, since CodeLocation is already referencing a File.

Superclass

FindingFact

Associations

file:File[1]	File of the system under investigation in which the original weakness has been reported
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

See 10.1.1.1

10.1.1.8 FindingIsReportedInBuild Class

The FindingIsReportedInBuild class represents a verb concept "Finding is reported in Build". This clause provides a direct association between a weakness finding and the specific Build of the system under investigation, when the original finding was reported by some Generator. For more details, see description of the Build class.

Situations where one instance of Finding is a subject of more than one FindingIsReportedInBuild clauses, may occur after merging multiple TOIFSegment in a TOIF repository in which case it may be beneficial to further normalize similar findings reported in multiple builds by merging them into a single instance.

Superclass

FindingFact

Associations

build: Build[1]	TOIF build has a name and description and is related to the project
finding: Finding[1]	Weakness that has been discovered in the code of the system under investigation

Example

See 10.1.1.1

10.1.1.9 WeaknessDescription Class

WeaknessDescription represents the proprietary description of the weakness type generated by the static code analysis tool. WeaknessDescription may be shared by multiple findings of the same type, or may be used to capture specific information about a particular finding generated by the static analysis tool.

Superclass

BasicEntity

Associations

text:Description[0..1]	Owned attribute that provides the text of the proprietary weakness description

Example

See 10.1.1.1

10.1.2 WeaknessType Class Diagram

This section describes the UML representation of the Weakness Type Identifier concept and the corresponding facts.

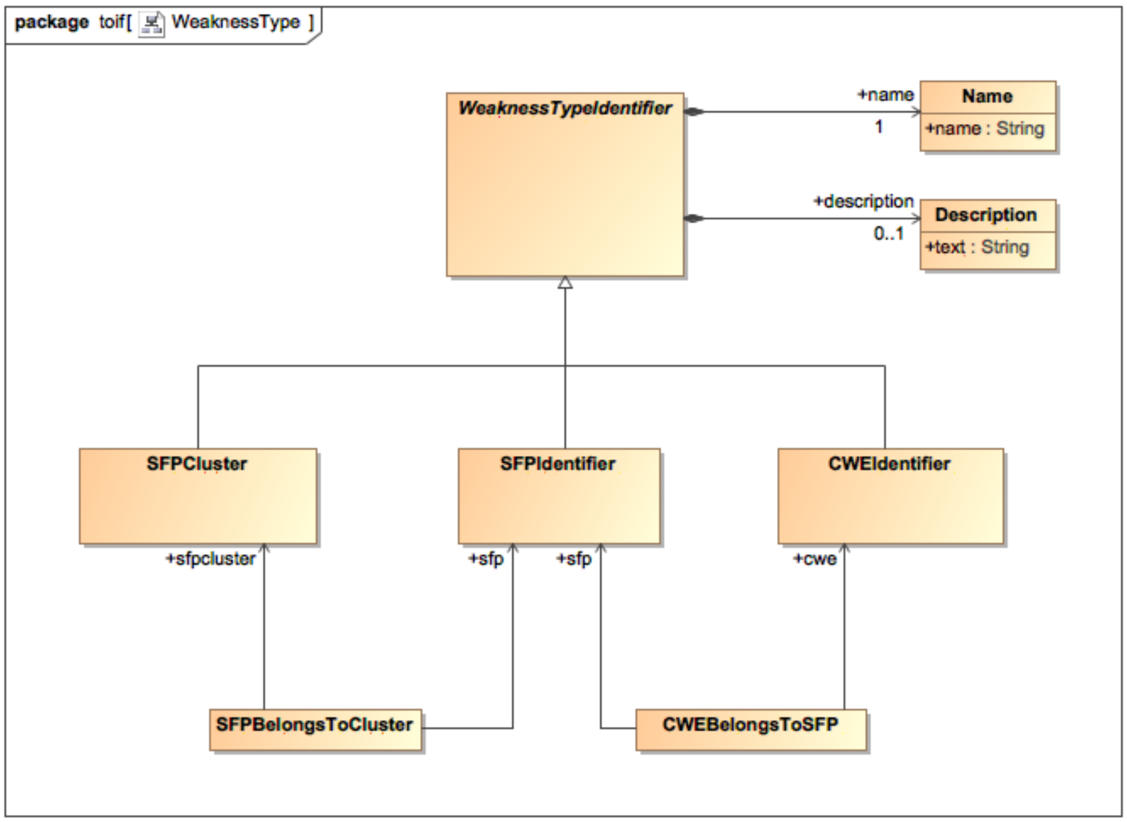


Figure 4. UML class diagram WeaknessType

10.1.2.1 WeaknessTypeIdentifier Class (abstract)

WeaknessTypeIdentifier is one of the key concepts in TOIF since it provides the means to achieve unique identification of weakness finding reports through a normalized standardized type identifier. The WeaknessTypeIdentifier in TOIF is a 3 level hierarchical structure consisting of the so-called SFP Cluster at the top, the SFP Identifier in the middle and the CWE identifier at the bottom. The use of Software Fault Patterns (SFP) catalog to augment CWE provides the means to overcome semantic ambiguity of CWE. Although TOIF uses the CWE identifiers, the allocation of such identifiers shall be coordinated with the mappings described in the SFP catalog, including the gaps and ambiguities. This strategy represents a unique formalized approach to normalization of (a discernable subset of) code weaknesses that is also aligned with the automated generation of test cases from the same set of formalizations. On the other hand, TOIF recognizes the importance of using CWE identifiers as the basis for the normalization.

Superclass

BasicEntity

Associations

name:Name[1]	Owned attribute that specifies the name of weakness type identifier
description:Description[0..1]	Owned attribute that provides the text description of the normalized weakness type

Example

```
<fact xmi:type=”toif:CWEIdentifier” xmi:id=”CWE-561”>
    <description text=”xxxxxx”/>
</fact>

<fact xmi:type=”toif:CWEBelongsToSFP”
cwe=“CWE-561” sfp=“SFP-8”/>
<fact xmi:type=”toif:SFPBelongsToCluster”
sfp=“SFP-8” cluster=“Authentication”/>

<fact xmi:type=”toif:SFPIdentifier” xmi:id=”SFP-8”>
    <name name=“es-ef-pi-eight”/>
    <description description=“this is the description that usually comes with
it”/>

<fact xmi:type=”toif:SFPCluster” xmi:id=”Authentication”>
    <name name=“Authentication Cluster”/>
    <description description=“Description of the cluster”/>
</fact>
```

10.1.2.2 CWEIdentifier Class

CWEIdentifier class represents the CWE Identifier concept.

Superclass

WeaknessTypeIdentifier

Example

See 10.1.2.1

10.1.2.3 SFPIdentifier Class

SFPIdentifier class represents the SFP Identifier concept.

Superclass

WeaknessTypeIdentifier

Example

See 10.1.2.1

10.1.2.4 SFPCluster Class

SFPCluster class represents the SFP Cluster concept.

Superclass

WeaknessTypeIdentifier

Example

See 10.1.2.1

10.1.2.5 CWEBelongsToSFP Class

CWEBelongsToSFP class represents the verb concept CWE belongs to SFP.

Superclass

WeaknessTypeFact

Associations

cwe:CWEIdentifier[1]	A weakness type defined by the Common Weakness Enumeration (CWE)
sfp: SFPIdentifier[1]	SFP Identifier which formalizes the mapping to the CWE identifier of the clause

Constraints

1. Each CWEIdentifier belongs to exactly one SFPIdentifier

Example

See 10.1.2.1

10.1.2.6 SFPBelongsToCluster Class

SFPBelongsToSCluster class represents the verb concept SFP belongs to Cluster.

Superclass

WeaknessTypeFact

Associations

sfp:SFPIdentifier[1]	SFP Identifier that is the subject of the clause
cluster: SFPCluster[1]	SFP Cluster to which the SFP Identifier belongs

Constraints

1. Each SFPIdentifier belongs to exactly one SFPCluster

Example

See 10.1.2.1

10.1.3 Weakness Class Diagram

This section describes the UML representation of Weakness concept and the corresponding facts.

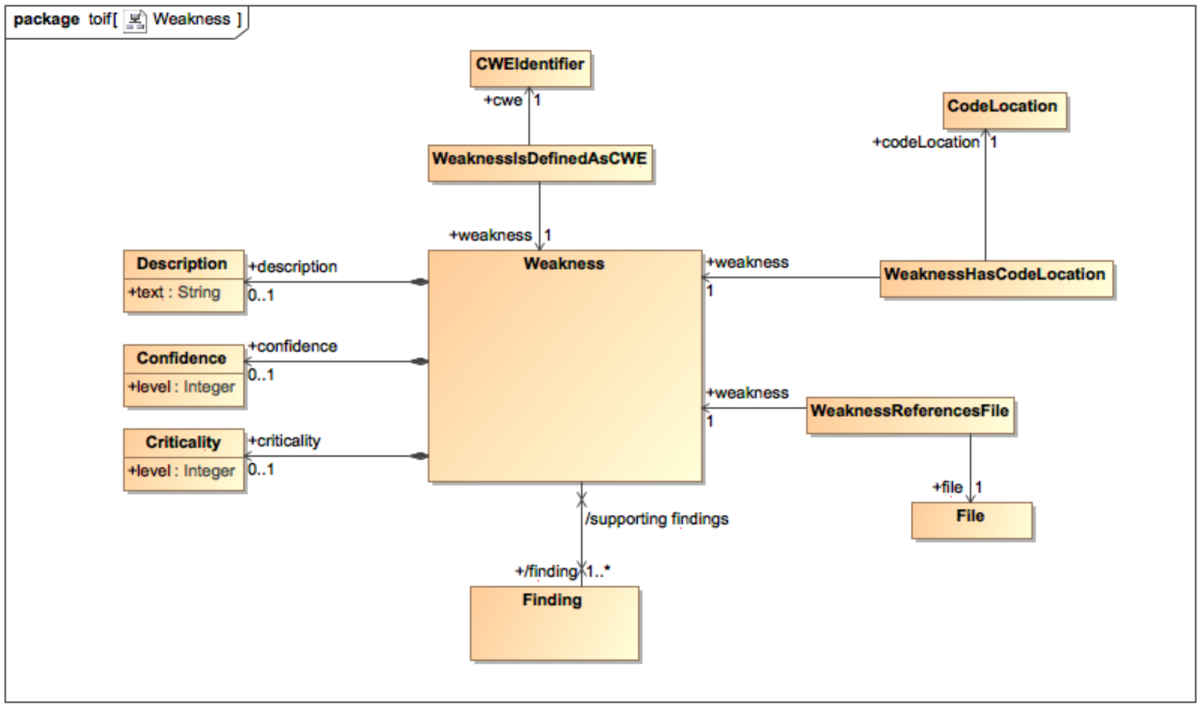


Figure 5. UML class diagram Weakness

10.1.3.1 Weakness Class

Weakness class represents the Weakness concept. Objects of this class are created by TOIF Analytics Tools, and not by the TOIF Adaptor Tools as are the Finding objects. A Weakness object represents a unique weakness in the code of system under assessment, as supported by one or more Findings. This class supports integration and analysis of multiple TOIF reports and serves as the subject for additional statements, mainly the criticality, confidence, and citing statements. Confidence and Criticality statements involve owned attributes of the Weakness class, and Citing statements involve additional instances of a Citing class, described in section 10.1.4.

The Weakness class is an important part of the TOIF interface for the consumer tools and integration tools that can be used for vulnerability management purposes. Property Finding is provided for illustration purposes only, as it is defined as derived, and the corresponding association is non-navigable in both directions. Relation between Weakness and its supporting Findings is dynamic: while Finding object is related to a particular Build, a Weakness is related to the entire Project, but may have a certain range of builds during which it was present, starting from the build where one or more tools has reported this weakness until the build where none of the tools were any longer reporting this weakness either because it was fixed or for other reasons.

Superclass

BasicEntity

Constraints

1. Each Weakness shall be the subject of exactly one WeaknessIsDefinedAsCWE clause
2. Each Weakness shall be the subject of exactly one WeaknessHasCodeLocation clause

Associations

description:Description[0..1]	Owned attribute that provides than informal text description of the weakness
criticality:Criticality[0..1]	Owned attribute that specifies criticality of the weakness in terms of the impact that it may cause.
confidence:Confidence[0..1]	Owned attribute that specifices the confidence in this weakness claim.

Example

```
<fact xmi:type="toif:Weakness" xmi:id="w0001">
     <criticality xmi:type="Criticality" level=80 />
</fact>

  <fact xmi:type="toif:WeaknessHasCodeLocation"
     finding="w0001" location="loc10"/>
  <fact xmi:type="toif:WeaknessHasCodeLocation"
     finding="w0001" location="loc10"/>


<fact xmi:type="toif:CodeLocation" xmi:id="loc10">
    <linenumber linenumber="1856"/>
</fact>

<fact xmi:type="toif:Finding" xmi:id="f0001"/>

For the facts related to the finding id="f0001" refer to example in Section
10.1.1.1
```

10.1.3.2 WeaknessIsDefinedAsCWE Class

CodeLocationReferencesFile class represents the verb concept "Code Location references File".

Superclass

WeaknessFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause
file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.3.1

10.1.3.3 WeaknessHasCodeLocation Class

CodeLocationReferencesFile class represents the verb concept “Code Location references File”.

Superclass

WeaknessFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause
file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.3.1

10.1.3.4 WeaknessReferencesFile Class

CodeLocationReferencesFile class represents the verb concept “Code Location references File”.

Superclass

WeaknessFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause
file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.3.1

10.1.4 Citing Class Diagram

This section describes the UML representation of Citing concept and the corresponding facts.

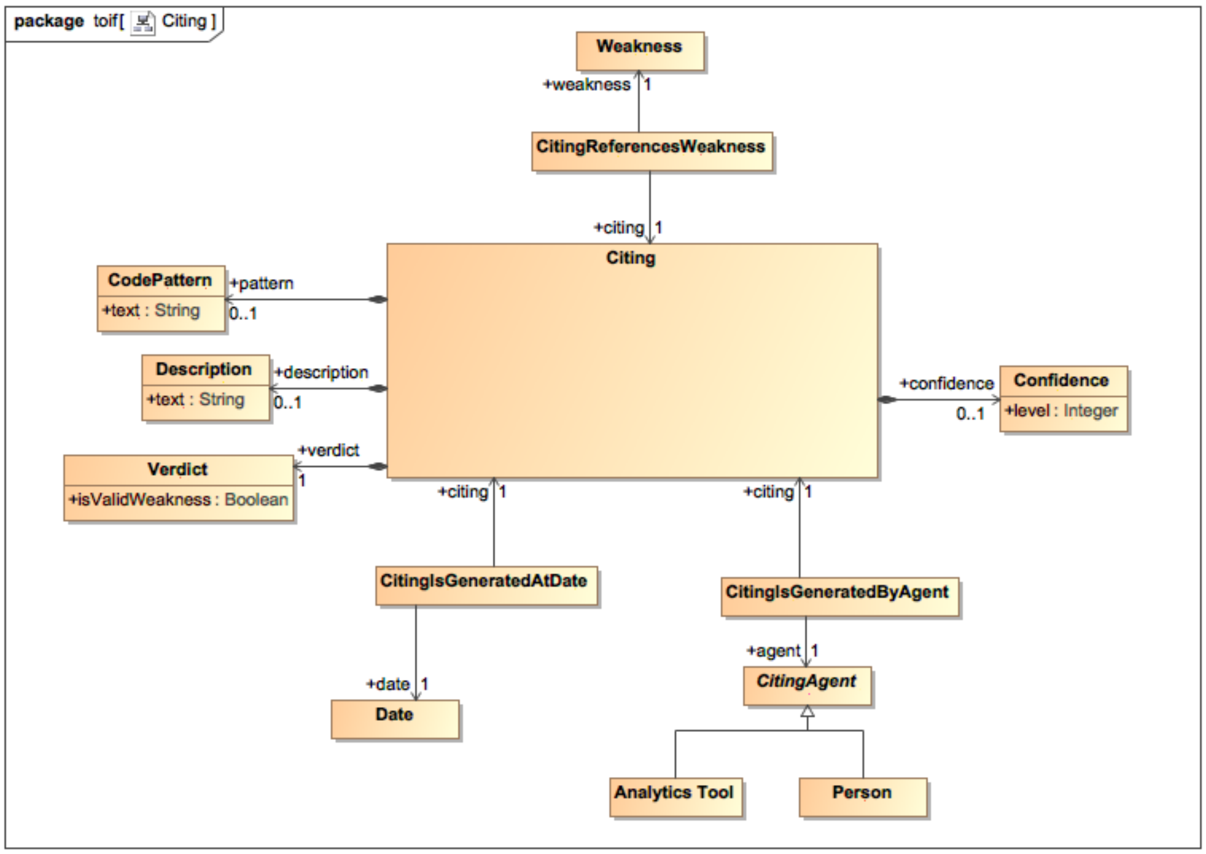


Figure 6. UML class diagram Citing

10.1.4.1 Citing Class

Citing class represents the Citing concept. Objects of this class are created by TOIF Analytics Tools. A Citing object supplies additional statements to some Weakness object, mainly the verdict, confidence as well as some audit trail. This class is an important part of the TOIF interface for the consumer tools and integration tools that can be used for vulnerability management purposes. CodePattern element can be used to group related Weaknesses that have the same CWE. This mechanism can use used by TOIF Analytics tools to identify the characteristics of a Weakness, and then identify other Weaknesses that have the same characteristics.

Superclass

BasicEntity

Constraints

1. Each Citing shall be the subject of exactly one CitingReferencesWeakness clause

Associations

description:Description[0..1]	Owned attribute that provides than informal text description of the weakness
verdict:Verdict	Owned attribute that specifies criticality of the weakness in terms of the impact that it may cause.

confidence:Confidence[0..1]	Owned attribute that specifices the confidence in this weakness claim.
pattern:CodePattern[0..1]	Owned attribute that specifices the confidence in this weakness claim.

Example

```
<fact xmi:type="toif:Citing" xmi:id="c110">
      <verdict xmi:type="Verdict" verdict="true"/>
      <condifence xmi:type="Confidence" level="90" />
</fact>

   <fact xmi:type="toif:CitingReferencesWeakness"
      location="c110" file="w0001"/>

For the facts related to Weakness id="w0001" refer to example in Section 10.1.3.1
```

10.1.4.2 CitingReferencesWeakness Class

CitingReferencesWeakness class represents the verb concept “Citing references Weakness”.

Superclass

WeaknessFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause
file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.4.1

10.1.4.3 CitingIsGeneratedAtDate Class

CitingIsGeneratedAtDate class represents the verb concept “Citing is generated at Date”.

Superclass

WeaknessFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause

file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.4.1

10.1.4.4 CitingAgent Class (abstract)

CitingAgent class represents the common supertype of agents that can generate Citings and is used as the endpoint class of the clause “CitingIsGeneratedByAgent”. Two subtypes of this class are Person and Analytics tool, defeined in Housekeeping concepts section.

Superclass

Element

10.1.4.5 CitingIsGeneratedByAgent Class

CitingIsGeneratedByAgent class represents the verb concept “Citing is generated at Agent”.

Superclass

WeaknessFact

Associations

citing:Citing[1]	Citing that is the subject of the clause
agent: CitingAgent[1]	CitingAgent that has generated the Citing of the clause

Example

See 10.1.3.1

10.1.5 Code Location Class Diagram

This section describes the UML representation of the Code Location concept and the corresponding facts.

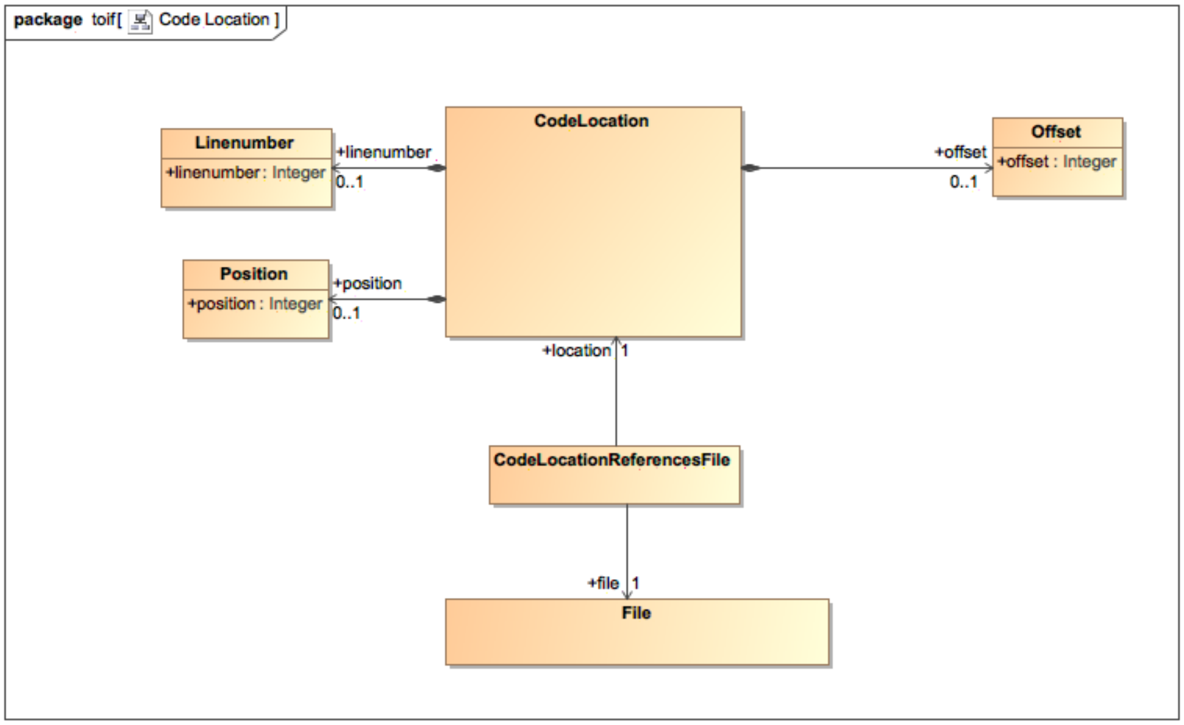


Figure 7. UML class diagram Code Location

10.1.5.1 CodeLocation Class

CodeLocation class represents the Code Location concept.

Superclass

BasicEntity

Constraints

3. Each CodeLocation shall define either Linenumber or Offset attribute
4. When CodeLocation defines Position attribute, the CodeLocation shall define Linenumber attribute

Associations

linenumber:Linenumber[0..1]	Owned attribute that specifies the linenumber of the Code Location. The Linenumber is taken to be in the File that is referenced by the CodeLocation
position:Position[0..1]	Owned attribute that specifies the position of the Code Location. The position is takes to be within the Linenumber.
offset:Offset[0..1]	Owned attribute that specifies the offset in a binary image. The offset is assumed to be in the File that is referenced by the Code Location.

Example

```
<fact xmi:type="toif:CodeLocation" xmi:id="loc10">
    <linenumber linenumber="1856"/>
</fact>

   <fact xmi:type="toif:CodeLocationReferencesFile"
      location="loc10" file="f10"/>

<fact xmi:type="toif:File" xmi:id="f10">
    <name name="main.c"/>
</fact>
```

10.1.5.2 CodeLocationReferencesFile Class

CodeLocationReferencesFile class represents the verb concept "Code Location references File".

Superclass

CodeLocationFact

Associations

location:CodeLocation[1]	Code Location that is the subject of the clause
file: File[1]	File that is referenced by the Code Location of the clause

Example

See 10.1.5.1

10.1.6 File Class Diagram

This section describes the UML representation of the File concept and the corresponding facts.

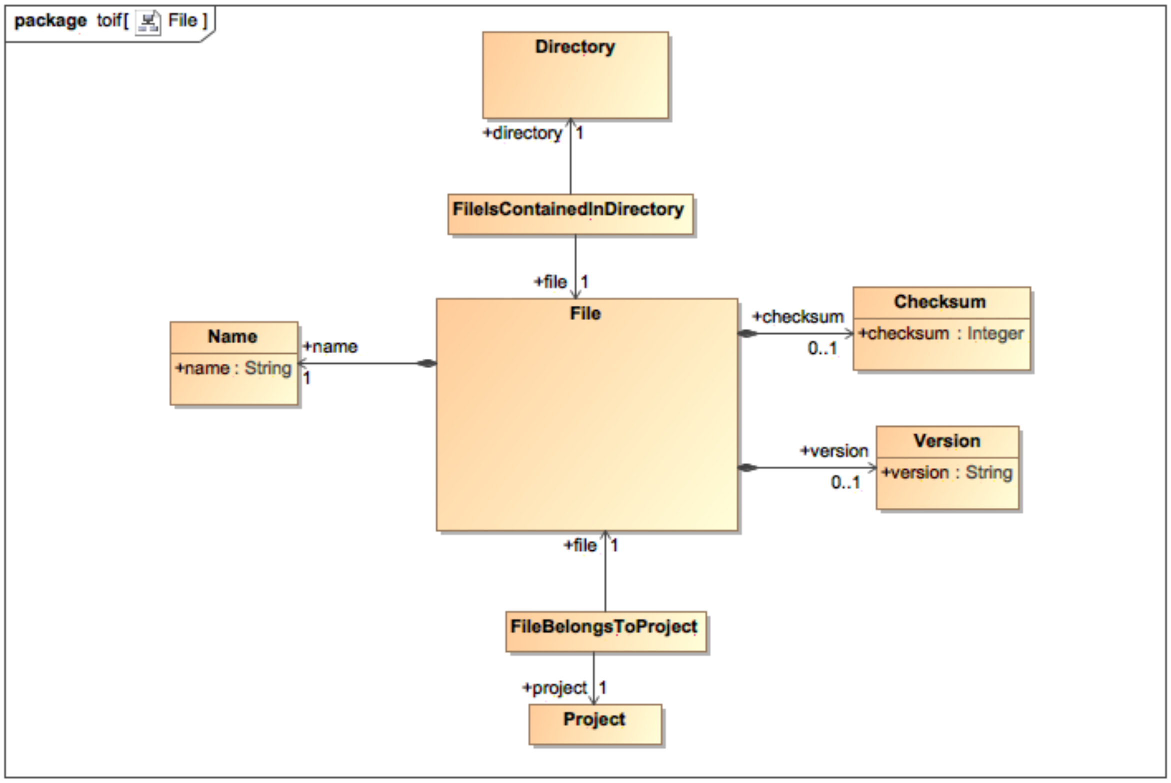


Figure 8. UML class diagram File

10.1.6.1 File Class

File class represents the File concept.

in TOIF corresponds to the InventoryItem concept in KDM. In TOIF a File is assumed to represent code of the system under investigation and is usually either a source file (KDM SourceFile) or an executable file (KDM ExecutableFile).

Superclass

BasicEntity

Associations

name:Name[1]	Owned attribute of the File, specifying its name
version:Version[0..1]	Owned attribute of the File, specifying its version
checksum:Checksum[0..1]	Owned attribute of the File, specifying its checksum

Constraints

1. Each File class shall be the subject of at least one FileBelongsToProject clause

Example

```
<fact xmi:type="toif:File" xmi:id="f10">
    <name name="main.c"/>
    <checksum checksum=”898432423894723”/>
    <version version=10092017”/>
```

```
</fact>


   <fact xmi:type="toif:FileIsContainedInDirectory"
      file="f10" directory="d10"/>
   <fact xmi:type="toif:FileBelongsToProject"
      file="f10" project="p10"/>


<fact xmi:type="toif:Directory" xmi:id="d10">
    <name name="applications/src"/>
</fact>
<fact xmi:type="toif:Project" xmi:id="p10">
    <name name="Dispatcher"/>
</fact>
```

10.1.6.2 FileIsContainedInDirectory Class

FileIsContainedInDirectory class represents the verb concept "File is contained in Directory".

Superclass

CodeLocationFact

Associations

file:File[1]	File that is the subject of the clause
directory: Directory[1]	Directory that the File is contained in

Example

See 10.1.6.1

10.1.6.3 FileBelongsToProject Class

FileBelongsToProject class represents the verb concept "File belongs to Project".

Superclass

ProjectFact

Associations

file:File[1]	File that is the subject of the clause
project: Project[1]	Project that the File belongs o

Example

See 10.1.6.1

10.1.7 Directory Class Diagram

This section describes the UML representation of the Directory concept and the corresponding facts.

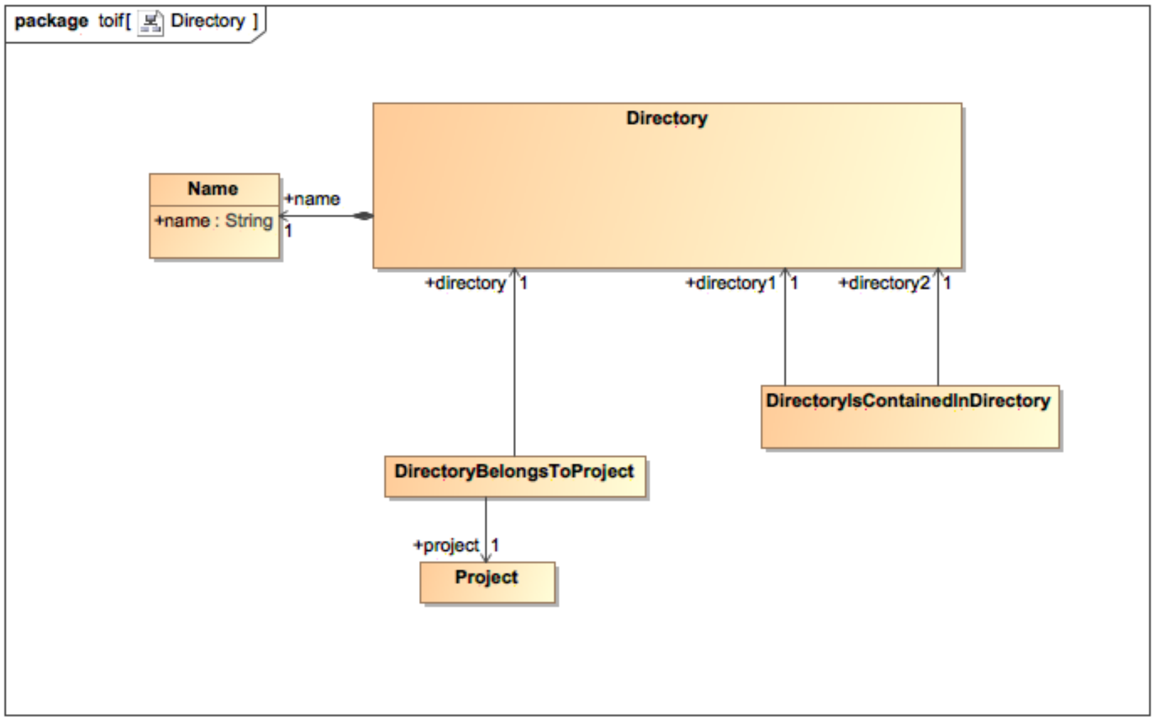


Figure 9. UML class diagram Directory

10.1.7.1 Directory Class

Directory class represents the Directory concept. Directories provide additional context to the TOIF Findings, which reference individual Files. TOIF does not make any assumptions on whether the name of the Directory represents an absolute or a relative path. TOIF also does not make any assumptions regarding the correlation between the names of the Directory and File and relations DirectoryIsContainedInDirectory and FileIsContainedInDiretory.

Superclass

BasicEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Directory

Example

```
<fact xmi:type="toif:Directory" xmi:id="d10">
    <name name="applications/src"/>
</fact>
```

```
   <fact xmi:type="toif:DirectoryIsContainedInDirectory"
      directory1="d10" directory2="d20"/>
   <fact xmi:type="toif:DirectoryBelongsToProject"
      directory="d10" project="p10"/>


<fact xmi:type="toif:Directory" xmi:id="d20">
    <name name="dispatcher"/>
</fact>
<fact xmi:type="toif:Project" xmi:id="p10">
    <name name="Dispatcher"/>
</fact>
```

10.1.7.2 DirectoryBelongsToProject Class

DirectoryBelongsToProject class represents the verb concept "Directory belongs to Project".

Superclass

ProjectFact

Associations

directory:Directory[1]	Directory that is the subject of this clause
project: Project[1]	Project that the Directory belongs to

Example

See 10.1.7.1

10.1.7.3 DirectoryIsContainedInDirectory Class

DirectoryIsContainedInDirectory class represents the verb concept "Directory$_1$ is contained in Directory$_2$".

Superclass

CodeLocationFact

Associations

directory1:Directory[1]	Directory that is the subject of this clause
directory2: Directory[1]	Directory in which the subject Directory is contained

Example

See 10.1.7.1

10.1.8 Semantic Statement Class Diagram

This section describes the UML representation of the Statement concept and the corresponding facts.

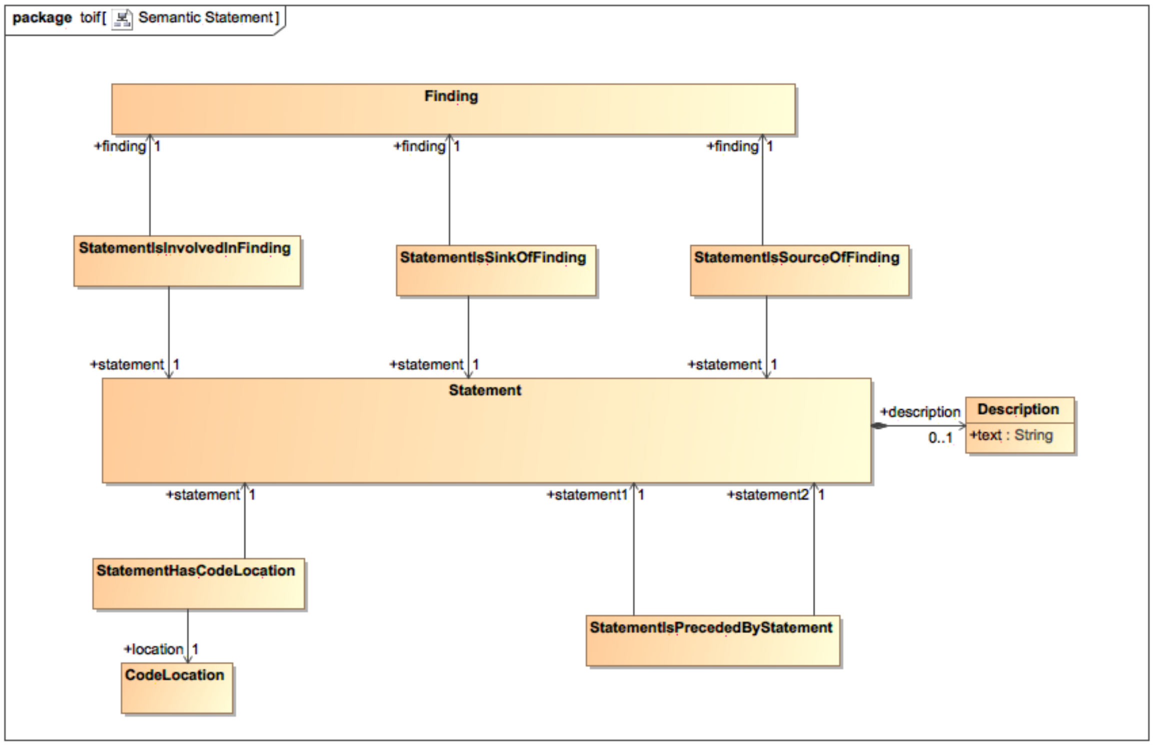


Figure 10. UML class diagram Semantic Statement

10.1.8.1 Statement Class

Statement class represents the Statement concept.

Superclass

BasicEntity

Associations

description:Description[0..1]	Owned attribute that an informal text description of the Statement

Constraints

1. Each Statement class shall be the subject of at least one StatementHasCodeLocation clause

Example

```
<fact xmi:type="toif:Statement" xmi:id="s10"/>


  <fact xmi:type="toif:StatementIsInvolvedInFinding"
     statement="s10" finding="f10"/>

  <fact xmi:type="toif:StatementIsSinkOfFinding"
```

```
       statement="s20" finding="f20"/>
   <fact xmi:type="toif:StatementIsSourceOfFinding"
       statement="s30" finding="f30"/>

   <fact xmi:type="toif:StatementPrecedesStatement"
       statement1="s30" statement2="s20"/>
   <fact xmi:type="toif:StatementPrecedesStatement"
       statement1="s10" statement2="s20"/>

   <fact xmi:type="toif:StatementHasCodeLocation"
       statement1="s10" location="loc10"/>

<fact xmi:type="toif:Statement" xmi:id="s20">
    <description text="*pHandler( pData, 0x200 );" />
</fact>

<fact xmi:type="toif:Statement" xmi:id="s30"/>

<fact xmi:type="toif:Finding" xmi:id="f10"/>
<fact xmi:type="toif:Finding" xmi:id="f20"/>


<fact xmi:type="toif:CodeLocation" xmi:id="loc10">
    <linenumber linenumber="1856"/>
</fact>
```

10.1.8.2 StatementIsInvolvedInFinding Class

StatementIsInvolvedInFinding class represents the verb concept “Statement is involved in Finding”.

Superclass

SemanticFact

Associations

statement:Statement[1]	Statement that is the subject of the clause
finding: Finding[1]	Finding in which the Statement is involved in

Example

See 10.1.8.1

10.1.8.3 StatementIsSinkOfFinding Class

StatementIsSinkOfFinding class represents the verb concept “Statement is sink of Finding”. A Sink of a Finding corresponds to the necessary condition of the Finding.

Superclass

SemanticFact

Associations

statement:Statement[1]	Statement that is the subject of the clause
finding: Finding[1]	Finding of which the Statement is the Sink

Example

See 10.1.8.1

10.1.8.4 StatementIsSourceOfFinding Class

StatementIsSourceOfFinding class represents the verb concept "Statement is source of Finding". A Source of a Finding corresponds to one of the sufficient conditions of the Finding.

Superclass

SemanticFact

Associations

statement:Statement[1]	Statement that is the subject of the clause
finding: Finding[1]	Finding of which the Statement is the Source

Example

See 10.1.8.1

10.1.8.5 StatementHasCodeLocation Class

StatementHasCodeLocation class represents the verb concept "Statement has Code Location".

Superclass

SemanticFact

Associations

statement:Statement[1]	Statement that is the subject of the clause
location: CodeLocation[1]	Code Location to which the Statement refers

Example

See 10.1.8.1

10.1.8.6 StatementIsPrecededByStatement Class

StatementIsPrecededByStatement class represents the verb concept "Statement$_1$ is preceded by Statement$_2$". This fact corresponds to a segment of the data flow path between a Source and a Sink of the Finding.

Superclass

SemanticFact

Associations

statement1:Statement[1]	Statement that is the subject of the clause
statement2: Statement[1]	Statement that precedes Statement1

Example

See 10.1.8.1

10.1.9 Semantic Data Class Diagram

This section describes the UML representation of the Data Element concept and the corresponding facts.

10.1.9.1 DataElement Class

DataElement class represents the Data Element concept.

Superclass

BasicEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Data Element
description:Description[0..1]	Owned attribute that an informal text description of the Data Element

Example

```
<fact xmi:type="toif:DataElement" xmi:id="d10">
    <name name="X"/>
    <description text=”struct pData * X[ MAXDATA];” />
</fact>


   <fact xmi:type="toif:DataIsInvolvedInFinding"
      data="d10" finding="f10"/>
   <fact xmi:type="toif:DataIsInvolvedInFinding"
      data="d10" project="f20"/>

   <fact xmi:type="toif:DataIsInvolvedInStatement"
      data="d10" statement="s20"/>
   <fact xmi:type="toif:DataIsInvolvedInStatement"
      data="d10" statement="s30"/>

   <fact xmi:type="toif:DataIsDefinedAtCodeLocation"
      data="d10" location="loc10"/>


<fact xmi:type="toif:Statement" xmi:id="s20"/>
<fact xmi:type="toif:Statement" xmi:id="s30"/>

<fact xmi:type="toif:Finding" xmi:id="f10"/>
<fact xmi:type="toif:Finding" xmi:id="f20"/>

<fact xmi:type="toif:CodeLocation" xmi:id="loc10">
    <linenumber linenumber="1856"/>
</fact>
```

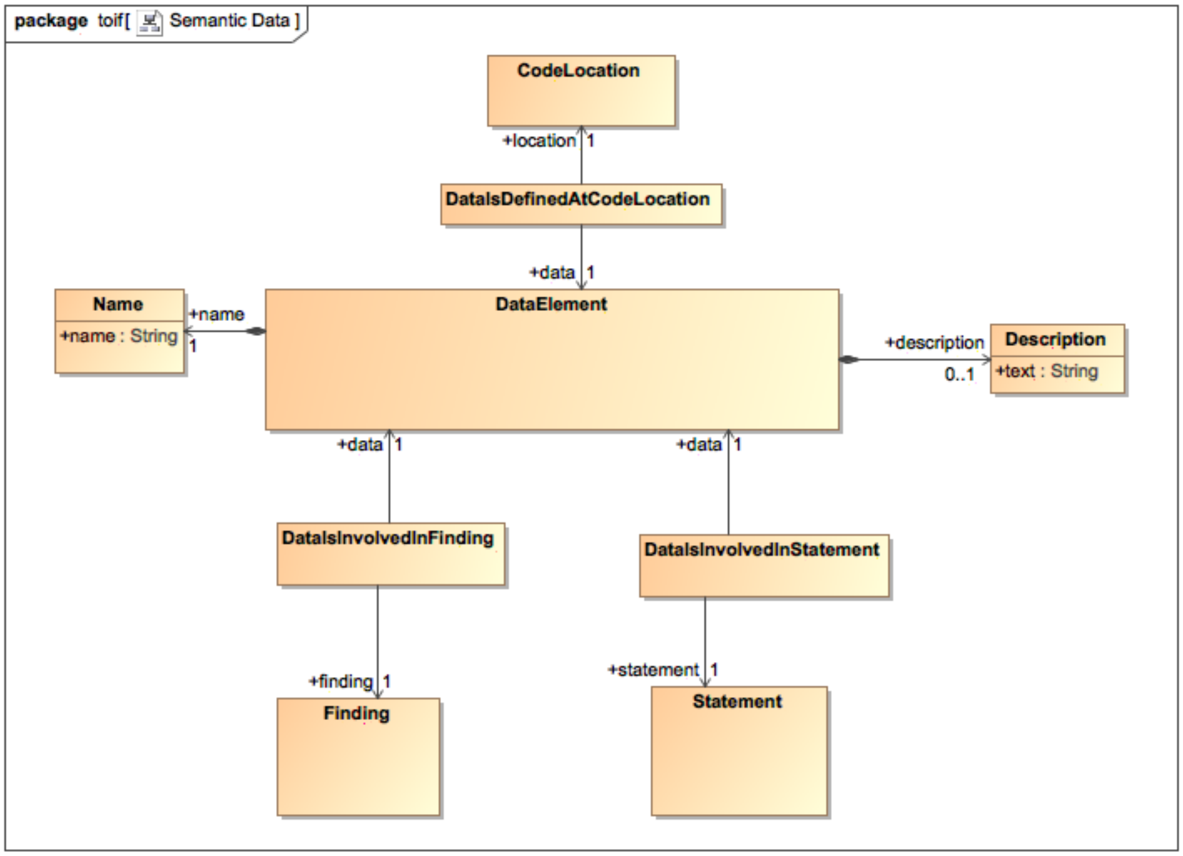


Figure 11. UML class diagram Semantic Data

10.1.9.2 DataIsInvolvedInFinding Class

DataIsInvolvedInFinding class represents the verb concept “Data Element is involved in Finding”.

Superclass

SemanticFact

Associations

data:DataElement[1]	Data Element that is the subject of the clause
finding: Finding[1]	Finding in which the Data Element is involved

Example

See 10.1.9.1

10.1.9.3 DataIsInvolvedInStatement Class

DataIsInvolvedInStatement class represents the verb concept "Data Element is involved in Statement". Data Element usually corresponds to the data flow path between the Source and the Sink of a Finding.

Superclass

SemanticFact

Associations

data:DataElement[1]	Data Element that is the subject of the clause
statement: Statement[1]	Statement in which the Data Element is involved

Example

See 10.1.9.1

10.1.9.4 DataIsDefinedAtCodeLocation Class

DataIsDefinedAtCodeLocation class represents the verb concept "Data Element is defined at Code Location".

Superclass

SemanticFact

Associations

data:DataElement[1]	DataElement that is the subject of the clause
location: Location[1]	Code Location at which the Data Element is defined

Example

See 10.1.9.1

10.2 The housekeeping elements of the TOIF XML

This section presents 7 UML class diagrams that describe the housekeeping elements of the TOIF XML: Build, Housekeeping, Project, Tools, Organization, Person, Role.

10.2.1 Build Class Diagram

This section describes the UML representation of the Build concept and illustrates the corresponding facts are described in the Basic Entities and Facts section. This diagram shows how housekeeping facts provide the context for the basic facts and allow management of the TOIF facts in the life-cycle of the system-under investigation, across multiple builds, evolving SCA tools. TOIF Adaptors, and TOIF Orchestration tools, and evolving understanding of the weaknesses. Also in an enterprise environment, source files and build may be shared across multiple systems.

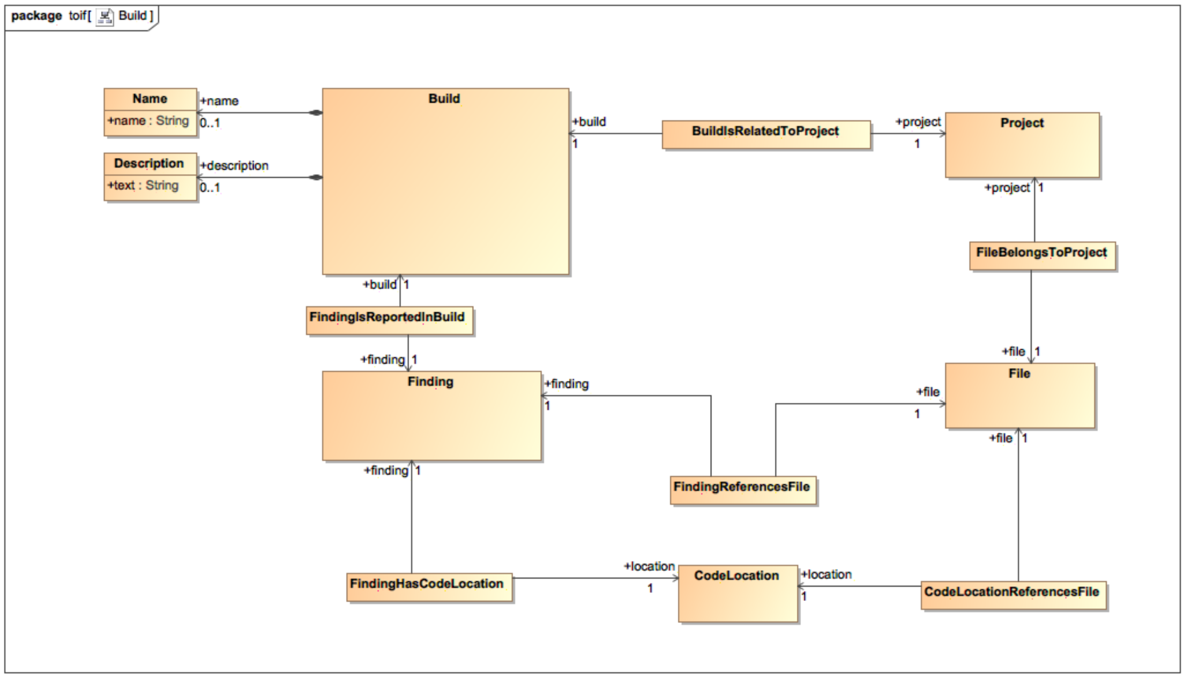


Figure 12. UML class diagram Build

10.2.1.1 Build Class

Build class represents the Build concept. The superclass Housekeeping Entity is defined in Section 10.3.5.8 Housekeeping Entities Class Diagram. Build represents (the results of) one particular build of the system under assessment, for example, corresponding to running a custom "Make" script.

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Build
description: Description[0..1]	Owned attribute that provides a text description of the Build

Constraints

1. Each Build class shall be the subject of at least one BuildIsRelatedToProject clause
2. Each Build class shall be the subject of at least one BuildIsGeneratedAtDate clause

Example

The following example illustrates 2 Builds, both belonging to the same Project, and a single Finding that was reported in both builds. The Finding references a File that is related to the same Project. Note that some mandatory clauses are omitted.

```
<fact xmi:type="toif:Build" xmi:id="b1020171330">
    <description text="xxxxxx"/>
</fact>
<fact xmi:type="toif:Build" xmi:id="b1020171340">
    <description text="xxxxxx"/>
</fact>

<fact xmi:type="toif:Project" xmi:id="proj01">
    <description text="xxxxxx"/>
</fact>

<fact xmi:type="toif:Finding" xmi:id="f0001"/>

<fact xmi:type="toif:FindingIsReportedToBuild"
      finding="f0001" build="b1020171330"/>
<fact xmi:type="toif:FindingIsReportedToBuild"
      finding="f0001" build="b1020171340"/>

<fact xmi:type="toif:FindingReferencesFile"
      finding="f0001" file="f10"/>

<fact xmi:type="toif:File" xmi:id="f10">
    <name name="main.c"/>
</fact>

<fact xmi:type="toif:BuildIsRelatedToProject"
      build=" b1020171330" project=" proj01"/>
<fact xmi:type="toif:BuildIsRelatedToProject"
      build=" b1020171340" project="proj01"/>

<fact xmi:type="toif:FileBelongsToProject"
      file=" f10" project="proj01"/>

<fact xmi:type="toif:BuildIsGeneratedAtDate"
      build=" b1020171330" date="2016-10-24 at 22:30 UTC"/>
<fact xmi:type="toif:BuildIsGeneratedAtDate"
      build=" b1020171340" date="2016-10-25 at 10:30 UTC"/>
```

10.2.1.2 BuildIsRelatedToProject Class

BuildIsRelatedToProject class represents the verb concept “Build is related to Project”.

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
project: Project[1]	Project to which the Build is related

Example

See 10.2.1.1

10.2.2 Housekeeping Class Diagram

This section describes the UML representation of several housekeeping facts related to the Build concept.

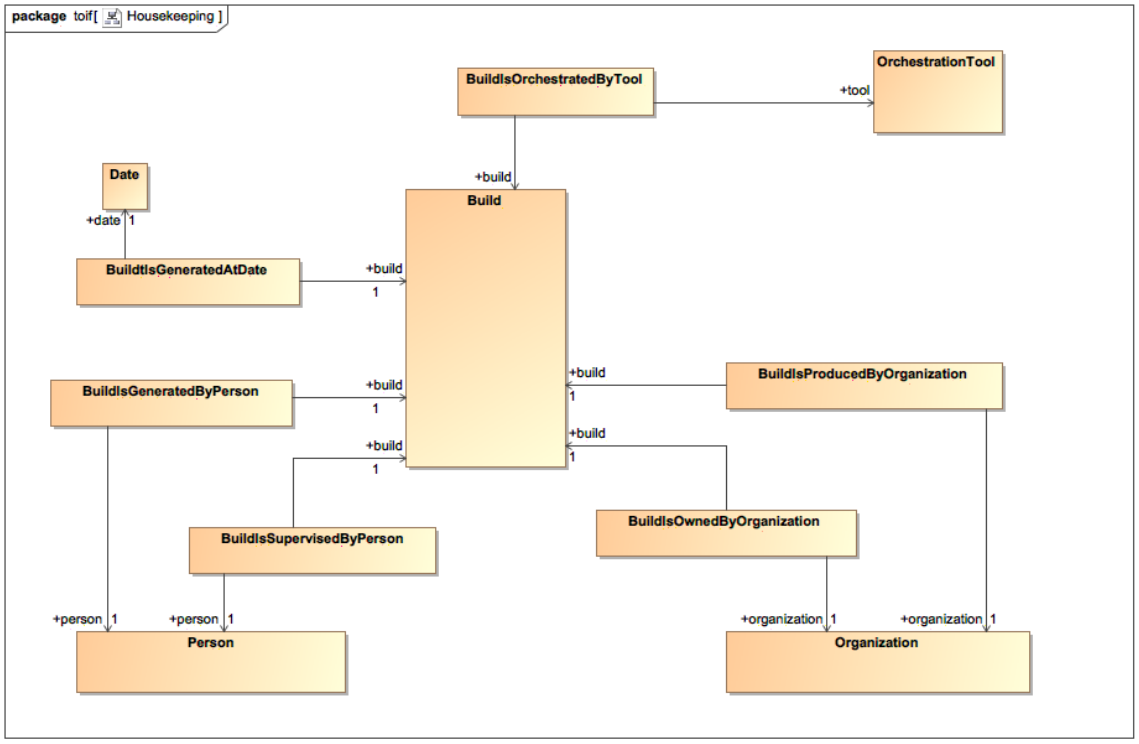


Figure 13. UML class diagram Housekeeping

10.2.2.1 BuildIsOrchestratedByTool Class

BuildIsOrchestratedByTool class represents the verb concept “Build is orchestrated by Tool”.

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
tool: OrchestrationTool[1]	Orchestration tool that produced the Build

Example

```
<fact xmi:type="toif:Build" xmi:id="b1020171330">
    <description text="xxxxxx"/>
</fact>
<fact xmi:type="toif:Build" xmi:id="b1020171340">
    <description text="xxxxxx"/>
</fact>

<fact xmi:type="toif:Project" xmi:id="proj01">
    <description text="xxxxxx"/>
</fact>

   <fact xmi:type="toif:BuildIsRelatedToProject"
      build=" b1020171330" project=" proj01"/>
   <fact xmi:type="toif:BuildIsRelatedToProject"
      build=" b1020171340" project="proj01"/>

   <fact xmi:type="toif:BuildIsGeneratedAtDate"
      build=" b1020171330" date="2016-10-24 at 22:30 UTC"/>
   <fact xmi:type="toif:BuildIsGeneratedAtDate"
build=" b1020171340" date="2016-10-25 at 10:30 UTC"/>

<fact xmi:type="toif:OrchestrationTool" xmi:id="bt01">
    <name name="Build Environment 2"/>
    <description text="xxxxxx"/>
    <version version="2.3.04A"/>
</fact>

<fact xmi:type="toif:OrchestrationTool" xmi:id="bt02">
    <name name="Build Environment 2"/>
    <description text="xxxxxx"/>
    <version version="2.3.05B"/>
</fact>


   <fact xmi:type="toif:BuildIsOrchestratedByTool"
      build=" b1020171330" project="bt01"/>
   <fact xmi:type="toif:BuildIsOrchestratedByTool"
      build=" b1020171340" project="bt01"/>


   <fact xmi:type="toif:BuildIsProducedByOrganization"
```

```
       build=" b1020171330" organization="org01"/>
   <fact xmi:type="toif:BuildIsProducedByOrganization"
       build=" b1020171340" organization="org02"/>

<fact xmi:type="toif:Organization" xmi:id="org01">
    <name name="Night Shift Build Group"/>
    <description text="xxxxxx"/>
</fact>
<fact xmi:type="toif:Organization" xmi:id="org02">
    <name name="Day Shift Build Group"/>
    <description text="xxxxxx"/>
</fact>

<fact xmi:type="toif:Person" xmi:id="p88997766">
    <name name="John The LoadBuilder"/>
    <description text="xxxxxx"/>
</fact>

   <fact xmi:type="toif:BuildIsSupervisedByPerson"
       build=" b1020171330" person="p88997766"/>
   <fact xmi:type="toif:BuildIsSupervisedByPerson"
       build=" b1020171340" person="p88997766"/>
```

10.2.2.2 BuildIsProducedByOrganization Class

BuildIsProducedByOrganization class represents the verb concept “Build is produced by Organization”.

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
organization: Organization[1]	Organization which produced the Build

Example

See 10.2.2.1

10.2.2.3 BuildIsOwnedByOrganization Class

BuildIsOwnedByOrganziation class represents the verb concept “Build is owned by Organization”.

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
organization: Organization[1]	Organization that owns the Build

Example

The following TOIF facts illustrate ownership of builds, described in the basic example in 10.2.2.1

```
   <fact xmi:type="toif:BuildIsOwnedByOrganization"
      build=" b1020171330" organization="org03"/>
   <fact xmi:type="toif:BuildIsOwnedByOrganization"
      build=" b1020171340" organization="org03"/>

<fact xmi:type="toif:Organization" xmi:id="org03">
    <name name="McDuck and Sons Assurance"/>
    <description text="xxxxxx"/>
</fact>
```

10.2.2.4 BuildIsGeneratedByPerson Class

BuildIsGeneratedByPerson class represents the verb concept “Build is generated by Person”.

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
person: Person[1]	Person that has generated the Build

Example

```
<fact xmi:type="toif:Build" xmi:id="b_007_025">
    <description text="xxxxxx"/>
</fact>

<fact xmi:type="toif:Person" xmi:id="p007">
    <name name="Scroodge The Inspector Guy"/>
    <description text="xxxxxx"/>
</fact>
   <fact xmi:type="toif:BuildIsRelatedToProject"
      build="b_007_025" project=" proj01"/>

   <fact xmi:type="toif:BuildIsProducedByPerson"
      build="b_007_025" person="p007"/>
   <fact xmi:type="toif:BuildIsSupervisedByPerson"
      build="b_007_025" person="p88997766"/>

   <fact xmi:type="toif:BuildIsGeneratedAtDate"
      build="b_007_025" date="2016-11-01 at 15:00 UTC"/>
```

10.2.2.5 BuildIsSupervisedByPerson Class

BuildIsSupervisedByPerson class represents the verb concept "Build is supervised by Person".

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
person: Person[1]	Person who has supervised the Build

Example

See 10.2.2.1 and 10.2.2.4

10.2.2.6 BuildIsGeneratedAtDate Class

BuildIsGeneratedAtDate class represents the verb concept "Build is generated at Date".

Superclass

BuildFact

Associations

build:Build[1]	Build that is the subject of the clause
date: Date[1]	Date at which the Build was generated

Example

See 10.2.2.1

10.2.3 Project Class Diagram

This section describes the UML representation of the Project concept and the corresponding facts.

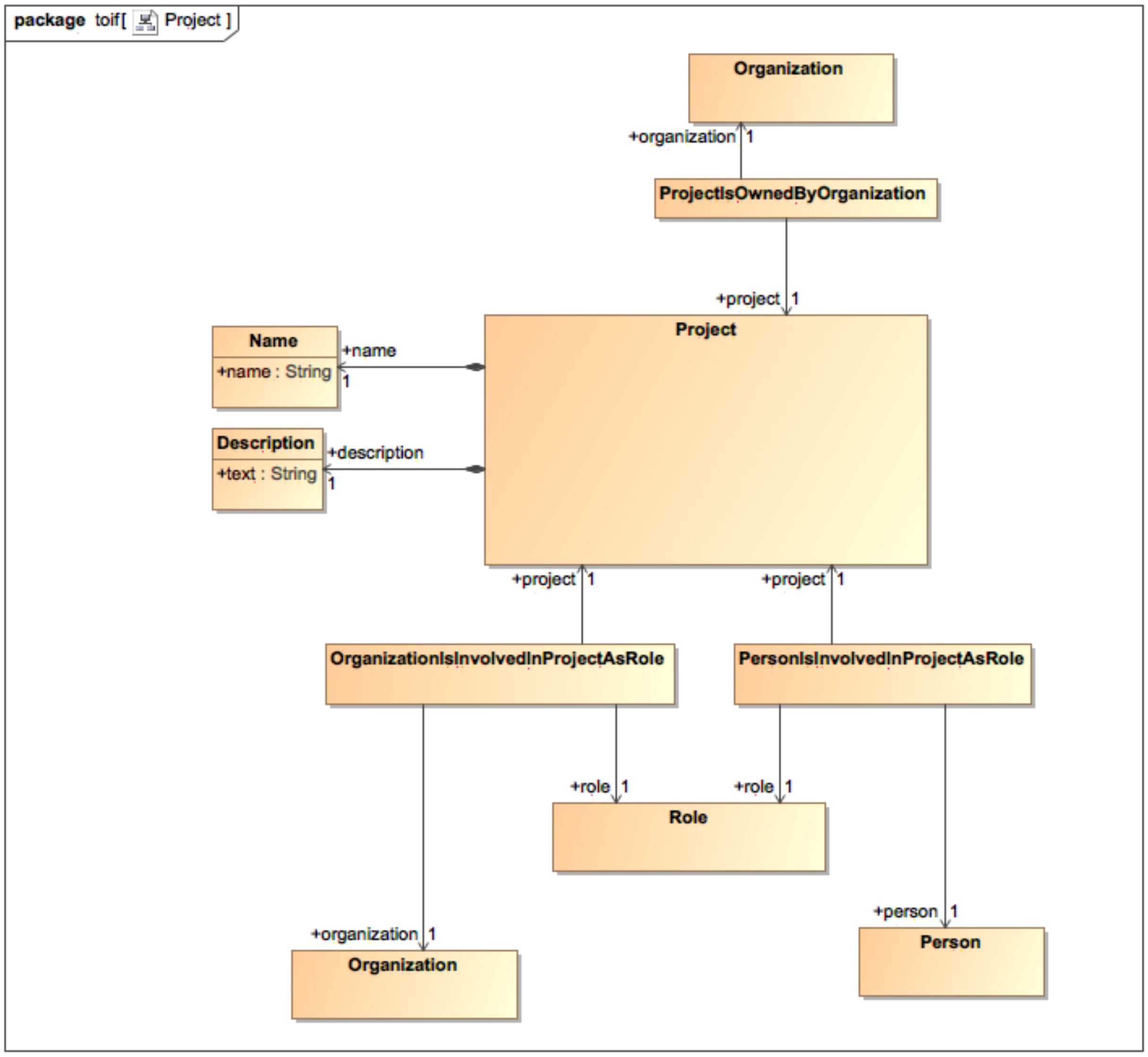


Figure 14. UML class diagram Project

10.2.3.1 Project Class

Project class represents the Project concept. Project corresponds to the system under assessment and is a container for the corresponding File and Directory elements. The corresponding facts are described in sections 10.1.6 and 10.1.7. Project is also a container for the related Builds. The corresponding facts are described in section 10.2.1

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Project
description: Description[0..1]	Owned attribute that provides an informal text description of the Project

Example

The following is an example how TOIF data is represented in TOIF XMI:

Suppose we want to represent the following statements:

There exists a project TOIF that *has* description "Flying Gizmo Assessment using TOIF".
There exists an organization that *has* name "McDuck & Sons Assurance"
There exists an organization that *has* name "Gizmo Mfg"
There exists a person that *has* name "Scroodge
There exists a role that *has* name "Prime Investigator"
There exists a role that *has* name "CTO"
There exists a role that *has* name "Third-party Assessor"
Scroodge *is employed by* McDuck & Sons *as* CTO
Scroodge *is involved in* project TOIF *as* Prime Investigator
Project TOIF *is owned by* Gizmo Mgf
McDuck & Sons Assurance *is involved in* Project TOIF *as* Third-party Assessor

The first 7 statements represent the so-called existential facts that introduce entities. Entity project will be referenced by an identifier TOIF, other entities will be referenced by their names. The last 4 facts correspond to the regular TOIF facts that refer to the entities. The facts above are represented in SBVR Structured English. Below is the TOIF XMI representation of these facts.

```
<fact xmi:type="toif:Project" xmi:id="pr1">
    <name name="TOIF"/>
    <description text="Flying Gizo Assessment using TOIF"/>
   </fact>

  <fact xmi:type="toif:Organization" xmi:id="o1">
    <name name="McDuck and Sons Assurance"/>
   </fact>

<fact xmi:type="toif:Organization" xmi:id="o2">
    <name name="Gizmo Mfg"/>
   </fact>

  <fact xmi:type="toif:Person" xmi:id="p1">
    <name name="Scroodge"/>
   </fact>

  <fact xmi:type="toif:Role" xmi:id="r1">
    <name name="Prime Investigator"/>
   </fact>

  <fact xmi:type="toif:Role" xmi:id="r2">
    <name name="CTO"/>
   </fact>

   <fact xmi:type="toif:Role" xmi:id="r3">
    <name name="Third-party Assessor"/>
   </fact>
   <fact xmi:type="toif:PersonIsInvolvedInProjectAsRole" project="pr1" role="r1"
person="p1"/>

   <fact xmi:type="toif:PersonIsEmployedByOrganizationAsRole" role="r2"
person="p1" organization="o1"/>

   <fact xmi:type="toif:ProjectIsOwnedByOrganization" project="pr1"
organization="o2"/>
   <fact xmi:type="toif:OrganizationIsInvolvedInProjectAsRole" organization="o1"
project="pr1" role="r3"/>
```

10.2.3.2 ProjectIsOwnedByOrganization Class

ProjectIsOwnedByOrganization class represents the verb concept "Project is owned by Organization".

Superclass

ProjectFact

Associations

project:Project[1]	Project that is the subject of the clause
organization: Organization[1]	Organization that owns the Project

Example

See 10.2.3.1

10.2.3.3 OrganizationIsInvolvedInProjectAsRole Class

OrganizationIsInvolvedInProjectAsRole class represents the verb concept "Organization is involved in Project as Role".

Superclass

ProjectFact

Associations

organization: Organization[1]	Organization that is the subject of the clause
project:Project[1]	Project in which Organization is involved in
role: Role[1]	Role in which the Organization is involved in the Project

Example

See 10.2.3.1

10.2.3.4 PersonIsInvolvedInProjectAsRole Class

PersonIsInvolvedInProjectAsRole class represents the verb concept “Person is involved in Project as Role”.

Superclass

ProjectFact

Associations

person: Person[1]	Person that is the subject of the clause
project:Project[1]	Project is which the Person is involved
role: Role[1]	Role in which the Person is involved in the Project

Example

See 10.2.3.1

10.2.4 Tools Class Diagram

This section describes the UML representation of the Tool concept, describes several concrete tools that are essential to the TOIF Ecosystem and the corresponding facts.

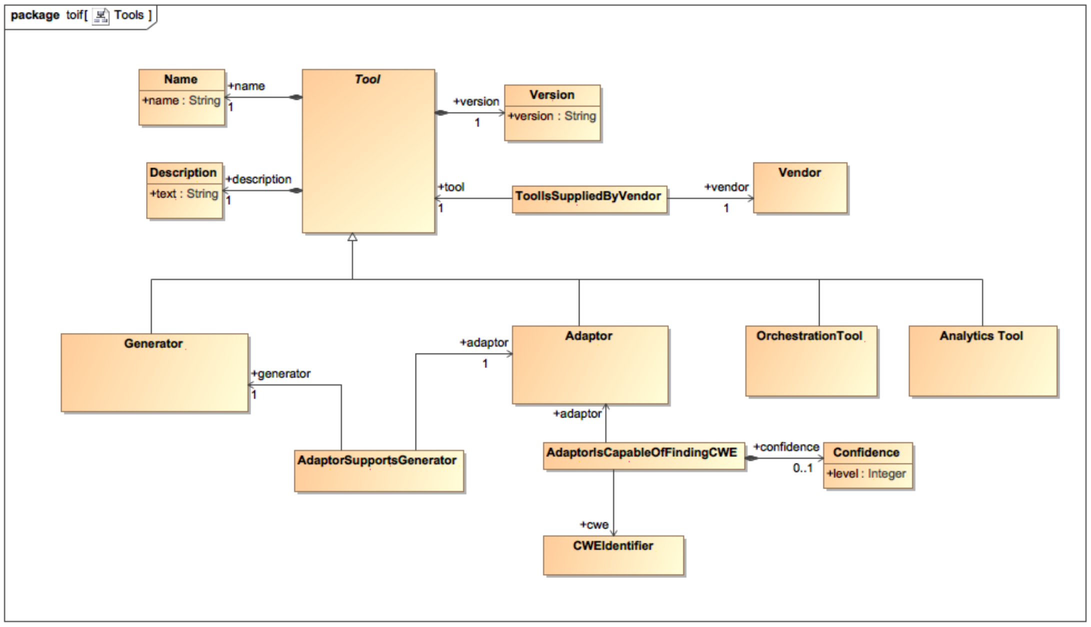


Figure 15. UML class diagram Tools

10.2.4.1 Tool Class (abstract)

Tool class represents the Tool concept.

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Tool
description: Description[1]	Owned attribute that provides an informal text description of the Tool
version: Version[1]	Owned attribute that specifies the Version of the Tool

Example

10.2.4.2 ToolIsSuppliedByVendor Class

ToolIsSuppliedByVendor class represents the verb concept "Tool is supported by Vendor".

Superclass

ToolFact

Associations

tool:Tool[1]	Tool that is the subject of the clause
vendor: Vendor[1]	Vendor which supplies the Tool

Example

```
<fact xmi:type="toif:OrchestrationTool" xmi:id="bt02">
    <name name="Build Environment 2"/>
    <description text="xxxxxx"/>
    <version version="2.3.05B"/>
</fact>


  <fact xmi:type="toif:Vendor" xmi:id="v1">
    <name name="McDuck Tool Craft"/>
   </fact>


  <fact xmi:type="toif:Vendor" xmi:id="o1">
    <name name="McDuck and Sons Assurance"/>
   </fact>


  <fact xmi:type="toif:Role" xmi:id="r1">
    <name name="Tiger Team"/>
   </fact>
```

```
<fact xmi:type="toif:ToolIsSuppliedByVendor" tool="bt02" vendor="v1"/>

<fact xmi:type="toif:OrganizationIsPartOfOrganizationAsRole" organization1="v1"
organization="o1" role=”r1”/>
```

10.2.4.3 Generator Class

Generator class represents the Generator concept.

Superclass

Tool

Example

See 10.1.1.1

10.2.4.4 Adaptor Class

Adaptor class represents the Adaptor concept.

Superclass

Tool

Constraints

1. Each Adaptor class shall be the subject of at least one AdaptorSupportsGenerator clause
2. Each Adaptor class shall be the subject of at least one AdaptorIsCapableOfFindingCWE clause
3. For each instance of Finding that is the subject of the clause FindingIsProducedByAdaptor, where A is the object is the above clause, and the Finding is the subject of the FindingIsDefinedAsCWE where X is the instance of CWEIdentifier that is the object of the above clause, A shall be the subject of the clause AdaptorIsCapableOfFindingCWE where X is the object.

Example

See 10.1.1.1

10.2.4.5 OrchestrationTool Class

OrchestrationTool class represents the Orchestration Tool concept.

Superclass

Tool

Example

See 10.2.2.1

10.2.4.6 Analytics Tool Class

Analytics Tool class represents the Analytics Tool concept.

Superclass

Tool

Example

See 10.2.2.1

10.2.4.7 AdaptorSupportsGenerator Class

AdaptorSupportsGenerator class represents the verb concept "Adaptor supports Generator".

Superclass

ToolFact

Constraints

1. Each Adaptor class shall be the subject of at least one AdaptorSupportsGenerator clause

Associations

adaptor:Adaptor[1]	Adaptor that is the subject of the clause
generator: Generator[1]	Generator that is supported by the Adaptor

Example

```
<fact xmi:type="toif:Generator" xmi:id="rats_2.3">
    <name name="RATS"/>
    <description text="xxxxxx"/>
    <version version="2.3"/>
</fact>
<fact xmi:type="toif:Adaptor" xmi:id="rats-toif-adaptor_1.1">
    <name name="RATS-TOIF"/>
    <description text="xxxxxx"/>
    <version version="1.1"/>
</fact>

   <fact xmi:type="toif:AdaptorSupportsGenerator" adaptor="rats-toif-adaptor_1.1"
generator="rats_2.3"/>
```

10.2.4.8 AdaptorIsCapableOfFindingCWE Class

AdaptorIsCapableOfFindingCWE class represents the verb concept “Adaptor is capable of finding CWE”.

Superclass

ToolFact

Associations

adaptor:Adaptor[1]	Adaptor that is the subject of the clause
cwe: CWEIdentifier[1]	CWE Identifier that specifies the type of weakness findings that the Adaptor is capable of producing
Confidence:Confidence[0..1]	Owned attribute that specifies the confidence that the Consumer of TOIF findings has in findings of the CWE of the clause by the tool of the clause

Constraints

1. Each Adaptor class shall be the subject of at least one AdaptorIsCapableOfFindingCWE clause
2. For each instance of Finding that is the subject of the clause FindingIsProducedByAdaptor, where A is the object is the above clause, and the Finding is the subject of the FindingIsDefinedAsCWE where X is the instance of CWEIdentifier that is the object of the above clause, A shall be the subject of the clause AdaptorIsCapableOfFindingCWE where X is the object.

Example

```
<fact xmi:type="toif:Adaptor" xmi:id="rats-toif-adaptor_1.1">
    <name name="RATS-TOIF"/>
    <description text="xxxxxx"/>
    <version version="1.1"/>
</fact>


   <fact xmi:type="toif:AdaptorIsCapableOfFindingCWE" adaptor="rats-toif-
adaptor_1.1" cwe="CWE-121"/>
   <fact xmi:type="toif:AdaptorIsCapableOfFindingCWE" adaptor="rats-toif-
adaptor_1.1" cwe="CWE-122"/>
   <fact xmi:type="toif:AdaptorIsCapableOfFindingCWE" adaptor="rats-toif-
adaptor_1.1" cwe="CWE-124"/>
   <fact xmi:type="toif:AdaptorIsCapableOfFindingCWE" adaptor="rats-toif-
adaptor_1.1" cwe="CWE-124">
      <confidence xmi:type=”toif:Confidence” level=20/>
   </fact>
```

10.2.5 Organization Class Diagram

This section describes the UML representation of the Organization concept and the corresponding facts.

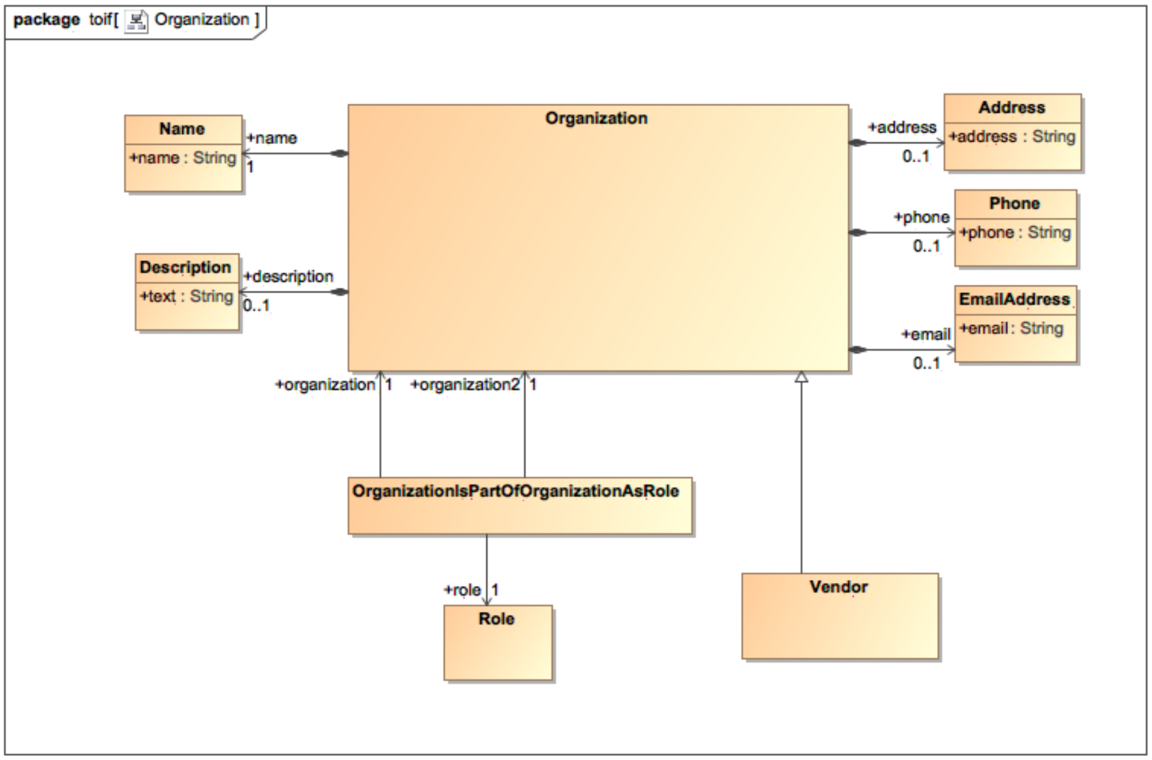


Figure 16. UML class diagram Organization

10.2.5.1 Organization Class

Organization class represents the Organization concept.

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Organization
description: Description[0..1]	Owned attribute that provides an informal text description of the Organization
address: Address[0..1]	Owned attribute that specifies the Address of the Organization
phone: Phone[0..1]	Owned attribute that specifies the contact Phone number for the Organization
email: EmailAddress[0..1]	Owned attribute that specifies the contact Email Address for the Organization

Example

See 10.2.3.1

10.2.5.2 Vendor Class

Vendor class represents the Vendor concept.

Superclass

Organization

Example

See 10.2.4.2

10.2.5.3 OrganizationIsPartOfOrganizationAsRole Class

OrganizationIsPartOfOrganizationAsRole class represents the verb concept "Organization$_1$ is part of Organization$_2$ as Role".

Superclass

ProjectFact

Associations

organization1:Organization[1]	Organization-1 that is the subject of the clause
organization2: Organization[1]	Organization-2 of which Organization-1 is a part
role: Role[1]	Role in which Organization-1 participates in Organization-2

Example

See 10.2.4.2

10.2.6 Person Class Diagram

This section describes the UML representation of the Person concept and the corresponding facts.

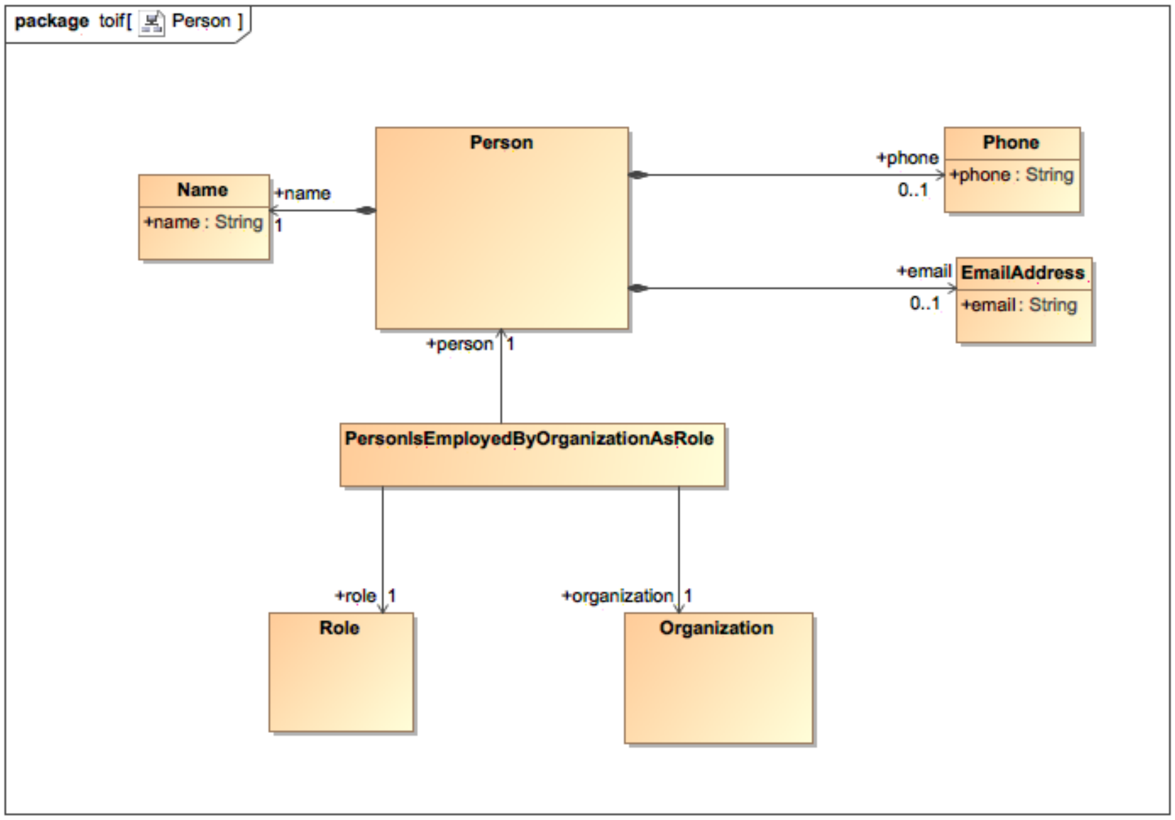


Figure 17. UML class diagram Person

10.2.6.1 Person Class

Person class represents the Person concept.

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Person
phone: Phone[0..1]	Owned attribute that provides a contact Phone number for the Person
email: EmailAddress[0..1]	Owned attribute that provides a contact Email Address for the Person

Example

See 10.2.3.1

10.2.6.2 PersonIsEmployedByOrganizationAsRole Class

PersonIsEmployedByOrganizationAsRole class represents the verb concept “Person is employed by Organization as Role”.

Superclass

ProjectFact

Associations

person:Person[1]	Person that is the subject of the clause
organization: Organization[1]	Organization which employs Person
role: Role[1]	Role in which the Person is employed by the Organization

Example

See 10.2.3.1

10.2.7 Role Class Diagram

This section describes the UML representation of the Role concept and the corresponding facts.

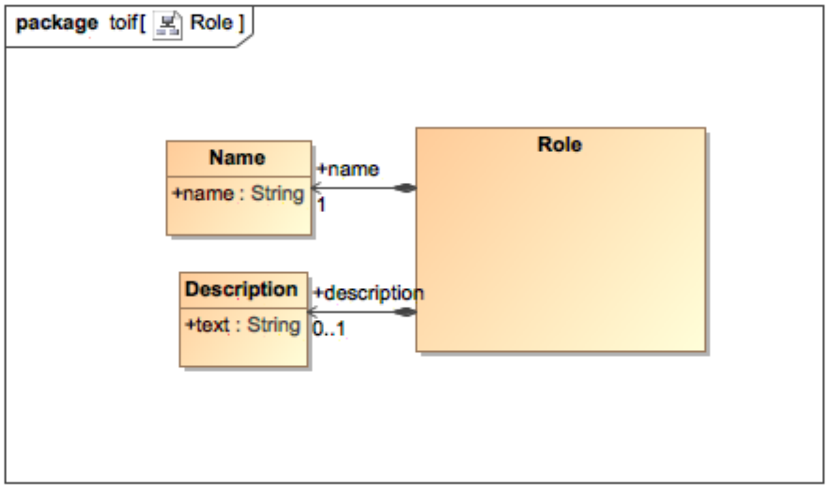


Figure 18. UML class diagram Role

10.2.7.1 Role Class

Role class represents the Role concept. Roles are useful in enterprise context to manage multiple TOIF Builds and multiple TOIF Projects performed by multiple people and oven organizations (for example, departments and contrators). Only a name and an uninterpreted description is associated with a role. TOIF does not link Role to any of the standard taxonomy, although an enterprise adopting TOIF may choose to interpret TOIF Roles more formally by referencing some standard taxonomy in the description.

Superclass

HousekeepingEntity

Associations

name:Name[1]	Owned attribute that specifies the name of the Role
description: Description[0..1]	Owned attribute that provides an informal text description of the role

Example

See 10.2.3.1

10.3 The fact-oriented structure of the TOIF XML

This section presents 13 UML diagrams that describes the physical structure of the TOIF XMI.

The Figure 19. UML class diagram Abstract Structure represent the physical structure of the TOIF XMI. All basic entities are defined as subclasses of class BasicEntity. All logical facts are defined as subclasses of class Fact. Similarly, all housekeeping entities are defined as subclasses of class HousekeepingEntity and all housekeeping facts are defined as subclasses of class Fact. All records are defined as subclasses of class Record.
Classes BasicEntity and HousekeepingEntity are both subclasses of class Entity.
This allows the TOIFSegment class to own an ordered list of both Entities, Facts and Records. Attributes are owned by the entities to which they belong, so they are not owned directly by the TOIFSegment.
Classes Entity, Fact and Record are subclasses of class TOIFElements.
Classes TOIFElements, TOIFSegment and Attribute are subclasses of class Element.
Class Element defines and XMIL attribute “xmi:id” which is used in the TOIF XML to reference elements. This makes all Entity, Fact, Attribute, Record and TOIFSegment referenceable.

The rest of this section presents 8 UML diagrams that arrange the basic and housekeeping facts, entities and attributes as subclasses of the 3 main structure elements – Entities, Facts and Attributes.

10.3.1 Abstract Structure Class Diagram

This section describes the UML representation of the TOIFSegment concept and the corresponding facts.

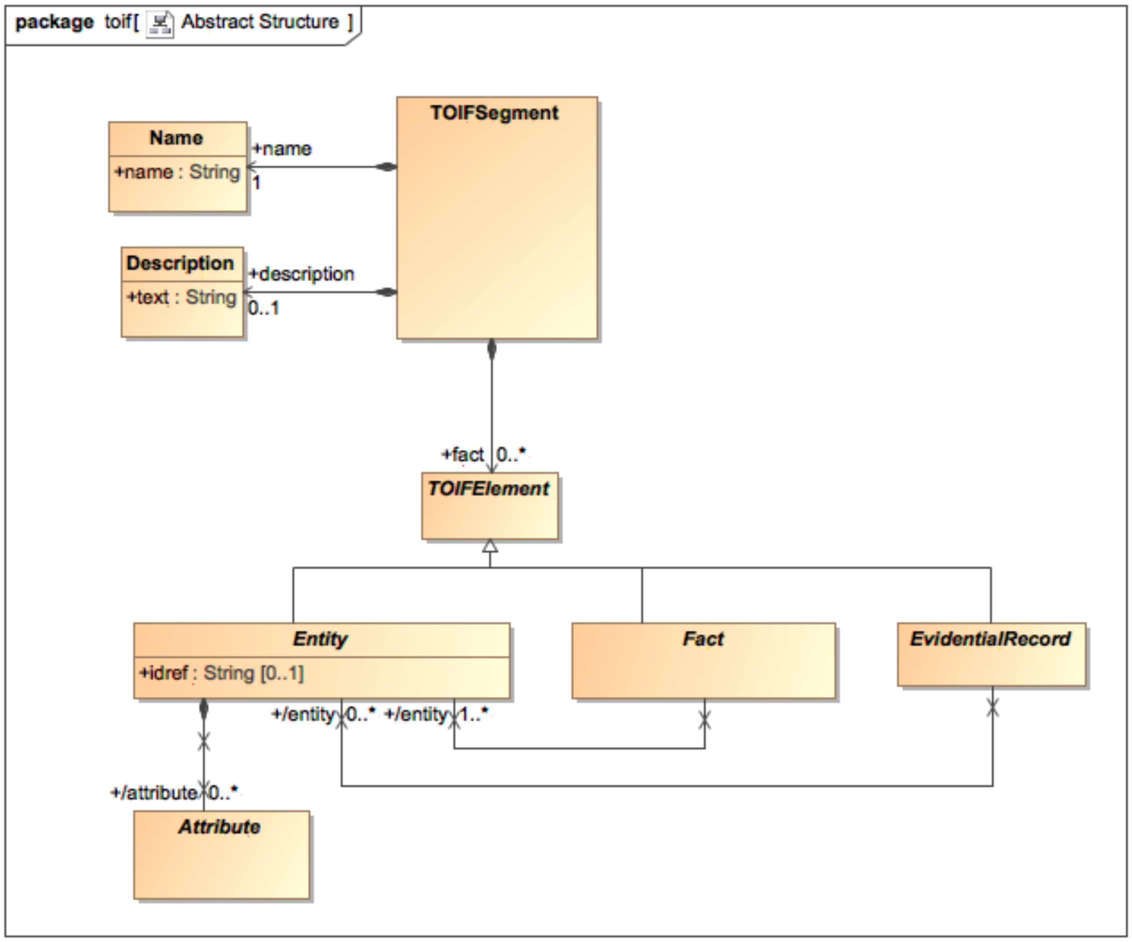


Figure 19. UML class diagram Abstract Structure

10.3.1.1 TOIFSegment Class

TOIFSegment class represents the TOIFSegment concept.

Superclass

Element

Associations

name:Name[1]	Owned attribute that specifies the name of the Segment
description: Description[0..1]	Owned attribute that provides an informal text description of the Segment
fact: TOIFElement[0..*]	Owned TOIFElement that represent the Facts contained in the Segment

10.3.1.2 TOIFElement Class (abstract)

Superclass

Element

10.3.1.3 Entity Class (abstract)

Entity class represents the Entity concept.

Superclass

TOIFElement

Attributes

idref:String[0..1]	Optional attribute reserved for alternative reference schemas for TOIF Entities

Associations

/attribute:Attribute[0..*]	Owned Attribute of this Entity. This is a derived property. The actual owned attributes are specified by the subclasses of the Entity class

10.3.1.4 Fact Class (abstract)

Fact class represents the Fact concept.

Superclass

TOIFElement

Associations

/entity:Entity[1..*]	Entity that are referenced by the Fact (clause). Each clause has a subject represented by an Entity, and one or mode objects. This is a derived property. The actual are specified by the subclasses of the Fact class

10.3.1.5 Attribute Class (abstract)

Attribute class represents the Attribute concept.

Superclass

Element

10.3.1.6 EvidentialRecord Class (abstract)

EvidentialRecord class represents the Evidential Record concept.

Superclass

TOIFElement

Associations

/entity:Entity[1..*]	Entity that are referenced by the Evidential Record. Each references one or mode objects. This is a derived property. The actual are specified by the subclasses of the Fact class. Concrete subclasses of Evidential Record may define owned attributes.

10.3.2 Abstract Types Class Diagram

This section describes the top class of the TOIF metamodel and its direct subclasses.

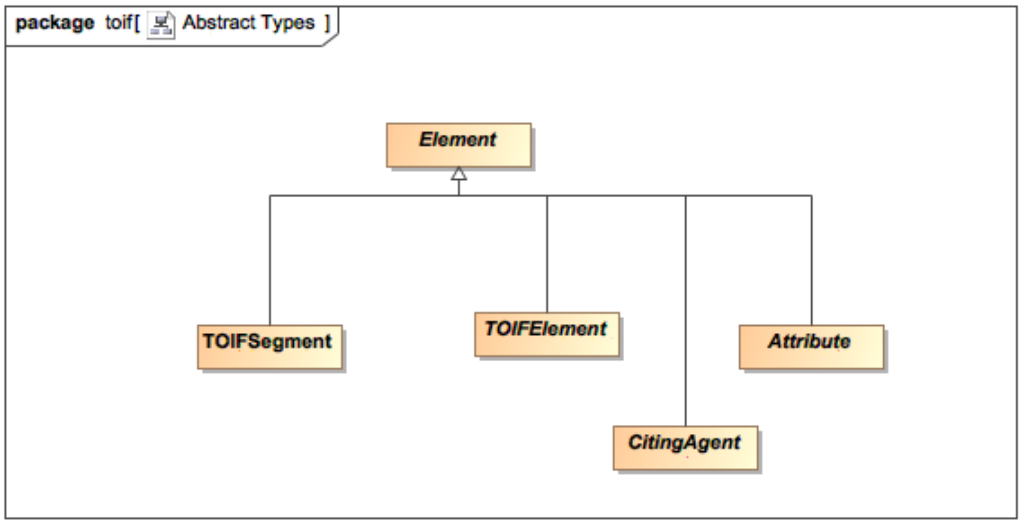


Figure 20. UML class diagram Abstract Types

10.3.2.1 Element Class (abstract)

Superclass

MOF Element

10.3.3 Basic Entities Class Diagram

This section describes the class hierarchy of the basic entities of the TOIF specification.

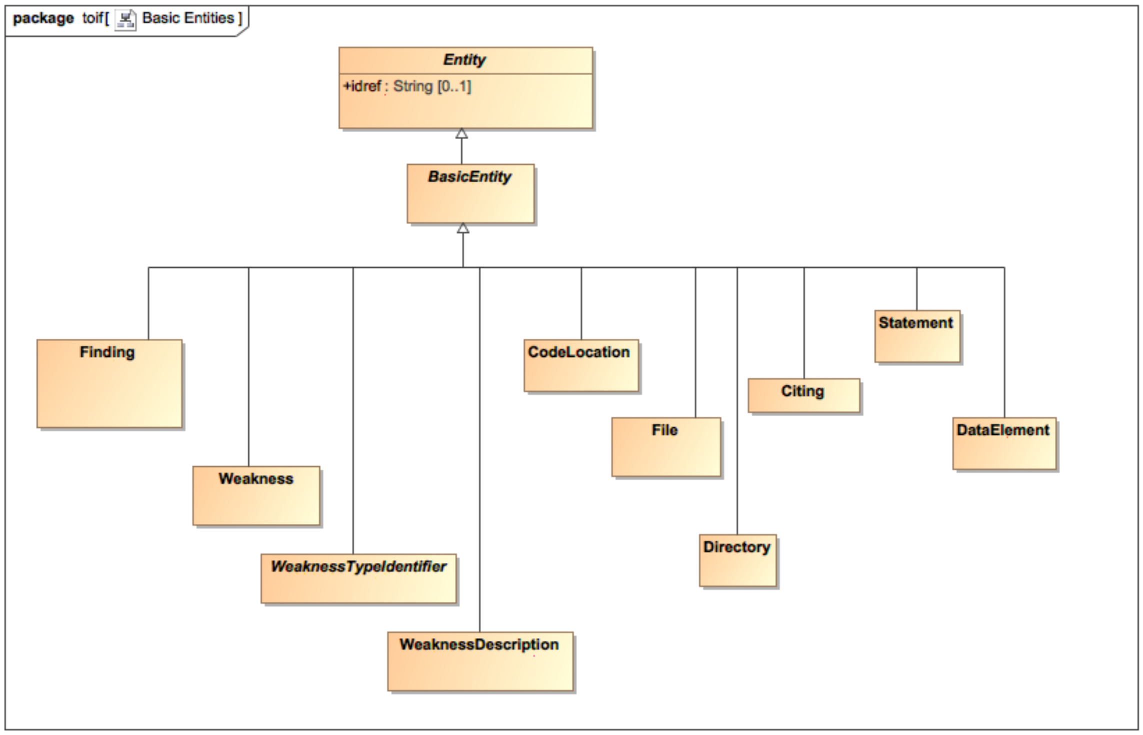


Figure 21. UML class diagram Basic entities

10.3.3.1 BasicEntity Class (abstract)

Superclass

Entity

10.3.4 Basic Facts Class Diagrams

This section describes the class hierarchy of the basic facts of the TOIF specification. Basic facts are grouped into the following four categories: Finding Facts, Weakness Facts, Code Location Facts and Semantic Facts. Each category is represented by own UML diagram. These diagrams introduce 4 abstract superclasses and provide the subclass relationships to the subclasses, defined earlier in Section 10.3.1

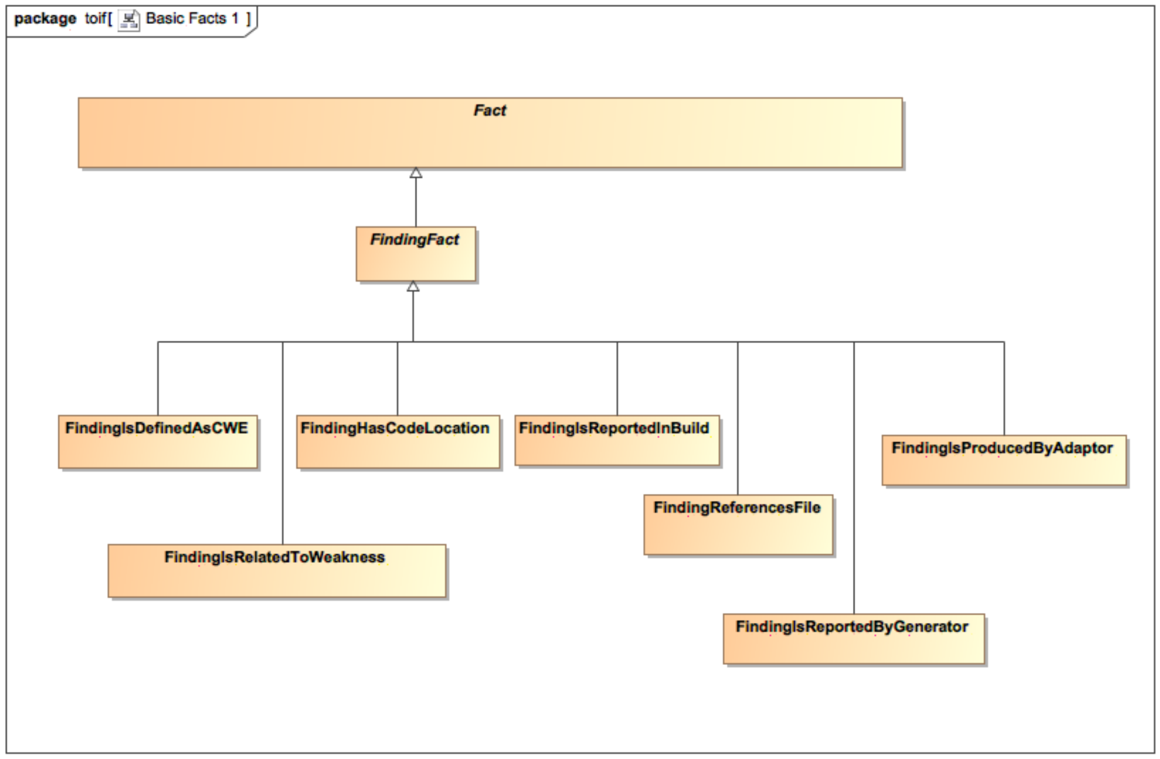

package toif[Basic Facts 1]
Fact
FindingFact
FindingIsDefinedAsCWE
FindingHasCodeLocation
FindingIsReportedInBuild
FindingIsProducedByAdaptor
FindingReferencesFile
FindingIsRelatedToWeakness
FindingIsReportedByGenerator

Figure 22. UML class diagram Basic Facts 1

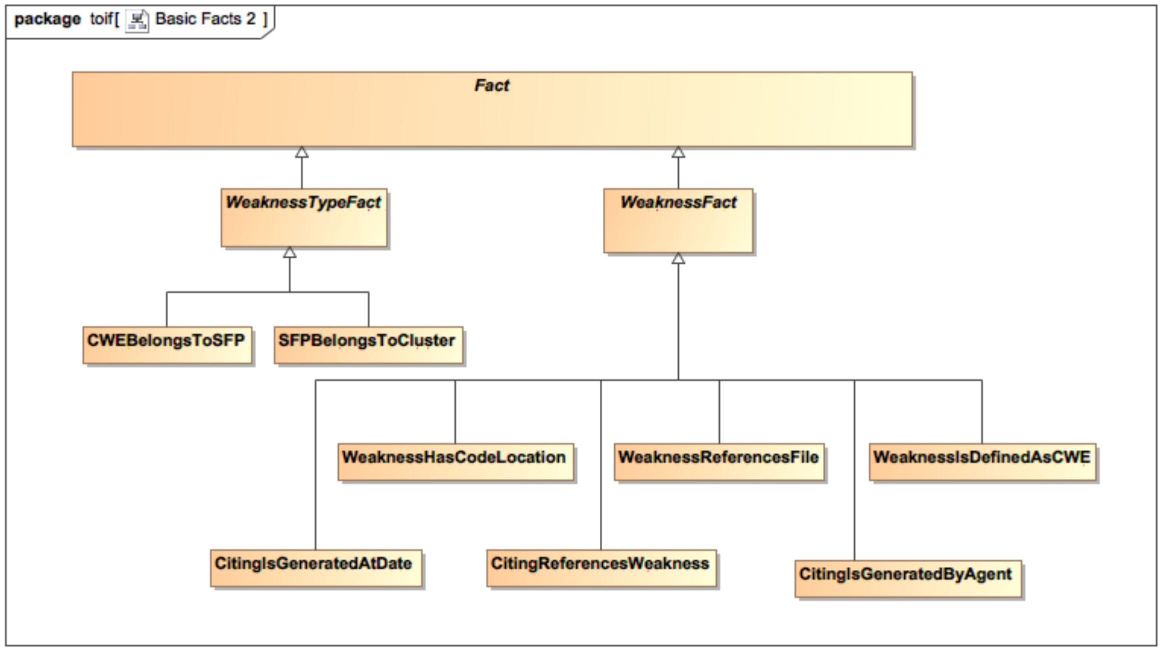


Figure 23. UML class diagram Basic Facts 2

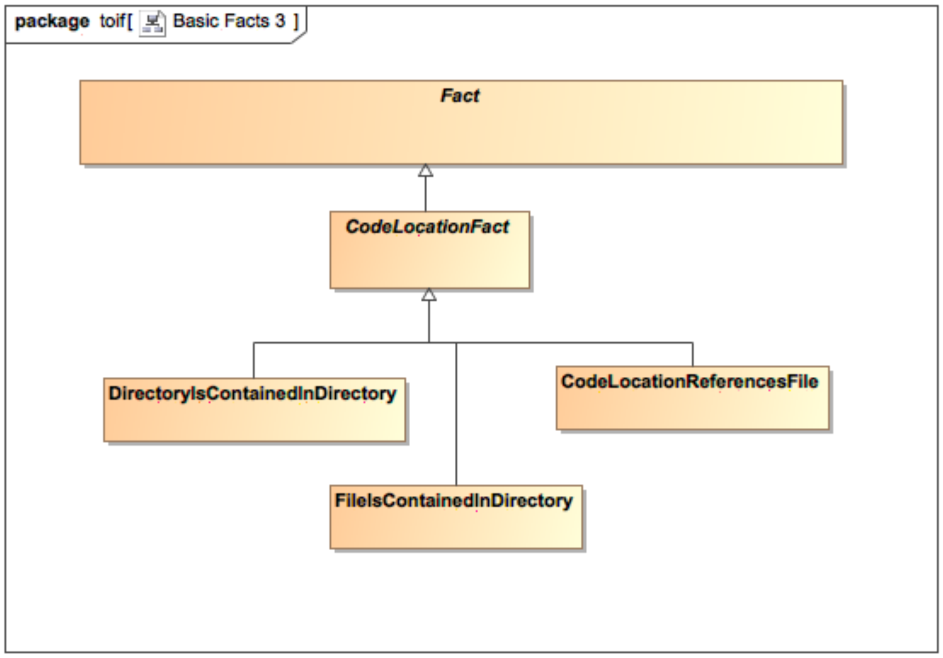

package toif[Basic Facts 3]
Fact
CodeLocationFact
DirectoryIsContainedInDirectory
CodeLocationReferencesFile
FileIsContainedInDirectory

Figure 24. UML class diagram Basic Facts 3

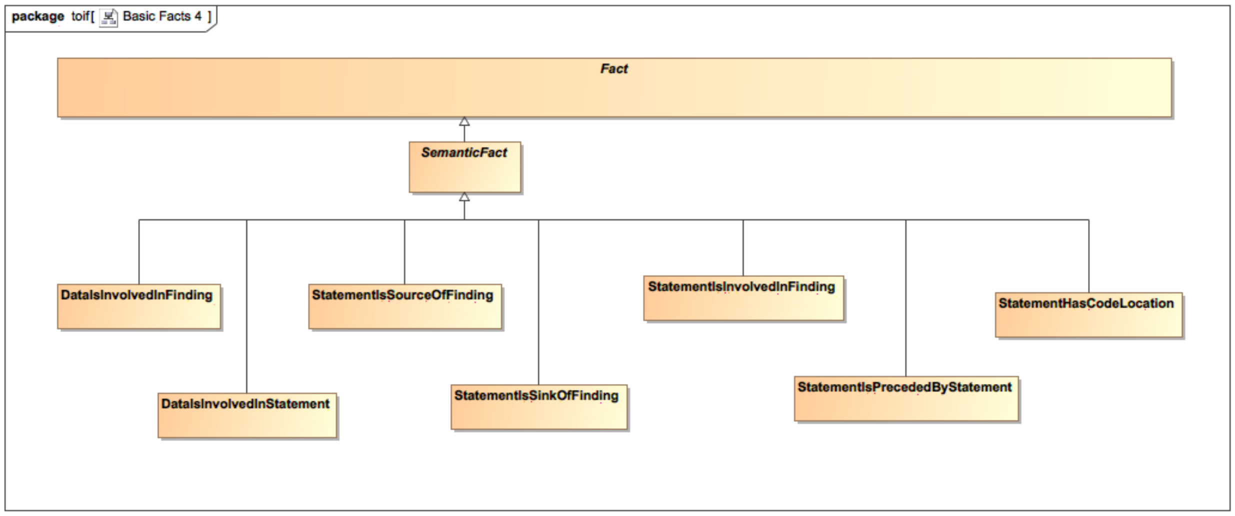

package toif[Basic Facts 4]
Fact
SemanticFact
DataIsInvolvedInFinding
StatementIsSourceOfFinding
StatementIsInvolvedInFinding
StatementHasCodeLocation
DataIsInvolvedInStatement
StatementIsSinkOfFinding
StatementIsPrecededByStatement

Figure 25. UML class diagram Basic Facts 4

10.3.4.1 FindingFact Class (abstract)

Superclass

Fact

10.3.4.2 WeaknessTypeFact Class (abstract)

Superclass

Fact

10.3.4.3 WeaknessFact Class (abstract)

Superclass

Fact

10.3.4.4 CodeLocationFact Class (abstract)

Superclass

Fact

10.3.4.5 SemanticFact Class (abstract)

Superclass

Fact

10.3.5 Basic Attributes Class Diagram

This section describes the class hierarchy of the attributes of the TOIF specification. More attributes are defined in the Housekeeping Attributes Class Diagram. TOIF does not make distinction between Basic Attributes and Housekeeping Attributes. The two diagrams are split mostly for the presentation purposes, as the attributes described in the Basic Attribute diagram are used both by the Basic as well as the Housekeeping entities.

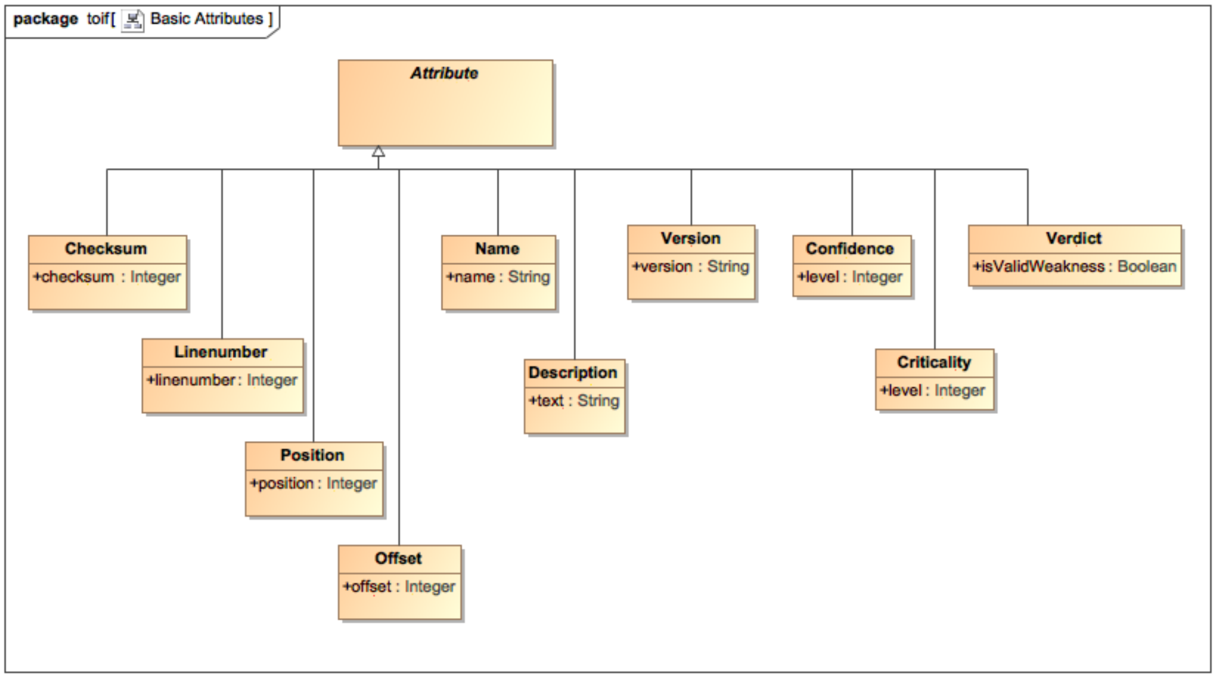


Figure 26. UML class diagram Basic Attributes

10.3.5.1 Offset Class

Superclass

Attribute

Attributes

offset:Integer[1]	Offset in a binary image file

10.3.5.2 Checksum Class

Superclass

Attribute

Attributes

checksum:Integer[1]	MD5 Checksum of a file

10.3.5.3 Linenumber Class

Superclass

Attribute

Attributes

linenumber:Integer[1]	Linenumber in a text File

10.3.5.4 Position Class

Superclass

Attribute

Attributes

position:Integer[1]	Position in a line in a text File

10.3.5.5 Name Class

Superclass

Attribute

Attributes

name:String[1]	Name of an Entity

10.3.5.6 Version Class

Superclass

Attribute

Attributes

version:String[1]	Version of an Thing that may involve multiple versions

10.3.5.7 Description Class

Superclass

Attribute

Attributes

text:String[1]	Informal text description

10.3.5.8 Confidence Class

Superclass

Attribute

Attributes

level:Integer[1]	Confidence level (0..100) as percent

10.3.5.9 Criticality Class

Superclass

Attribute

Attributes

level:Integer[1]	Criticality level (0..100) as percent

10.3.5.10 Verdict Class

Superclass

Attribute

Attributes

isValidWeakness:Boolean[1]	True or false

10.3.6 Housekeeping Entities Class Diagram

This section describes the class hierarchy of the housekeeping entities of the TOIF specification.

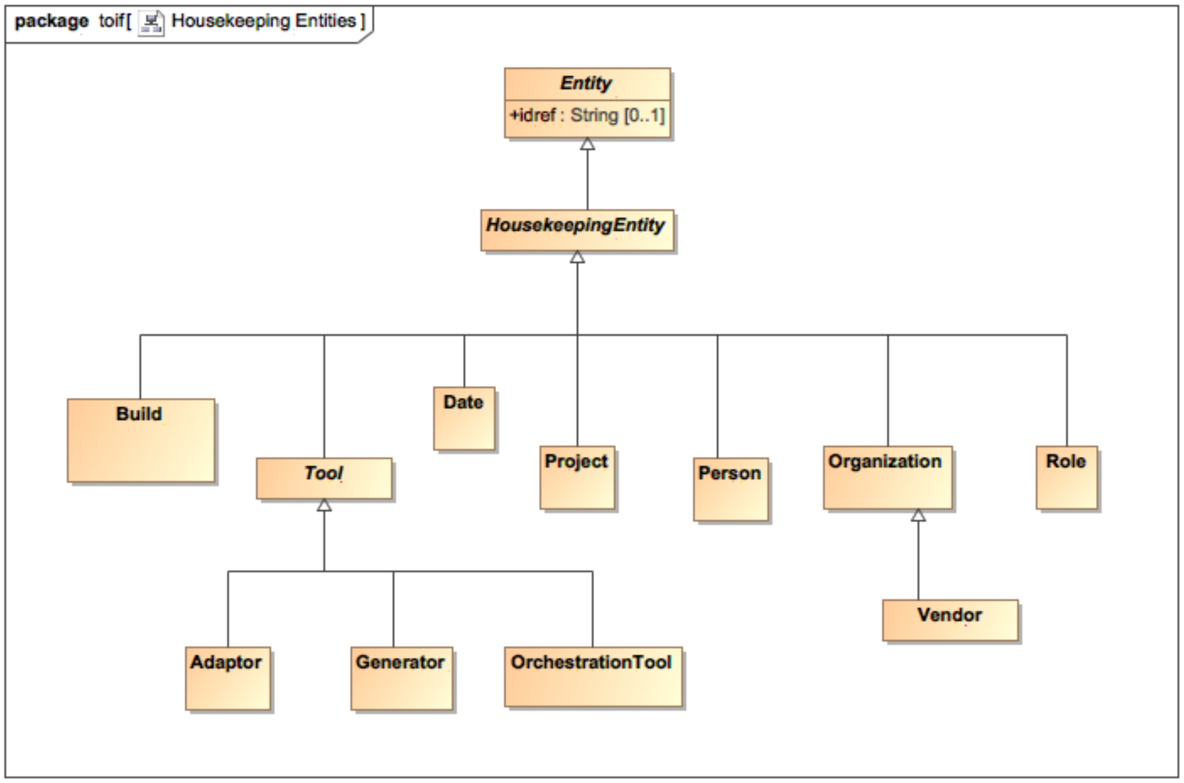


Figure 27. UML class diagram Housekeeping entities

10.3.6.1 HousekeepingEntity Class (abstract)

Superclass

Entity

10.3.7 Housekeeping Facts Class Diagrams

This section describes the class hierarchy of the housekeeping facts of the TOIF specification. Housekeeping facts are grouped into the following three categories: Tool Facts, Build Facts and Project Facts. Each category is represented by own UML diagram. These diagrams introduce 3 abstract superclasses and provide the subclass relationships to the subclasses, defined earlier in Section 10.3.2

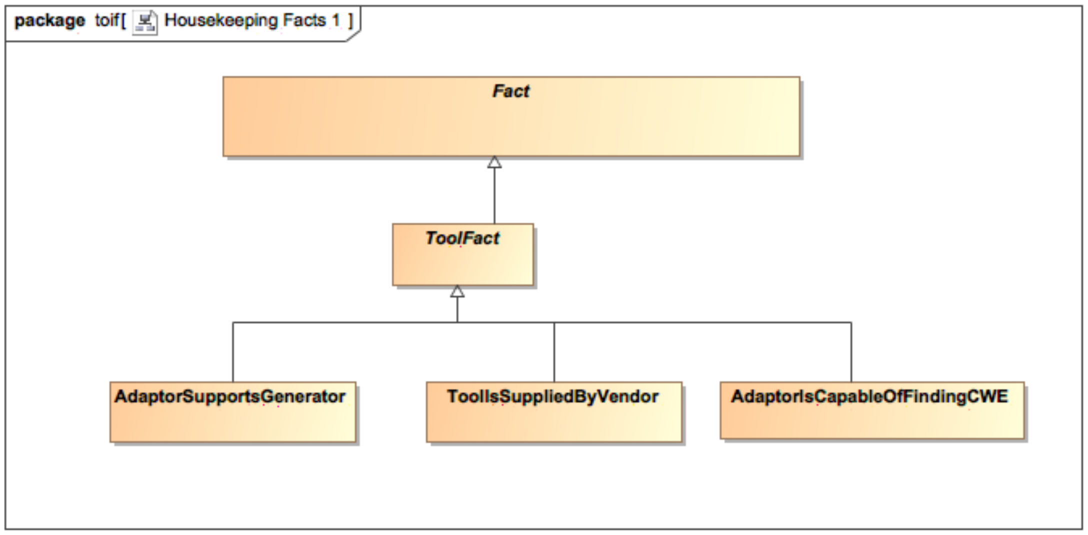

package toif[Housekeeping Facts 1]
Fact
ToolFact
AdaptorSupportsGenerator
ToolIsSuppliedByVendor
AdaptorIsCapableOfFindingCWE

Figure 28. UML class diagram Housekeeping Facts 1

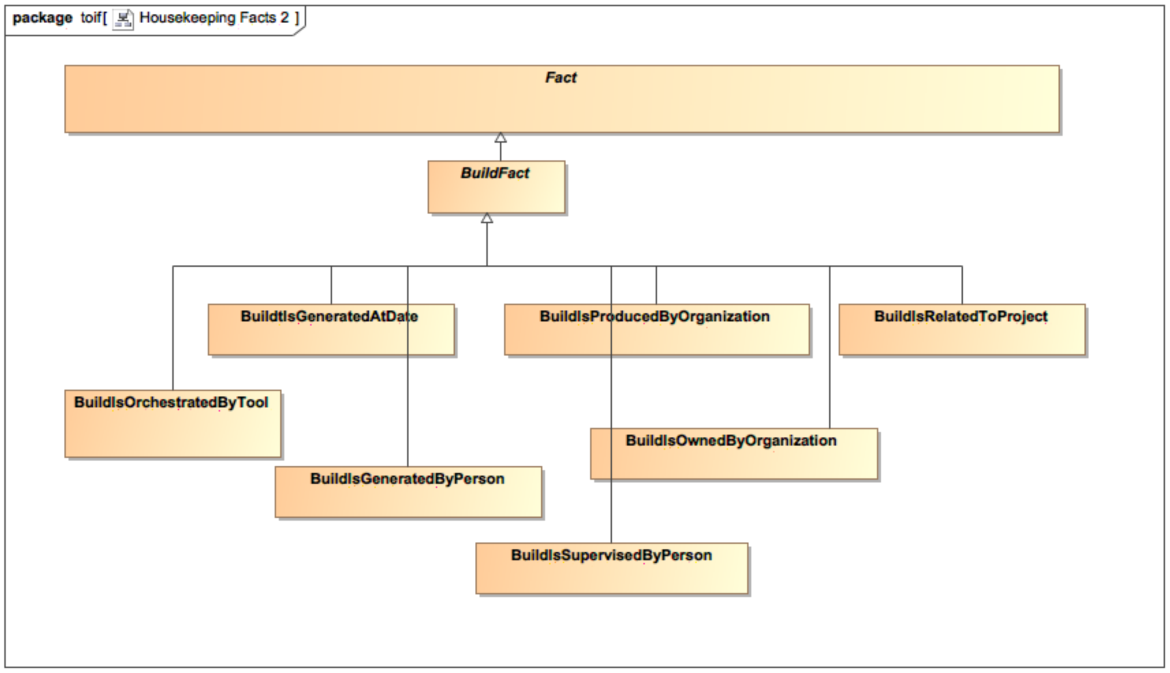

package toif[Housekeeping Facts 2]
Fact
BuildFact
BuildtIsGeneratedAtDate
BuildIsProducedByOrganization
BuildIsRelatedToProject
BuildIsOrchestratedByTool
BuildIsOwnedByOrganization
BuildIsGeneratedByPerson
BuildIsSupervisedByPerson

Figure 29. UML class diagram Housekeeping Facts 2

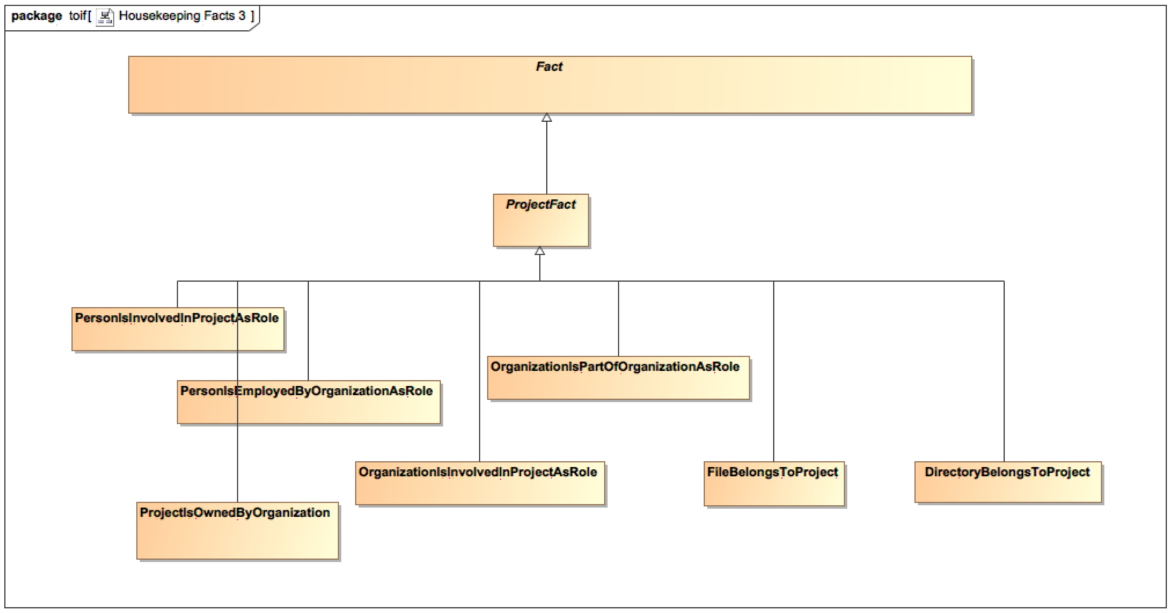

package toif[Housekeeping Facts 3]
Fact
ProjectFact
PersonIsInvolvedInProjectAsRole
PersonIsEmployedByOrganizationAsRole
OrganizationIsPartOfOrganizationAsRole
OrganizationIsInvolvedInProjectAsRole
FileBelongsToProject
DirectoryBelongsToProject
ProjectIsOwnedByOrganization

Figure 30. UML class diagram Housekeeping Facts 3

10.3.7.1 ToolFact Class (abstract)

Superclass

Fact

10.3.7.2 BuildFact Class (abstract)

Superclass

Fact

10.3.7.3 ProjectFact Class (abstract)

Superclass

Fact

10.3.8 Housekeeping Attributes Class Diagram

This section continues with the description of the class hierarchy of the attributes of the TOIF specification. More attributes are defined in the Basic Attributes Class Diagram. TOIF does not make distinction between Basic Attributes and Housekeeping Attributes, the two diagrams are split mostly for the presentation purposes.

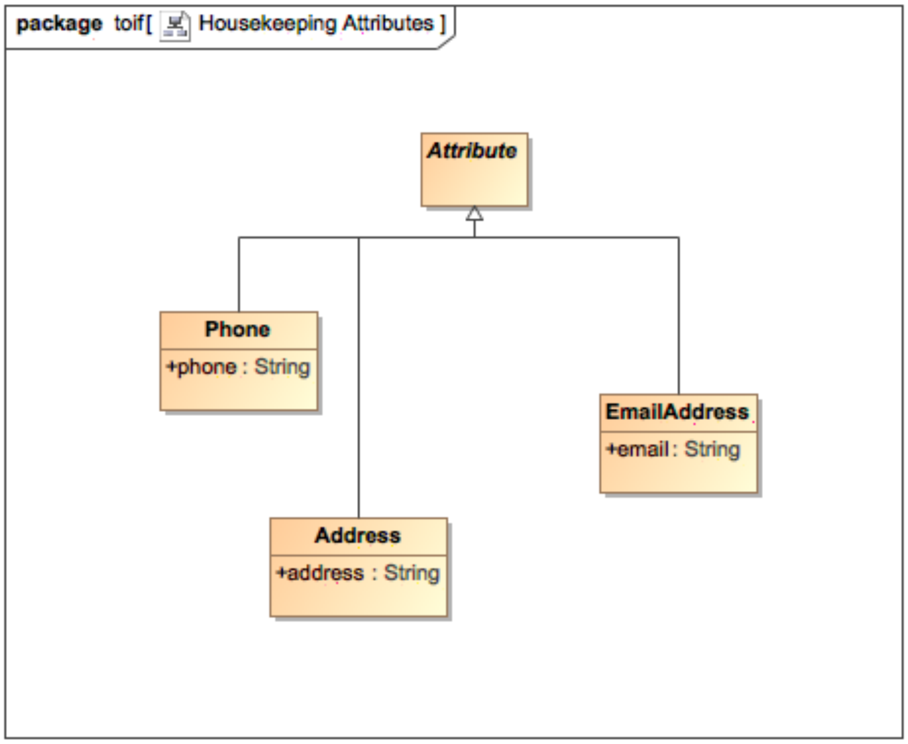


Figure 31. UML class diagram Housekeeping Attributes

10.3.8.1 Phone Class

Superclass

Attribute

Attributes

phone:String[1]	Phone number

10.3.8.2 Address Class

Superclass

Attribute

Attributes

address:String[1]	Postal Address of some Thing

10.3.8.3 EmailAddress Class

Superclass

Attribute

Attributes

email:String[1]	Electonic Mail Address of some Thing

10.4 Evidential Records in TOIF XML

This section presents a single UML diagram that describes evidential records defined in TOIF XMI.

10.4.1 EvidentialRecord Class Diagram

This section describes the UML representation of the BuildRecord, CompileRecord and GeneratorRecord records.

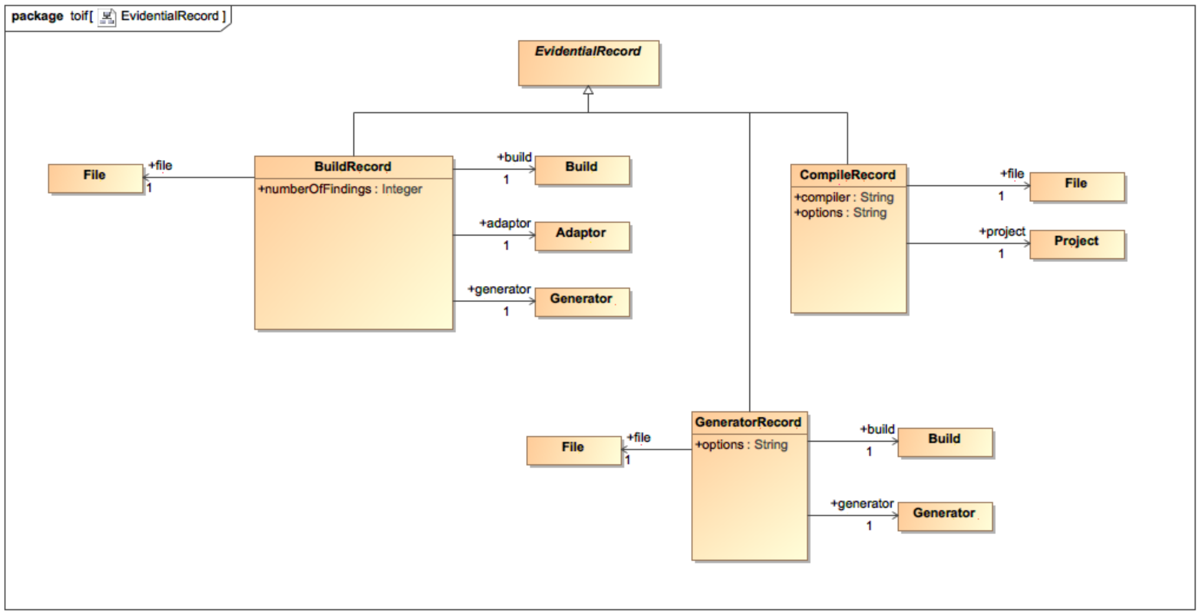


Figure 32 UML class diagram EvidentialRecord

10.4.1.1 BuildRecord Class

Superclass

Record

Attributes

numberOfFindings:Integer[1]	Record of the number of findings produced by Adaptor that was processing the output of the Generator processing File in Build. This number can be equal to zero, which indicates the absence of findings, but confirms the fact that File was processed by Generator.

Associations

file:File[1]	File of the BuildRecord
adaptor:Adaptor[1]	Adaptor of the BuildRecord
generator:Generator[1]	Generator of the BuildRecord
build:Build[1]	Build of the BuildRecord

Example

```
   <fact xmi:type="toif:BuildRecord" file="f10" adaptor="rats-toif-adaptor_1.1"
cwe="CWE-121" generator="rats" build="b10" numberOfFindings=0/>
   <fact xmi:type="toif:BuildRecord" file="f11" adaptor="rats-toif-adaptor_1.1"
cwe="CWE-121" generator="rats" build="b10" numberOfFindings=10/>
```

10.4.1.2 CompileRecord Class

Superclass

Record

Attributes

compiler:String[1]	Name of the compiler that was used to compile File in Project.
options:String[1]	Command line options that were used by the compiler to compile File in Project

Associations

file:File[1]	File of the CompileRecord
project:Project[1]	Project of the CompileRecord

Example

```
   <fact xmi:type="toif:CompileRecord" file="f10" project="pr1" compiler="gcc"
options="-wall –I /usr/include" />
```

10.4.1.3 GeneratorRecord Class

Superclass

Record

Attributes

options:String[1]	Command line options that were used by the Generator to process File in Build

Associations

file:File[1]	File of the GeneratorRecord
build:Build[1]	Build of the GeneratorRecord
generator:Generator[1]	Generator of the GeneratorRecord

Example

```
   <fact xmi:type="toif:GeneratorRecord" file=”f10” build="b10" compiler="gcc"
options=”-wall –I /usr/include” />
   <fact xmi:type="toif:GeneratorRecord" file=”f10” build="b11" compiler="gcc"
options=”-wall –I /usr/include” –I /test/sonic-boon/stub />
```