

Internet Engineering Task Force (IETF)  
Request for Comments: 8727  
Category: Standards Track  
ISSN: 2070-1721

T. Takahashi  
NICT  
R. Danyliw  
CERT  
M. Suzuki  
NICT  
August 2020

## JSON Binding of the Incident Object Description Exchange Format

### Abstract

The Incident Object Description Exchange Format (IODEF) defined in RFC 7970 provides an information model and a corresponding XML data model for exchanging incident and indicator information. This document gives implementers and operators an alternative format to exchange the same information by defining an alternative data model implementation in JSON and its encoding in Concise Binary Object Representation (CBOR).

### Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc8727>.

### Copyright Notice

Copyright (c) 2020 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

### Table of Contents

1. Introduction
  - 1.1. Requirements Language
2. IODEF Data Types
  - 2.1. Abstract Data Type to JSON Data Type Mapping
  - 2.2. Complex JSON Types
    - 2.2.1. Integer
    - 2.2.2. Multilingual Strings
    - 2.2.3. Enum
    - 2.2.4. Software and Software Reference
    - 2.2.5. Structured Information

- 2.2.6. EXTENSION
- 3. IODEF JSON Data Model
  - 3.1. Classes and Elements
  - 3.2. Mapping between JSON and XML IODEF
- 4. Examples
  - 4.1. Minimal Example
  - 4.2. Indicators from a Campaign
- 5. Mapkeys
- 6. The IODEF Data Model (CDDL)
- 7. IANA Considerations
- 8. Security Considerations
- 9. References
  - 9.1. Normative References
  - 9.2. Informative References
- Appendix A. Data Types Used in This Document
- Appendix B. The IODEF Data Model (JSON Schema)
- Acknowledgments
- Authors' Addresses

## 1. Introduction

The Incident Object Description Exchange Format (IODEF) [RFC7970] defines a data representation for security incident reports and indicators commonly exchanged by operational security teams. It facilitates the automated exchange of this information to enable mitigation and watch-and-warning. An information model using Unified Modeling Language (UML) is defined in Section 3 of [RFC7970] and a corresponding Extensible Markup Language (XML) schema data model is defined in Section 8 of [RFC7970]. This UML-based information model and XML-based data model are referred to as IODEF UML and IODEF XML, respectively, in this document.

IODEF documents are structured and thus suitable for machine processing. They will streamline incident response operations. Another well-used and structured format that is suitable for machine processing is JavaScript Object Notation (JSON) [RFC8259]. To facilitate the automation of incident response operations, IODEF documents and implementations should support JSON representation and its encoding in Concise Binary Object Representation (CBOR) [RFC7049].

This document defines an alternate implementation of the IODEF UML information model by specifying a JSON data model using Concise Data Definition Language (CDDL) [RFC8610] and a JSON Schema [JSON-SCHEMA]. This JSON data model is referred to as IODEF JSON in this document. IODEF JSON provides all of the expressivity of IODEF XML. It gives implementers and operators an alternative format to exchange the same information.

The normative IODEF JSON data model is found in Section 6. Sections 2 and 3 describe the data types and elements of this data model. Section 4 provides examples.

### 1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

## 2. IODEF Data Types

IODEF JSON implements the abstract data types specified in Section 2 of [RFC7970].

## 2.1. Abstract Data Type to JSON Data Type Mapping

IODEF JSON uses native and derived JSON data types. Table 1 describes the mapping between the abstract data types in Section 2 of [RFC7970] and their corresponding implementations in IODEF JSON.

IODEF Data Type	Reference	JSON Data Type
INTEGER	Section 2.1 of [RFC7970]	integer; see Section 2.2.1
REAL	Section 2.2 of [RFC7970]	"number" per [RFC8259]
CHARACTER	Section 2.3 of [RFC7970]	"string" per [RFC8259]
STRING	Section 2.3 of [RFC7970]	"string" per [RFC8259]
ML_STRING	Section 2.4 of [RFC7970]	see Section 2.2.2
BYTE	Section 2.5.1 of [RFC7970]	"string" per [RFC8259]
BYTE[]	Section 2.5.1 of [RFC7970]	"string" per [RFC8259]
HEXBIN	Section 2.5.2 of [RFC7970]	"string" per [RFC8259]
HEXBIN[]	Section 2.5.2 of [RFC7970]	"string" per [RFC8259]
ENUM	Section 2.6 of [RFC7970]	see Section 2.2.3
DATETIME	Section 2.7 of [RFC7970]	"string" per [RFC8259]
TIMEZONE	Section 2.8 of [RFC7970]	"string" per [RFC8259]
PORTLIST	Section 2.9 of [RFC7970]	"string" per [RFC8259]
POSTAL	Section 2.10 of [RFC7970]	ML_STRING; see Section 2.2.2
PHONE	Section 2.11 of [RFC7970]	"string" per [RFC8259]
EMAIL	Section 2.12 of [RFC7970]	"string" per [RFC8259]
URL	Section 2.13 of [RFC7970]	"string" per [RFC8259]
ID	Section 2.14 of [RFC7970]	"string" per [RFC8259]
IDREF	Section 2.14 of [RFC7970]	"string" per [RFC8259]

SOFTWARE	Section 2.15 of [RFC7970]	see Section 2.2.4
STRUCTUREDINFO	Section 4.4 of [RFC7203]	see Section 2.2.5
EXTENSION	Section 2.16 of [RFC7970]	see Section 2.2.6

Table 1: JSON Data Types

IODEF Data Type	CBOR Data Type	CDDL Prelude [RFC8610]
INTEGER	0, 1, 6 tag 2, 6 tag 3	integer
REAL	7 bits 26	float32
CHARACTER	3	text
STRING	3	text
ML_STRING	5	Maps/Structs (Section 3.5.1 of [RFC8610])
BYTE	6 tag 22	eb64legacy
BYTE[ ]	6 tag 22	eb64legacy
HEXBIN	6 tag 23	eb16
HEXBIN[ ]	6 tag 23	eb16
ENUM	-	Choices (Section 2.2.2 of [RFC8610])
DATETIME	6 tag 0	tdate
TIMEZONE	3	text
PORTLIST	3	text
POSTAL	3	ML_STRING (Section 2.2.2)
PHONE	3	text
EMAIL	3	text
URL	6 tag 32	uri
ID	3	text
IDREF	3	text
SOFTWARE	5	Maps/Structs (Section 3.5.1 of [RFC8610])
STRUCTUREDINFO	5	Maps/Structs (Section 3.5.1 of [RFC8610])
EXTENSION	5	Maps/Structs (Section 3.5.1 of [RFC8610])

Table 2: CBOR Data Types

## 2.2. Complex JSON Types

### 2.2.1. Integer

An integer is a subset of the "number" type of JSON, which represents signed digits encoded in Base 10. The definition of this integer is "[ minus ] int" per [RFC8259], Section 6.

### 2.2.2. Multilingual Strings

A string that needs to be represented in a human-readable language different from the default encoding of the document is represented in the information model by the ML\_STRING data type. This data type is implemented as either an object with "value", "lang", and "translation-id" elements or a text string as defined in Section 6. An example is shown below.

```
"MLStringType": {
  "value": "free-form text",          # STRING
  "lang": "en",                      # ENUM
  "translation-id": "jp2en0023"      # STRING
}
```

Note that in figures throughout this document, some supplementary information follows "#", but these are not valid syntax in JSON; instead, they are intended to facilitate reader understanding.

### 2.2.3. Enum

Enum is an ordered list of acceptable string values. Each value has a representative keyword. Within the data model, the enumerated type keywords are used as attribute values.

### 2.2.4. Software and Software Reference

A particular version of software is represented in the information model by the SOFTWARE data type. This software can be described by using a reference, a Uniform Resource Locator (URL) [RFC3986], or free-form text. The SOFTWARE data type is implemented as an object with "SoftwareReference", "URL", and "Description" elements as defined in Section 6. Examples are shown below.

```
"SoftwareType": {
  "SoftwareReference": {...},          # SoftwareReference
  "Description": ["MS Windows"]       # STRING
}
```

SoftwareReference class is a reference to a particular version of software. Examples are shown below.

```
"SoftwareReference": {
  "value": "cpe:/a:google:chrome:59.0.3071.115", # STRING
  "spec-name": "cpe",                          # ENUM
  "dtype": "string"                             # ENUM
}
```

### 2.2.5. Structured Information

Information provided in the form of a structured string, such as an ID, or structured information, such as XML documents, is represented in the information model by the STRUCTUREDINFO data type. Note that this type was originally specified in Section 4.4 of [RFC7203] as a basic structure of its extension classes. The STRUCTUREDINFO data type is implemented as an object with "SpecID", "ext-SpecID",

"ContentID", "RawData", and "Reference" elements. An example for embedding a structured ID is shown below.

```
"STRUCTUREDINFO": {
  "SpecID": "urn:ietf:params:xml:ns:mile:cwe:3.3",          # ENUM
  "ContentID": "CWE-89"                                     # STRING
}
```

When embedding the raw data, it should be encoded as a BYTE type object, as shown below.

```
"STRUCTUREDINFO": {
  "SpecID": "urn:ietf:params:xml:ns:mile:mmdef:1.2",        # ENUM
  "RawData": "<<< encoded structured data >>>"            # BYTE
}
```

When embedding the raw data, base64 encoding defined in Section 4 of [RFC4648] MUST be used for JSON IODEF while binary representation MUST be used for CBOR IODEF.

2.2.6. EXTENSION

Information not otherwise represented in the IODEF can be added using the EXTENSION data type. This data type is a generic extension mechanism. The EXTENSION data type is implemented as an ExtensionType object with "value", "name", "dtype", "ext-dtype", "meaning", "formatid", "restriction", "ext-restriction", and "observable-id" elements. An example for embedding a structured ID is shown below.

```
"ExtensionType": {
  "value": "xxxxxxx",                                     # STRING
  "name": "Syslog",                                       # STRING
  "dtype": "string",                                       # ENUM
  "meaning": "Syslog from the security appliance X"       # STRING
}
```

Note that this data type is specified in [RFC7970] as its generic extension mechanism. If a data item has internal structure that is intended to be processed outside of the IODEF framework, one may consider using the STRUCTUREDINFO data type mentioned in Section 2.2.5.

3. IODEF JSON Data Model

3.1. Classes and Elements

The following table shows the list of IODEF classes and their elements and the corresponding sections in [RFC7970]. Note that the complete JSON schema is defined in Section 6 using CDDL.

IODEF Class	Class, Element, and Attribute	Section in [RFC7970]
IODEF-Document	version lang? format-id? private-enum-name? private-enum-id? Incident+ AdditionalData*	3.1
Incident	purpose ext-purpose? status?	3.2

	ext-status? lang? restriction? ext-restriction? observable-id? IncidentID AlternativeID? RelatedActivity* DetectTime? StartTime? EndTime? RecoveryTime? ReportTime? GenerationTime Description* Discovery* Assessment* Method* Contact+ EventData* Indicator* History? AdditionalData*	
IncidentID	id name instance? restriction? ext-restriction?	3.4
AlternativeID	restriction? ext-restriction? IncidentID+	3.5
RelatedActivity	restriction? ext-restriction? IncidentID* URL* ThreatActor* Campaign* IndicatorID* Confidence? Description* AdditionalData*	3.6
ThreatActor	restriction? ext-restriction? ThreatActorID* URL* Description* AdditionalData*	3.7
Campaign	restriction? ext-restriction? CampaignID* URL* Description* AdditionalData*	3.8
Contact	role ext-role? type ext-type? restriction? ext-restriction? ContactName*	3.9

	ContactTitle* Description* RegistryHandle* PostalAddress* Email* Telephone* Timezone? Contact* AdditionalData*	
RegistryHandle	handle registry ext-registry?	3.9.1
PostalAddress	type? ext-type? PAddress Description*	3.9.2
Email	type? ext-type? EmailTo Description*	3.9.3
Telephone	type? ext-type? TelephoneNumber Description*	3.9.4
Discovery	source? ext-source? restriction? ext-restriction? Description* Contact* DetectionPattern*	3.10
DetectionPattern	restriction? ext-restriction? observable-id? Application Description* DetectionConfiguration*	3.10.1
Method	restriction? ext-restriction? Reference* Description* AttackPattern* Vulnerability* Weakness* AdditionalData*	3.11
Weakness	restriction? ext-restriction?	4.5.5 in [RFC7203]
Reference	observable-id? ReferenceName? URL* Description*	3.11.1
Assessment	occurrence? restriction? ext-restriction? observable-id? IncidentCategory*	3.12



	SystemImpact* BusinessImpact* TimeImpact* MonetaryImpact* IntendedImpact* Counter* MitigatingFactor* Cause* Confidence? AdditionalData*	
SystemImpact	severity? completion? type ext-type? Description*	3.12.1
BusinessImpact	severity? ext-severity? type ext-type? Description*	3.12.2
TimeImpact	value severity? metric ext-metric? duration? ext-duration?	3.12.3
MonetaryImpact	value severity? currency?	3.12.4
Confidence	value rating ext-rating?	3.12.5
History	restriction? ext-restriction? HistoryItem+	3.13
HistoryItem	action ext-action? restriction? ext-restriction? observable-id? DateTime IncidentID? Contact? Description* DefinedCOA* AdditionalData*	3.13.1
EventData	restriction? ext-restriction? observable-id? Description* DetectTime? StartTime? EndTime? RecoveryTime? ReportTime? Contact* Discovery* Assessment?	3.14

	Method* System* Expectation* RecordData* EventData* AdditionalData*	
Expectation	action? ext-action? severity? restriction? ext-restriction? observable-id? Description* DefinedCOA* StartTime? EndTime? Contact?	3.15
System	category? ext-category? interface? spoofed? virtual? ownership? ext-ownership? restriction? ext-restriction? Node NodeRole* Service* OperatingSystem* Counter* AssetID* Description* AdditionalData*	3.17
Node	DomainData* Address* PostalAddress? Location* Counter*	3.18
Address	value category ext-category? vlan-name? vlan-num? observable-id?	3.18.1
NodeRole	category ext-category? Description*	3.18.2
Counter	value type ext-type? unit ext-unit? meaning? duration? ext-duration?	3.18.3
DomainData	system-status ext-system-status? domain-status	3.19

	ext-domain-status? observable-id? Name DateDomainWasChecked? RegistrationDate? ExpirationDate? RelatedDNS* Nameservers* DomainContacts?	
Nameservers	Server Address*	3.19.1
DomainContacts	SameDomainContact? Contact+	3.19.2
Service	ip-protocol? observable-id? ServiceName? Port? Portlist? ProtoCode? ProtoType? ProtoField? ApplicationHeaderField* EmailData? Application?	3.20
ServiceName	IANAService? URL* Description*	3.20.1
EmailData	observable-id? EmailTo* EmailFrom? EmailSubject? EmailX-Mailer? EmailHeaderField* EmailHeaders? EmailBody? EmailMessage? HashData* Signature*	3.21
RecordData	restriction? ext-restriction? observable-id? DateTime? Description* Application? RecordPattern* RecordItem* URL* FileData* WindowsRegistryKeysModified* CertificateData* AdditionalData*	3.22.1
RecordPattern	type ext-type? offset? offsetunit? ext-offsetunit? instance? value	3.22.2

WindowsRegistryKeysModified	observable-id? Key+	3.23
Key	registryaction? ext-registryaction? observable-id? KeyName KeyValue?	3.23.1
CertificateData	restriction? ext-restriction? observable-id? Certificate+	3.24
Certificate	observable-id? X509Data Description*	3.24.1
FileData	restriction? ext-restriction? observable-id? File+	3.25
File	observable-id? FileName? FileSize? FileType? URL* HashData? Signature* AssociatedSoftware? FileProperties*	3.25.1
HashData	scope HashTargetID? Hash* FuzzyHash*	3.26
Hash	DigestMethod DigestValue CanonicalizationMethod? Application?	3.26.1
FuzzyHash	FuzzyHashValue+ Application? AdditionalData*	3.26.2
Indicator	restriction? ext-restriction? IndicatorID AlternativeIndicatorID* Description* StartTime? EndTime? Confidence? Contact* Observable? uid-ref? IndicatorExpression? IndicatorReference? NodeRole* AttackPhase* Reference* AdditionalData*	3.29
IndicatorID	id	3.29.1

	name version	
AlternativeIndicatorID	restriction? ext-restriction? IndicatorID+	3.29.2
Observable	restriction? ext-restriction? System? Address? DomainData? Service? EmailData? WindowsRegistryKeysModified? FileData? CertificateData? RegistryHandle? RecordData? EventData? Incident? Expectation? Reference? Assessment? DetectionPattern? HistoryItem? BulkObservable? AdditionalData*	3.29.3
BulkObservable	type? ext-type? BulkObservableFormat? BulkObservableList AdditionalData*	3.29.3.1
BulkObservableFormat	Hash? AdditionalData*	3.29.3.1.1
IndicatorExpression	operator? ext-operator? IndicatorExpression* Observable* uid-ref* IndicatorReference* Confidence? AdditionalData*	3.29.4
IndicatorReference	uid-ref? euid-ref? version?	3.29.7
AttackPhase	AttackPhaseID* URL* Description* AdditionalData*	3.29.8

Table 3: IODEF Classes

### 3.2. Mapping between JSON and XML IODEF

- \* Attributes and elements of each class in the XML IODEF document are both presented as JSON attributes in the JSON IODEF document, and the order of their appearances is ignored.
- \* Flow class is deleted, and classes with its instances now directly

have instances of the `EventData` class that used to belong to the `Flow` class.

- \* `ApplicationHeader` class is deleted, and classes with its instances now directly have instances of the `ApplicationHeaderField` class that used to belong to the `ApplicationHeader` class.
- \* `SignatureData` class is deleted, and classes with its instances now directly have instances of the `Signature` class that used to belong to the `SignatureData` class.
- \* `IndicatorData` class is deleted, and classes with its instances now directly have instances of the `Indicator` class that used to belong to the `IndicatorData` class.
- \* `ObservableReference` class is deleted, and classes with its instances now directly have `uid-ref` as an element.
- \* `Record` class is deleted, and classes with its instances now directly have instances of the `RecordData` class that used to belong to the `Record` class.
- \* The `MLStringType` was modified to support simple string by allowing the type to have not only a predefined object type but also a text type, in order to allow simple descriptions of elements of the type. Implementations need to be capable of parsing an `MLStringType` that could take the form of both text and an object.
- \* The elements of the `ML_STRING` type in the XML IODEF document are presented as either `STRING` type or `ML_STRING` type in the JSON IODEF document. When converting from the XML IODEF document to the JSON IODEF document, or vice versa, the information contained in the original data of the `ML_STRING` type must be preserved. When `STRING` is used instead of `ML_STRING`, parsers can assume that its `"xml:lang"` is set to `"en"`.
- \* Data models of the extension classes defined by [RFC7203] and referenced by [RFC7970] are represented by the `STRUCTUREDINFO` class defined in this document.
- \* `Signature`, `X509Data`, and `RawData` are encoded using base64 encoding for JSON IODEF and binary representation for CBOR IODEF to represent them as `BYTE` objects.
- \* `EmailBody` represents a whole message body including MIME structure in the same manner defined in [RFC7970]. In case of an email composed of a MIME multipart, the `EmailBody` contains multiple body parts separated by boundary strings.
- \* The `"ipv6-net-mask"` type attribute of the `BulkObservable` class remains available for the purpose of backward compatibility, but the use of this attribute is not recommended because IPv6 does not use netmask any more.
- \* `ENUM` values in this document are extensible and managed by IANA, which is also the case in [RFC7970]. The values in the table are used both by [RFC7970] implementations and by their JSON (and CBOR) bindings as specified by this document.
- \* This document uses JSON's `"number"` type to represent integers that only have full precision for integer values between  $-2^{(53)}$  and  $2^{(53)}$ . When dealing with integers outside the range, this issue needs to be considered.
- \* Binaries are encoded in bytes. Note that XML IODEF in [RFC7970] uses `HEXBIN` due to the incapability of XML for embedding binaries

as they are.

#### 4. Examples

This section provides examples of IODEF documents. These examples do not represent the full capabilities of the data model or the only way to encode particular information.

##### 4.1. Minimal Example

A document containing only the mandatory elements and attributes is shown below in JSON and CBOR, respectively.

```
{
  "version": "2.0",
  "lang": "en",
  "Incident": [{
    "purpose": "reporting",
    "restriction": "private",
    "IncidentID": {
      "id": "492382",
      "name": "csirt.example.com"
    },
    "GenerationTime": "2015-07-18T09:00:00-05:00",
    "Contact": [{
      "type": "organization",
      "role": "creator",
      "Email": [{"EmailTo": "contact@csirt.example.com"}]
    }]
  }]
}
```

Figure 1: A Minimal Example in JSON

A3		# map(3)
37		# negative(23)
63		# text(3)
	322E30	# "2.0"
36		# negative(22)
62		# text(2)
	656E	# "en"
32		# negative(18)
81		# array(1)
	A5	# map(5)
	21	# negative(1)
	69	# text(9)
	7265706F7274696E67	# "reporting"
	29	# negative(9)
	67	# text(7)
	70726976617465	# "private"
	02	# unsigned(2)
	A2	# map(2)
	12	# unsigned(18)
	66	# text(6)
	343932333832	# "492382"
	2E	# negative(14)
	71	# text(17)
	63736972742E6578616D706C652E636F6D	# "csirt.example.com"
	0A	# unsigned(10)
	78 19	# text(25)
	323031352D30372D31385430393A30303A30302D30353A3030	# "2015-07-18T09:00:00"
		# "-05:00"
	0E	# unsigned(14)
	81	# array(1)

```

A3                                     # map(3)
  18 1C                               # unsigned(28)
  6C                                   # text(12)
    6F7267616E697A6174696F6E # "organization"
  18 1A                               # unsigned(26)
  67                                   # text(7)
    63726561746F72             # "creator"
  18 22                               # unsigned(34)
  81                                   # array(1)
    A1                             # map(1)
      18 29                       # unsigned(41)
      78 19                       # text(25)
        636F6E746163744063736972742E6578616D70
        6C652E636F6D            # "contact@csirt.example.com"

```

Figure 2: A Minimal Example in CBOR

#### 4.2. Indicators from a Campaign

An example of C2 domains from a given campaign is shown below in JSON and CBOR, respectively.

```

{
  "version": "2.0",
  "lang": "en",
  "Incident": [{
    "purpose": "watch",
    "restriction": "green",
    "IncidentID": {
      "id": "897923",
      "name": "csirt.example.com"
    }
  }],
  "RelatedActivity": [{
    "ThreatActor": [{
      "ThreatActorID": ["TA-12-AGGRESSIVE-BUTTERFLY"],
      "Description": ["Aggressive Butterfly"]}],
    "Campaign": [{
      "CampaignID": ["C-2015-59405"],
      "Description": ["Orange Giraffe"]
    }]
  }],
  "GenerationTime": "2015-10-02T11:18:00-05:00",
  "Description": ["Summarizes the Indicators of Compromise for the
    Orange Giraffe campaign of the Aggressive Butterfly crime
    gang."],
  "Assessment": [{
    "Impact": [{"BusinessImpact": {"type": "breach-proprietary"}}]
  }],
  "Contact": [{
    "type": "organization",
    "role": "creator",
    "ContactName": ["CSIRT for example.com"],
    "Email": [{
      "EmailTo": "contact@csirt.example.com"
    }]
  }],
  "Indicator": [{
    "IndicatorID": {
      "id": "G90823490",
      "name": "csirt.example.com",
      "version": "1"
    },
    "Description": ["C2 domains"],
    "StartTime": "2014-12-02T11:18:00-05:00",
    "Observable": {

```





```

# "Orange Giraffe"
0A                                     # unsigned(10)
78 19                               # text(25)
323031352D31302D30325431313A31383A30302D30353A3030
                                     # "2015-10-02T11:18:00-05:00"
24                                   # negative(4)
81                                   # array(1)
78 6F                               # text(111)
53756D6D6172697A65732074686520496E64696361746F7
273206F6620436F6D70726F6D69736520666F7220746865
204F72616E676520476972616666652063616D706169676
E206F662074686520416767726573736976652042757474
6572666C79206372696D652067616E672E
                                     # "Summarizes the Indicators
                                     # of Compromise for the
                                     # Orange Giraffe campaign
                                     # of the Aggressive
                                     # Butterfly crime gang."
0C                                   # unsigned(12)
81                                   # array(1)
A1                                   # map(1)
18 3F                               # unsigned(63)
81                                   # array(1)
A1                                   # map(1)
18 41                               # unsigned(65)
A1                                   # map(1)
18 1C                               # unsigned(28)
72                                   # text(18)
6272656163682D70726F7072696574617279
                                     # "breach-proprietary"
0E                                   # unsigned(14)
81                                   # array(1)
A4                                   # map(4)
18 1C                               # unsigned(28)
6C                                   # text(12)
6F7267616E697A6174696F6E
                                     # "organization"
18 1A                               # unsigned(26)
67                                   # text(7)
63726561746F72                     # "creator"
18 1E                               # unsigned(30)
81                                   # array(1)
75                                   # text(21)
435349525420666F72206578616D706C652E636F6D
                                     # "CSIRT for example.com"
18 22                               # unsigned(34)
81                                   # array(1)
A1                                   # map(1)
18 29                               # unsigned(41)
78 19                               # text(25)
636F6E746163744063736972742E6578616D70
6C652E636F6D
                                     # "contact@csirt.example.com"
10                                   # unsigned(16)
81                                   # array(1)
A4                                   # map(4)
16                                   # unsigned(22)
A3                                   # map(3)
12                                   # unsigned(18)
69                                   # text(9)
473930383233343930                # "G90823490"
2E                                   # negative(14)
71                                   # text(17)
63736972742E6578616D706C652E636F6D
                                     # "csirt.example.com"
37                                   # negative(23)

```

```

        61          # text(1)
      31          # "1"
    24          # negative(4)
    81          # array(1)
      6A          # text(10)
        433220646F6D61696E73 # "C2 domains"
    06          # unsigned(6)
    78 19        # text(25)
        323031342D31322D30325431313A31383A30302D30353A3030
                                # "2014-12-02T11:18:00-05:00"
    18 AB        # unsigned(171)
    A1          # map(1)
      18 B0        # unsigned(176)
      A2          # map(2)
        18 1C        # unsigned(28)
        6B          # text(11)
            646F6D61696E2D6E616D65
                                # "domain-name"
        18 B2        # unsigned(178)
        78 1A        # text(26)
            6B6A3239303032336A30397233342E6578616D
            706C652E636F6D
                                # "kj290023j09r34.example.com"

```

Figure 4: Indicators from a Campaign in CBOR

## 5. Mapkeys

The mapkeys are provided in Table 4 for minimizing the CBOR size.

mapkey	cborkey
iodef-version	-24
iodef-lang	-23
iodef-format-id	-22
iodef-private-enum-name	-21
iodef-private-enum-id	-20
iodef-Incident	-19
iodef-AdditionalData	-18
iodef-value	-17
iodef-translation-id	-16
iodef-name	-15
iodef-dtype	-14
iodef-ext-dtype	-13
iodef-meaning	-12
iodef-formatid	-11
iodef-restriction	-10
iodef-ext-restriction	-9
iodef-observable-id	-8

iodef-SoftwareReference	-7	
iodef-URL	-6	
iodef-Description	-5	
iodef-spec-name	-4	
iodef-ext-spec-name	-3	
iodef-purpose	-2	
iodef-ext-purpose	-1	
iodef-status	0	
iodef-ext-status	1	
iodef-IncidentID	2	
iodef-AlternativeID	3	
iodef-RelatedActivity	4	
iodef-DetectTime	5	
iodef-StartTime	6	
iodef-EndTime	7	
iodef-RecoveryTime	8	
iodef-ReportTime	9	
iodef-GenerationTime	10	
iodef-Discovery	11	
iodef-Assessment	12	
iodef-Method	13	
iodef-Contact	14	
iodef-EventData	15	
iodef-Indicator	16	
iodef-History	17	
iodef-id	18	
iodef-instance	19	
iodef-ThreatActor	20	
iodef-Campaign	21	
iodef-IndicatorID	22	
iodef-Confidence	23	
iodef-ThreatActorID	24	
iodef-CampaignID	25	

iodef-role	26	
iodef-ext-role	27	
iodef-type	28	
iodef-ext-type	29	
iodef-ContactName	30	
iodef-ContactTitle	31	
iodef-RegistryHandle	32	
iodef-PostalAddress	33	
iodef-Email	34	
iodef-Telephone	35	
iodef-Timezone	36	
iodef-handle	37	
iodef-registry	38	
iodef-ext-registry	39	
iodef-PAddress	40	
iodef-EmailTo	41	
iodef-TelephoneNumber	42	
iodef-source	43	
iodef-ext-source	44	
iodef-DetectionPattern	45	
iodef-DetectionConfiguration	46	
iodef-Application	47	
iodef-Reference	48	
iodef-AttackPattern	49	
iodef-Vulnerability	50	
iodef-Weakness	51	
iodef-SpecID	52	
iodef-ext-SpecID	53	
iodef-ContentID	54	
iodef-RawData	55	
iodef-Platform	56	
iodef-Scoring	57	
iodef-ReferenceName	58	

iodef-specIndex	59	
iodef-ID	60	
iodef-occurrence	61	
iodef-IncidentCategory	62	
iodef-Impact	63	
iodef-SystemImpact	64	
iodef-BusinessImpact	65	
iodef-TimeImpact	66	
iodef-MonetaryImpact	67	
iodef-IntendedImpact	68	
iodef-Counter	69	
iodef-MitigatingFactor	70	
iodef-Cause	71	
iodef-severity	72	
iodef-completion	73	
iodef-ext-severity	74	
iodef-metric	75	
iodef-ext-metric	76	
iodef-duration	77	
iodef-ext-duration	78	
iodef-currency	79	
iodef-rating	80	
iodef-ext-rating	81	
iodef-HistoryItem	82	
iodef-action	83	
iodef-ext-action	84	
iodef-DateTime	85	
iodef-DefinedCOA	86	
iodef-System	87	
iodef-Expectation	88	
iodef-RecordData	89	
iodef-category	90	
iodef-ext-category	91	

iodef-interface	92
iodef-spoofed	93
iodef-virtual	94
iodef-ownership	95
iodef-ext-ownership	96
iodef-Node	97
iodef-NodeRole	98
iodef-Service	99
iodef-OperatingSystem	100
iodef-AssetID	101
iodef-DomainData	102
iodef-Address	103
iodef-Location	104
iodef-vlan-name	105
iodef-vlan-num	106
iodef-unit	107
iodef-ext-unit	108
iodef-system-status	109
iodef-ext-system-status	110
iodef-domain-status	111
iodef-ext-domain-status	112
iodef-Name	113
iodef-DateDomainWasChecked	114
iodef-RegistrationDate	115
iodef-ExpirationDate	116
iodef-RelatedDNS	117
iodef-NameServers	118
iodef-DomainContacts	119
iodef-Server	120
iodef-SameDomainContact	121
iodef-ip-protocol	122
iodef-ServiceName	123
iodef-Port	124

iodef-Portlist	125	
iodef-ProtoCode	126	
iodef-ProtoType	127	
iodef-ProtoField	128	
iodef-ApplicationHeaderField	129	
iodef-EmailData	130	
iodef-IANAService	131	
iodef-EmailFrom	132	
iodef-EmailSubject	133	
iodef-EmailX-Mailer	134	
iodef-EmailHeaderField	135	
iodef-EmailHeaders	136	
iodef-EmailBody	137	
iodef-EmailMessage	138	
iodef-HashData	139	
iodef-Signature	140	
iodef-RecordPattern	141	
iodef-RecordItem	142	
iodef-FileData	143	
iodef-WindowsRegistryKeysModified	144	
iodef-CertificateData	145	
iodef-offset	146	
iodef-offsetunit	147	
iodef-ext-offsetunit	148	
iodef-Key	149	
iodef-registryaction	150	
iodef-ext-registryaction	151	
iodef-KeyName	152	
iodef-KeyValue	153	
iodef-Certificate	154	
iodef-X509Data	155	
iodef-File	156	
iodef-FileName	157	



iodef-FileSize	158	
iodef-FileType	159	
iodef-AssociatedSoftware	160	
iodef-FileProperties	161	
iodef-scope	162	
iodef-HashTargetID	163	
iodef-Hash	164	
iodef-FuzzyHash	165	
iodef-DigestMethod	166	
iodef-DigestValue	167	
iodef-CanonicalizationMethod	168	
iodef-FuzzyHashValue	169	
iodef-AlternativeIndicatorID	170	
iodef-Observable	171	
iodef-uid-ref	172	
iodef-IndicatorExpression	173	
iodef-IndicatorReference	174	
iodef-AttackPhase	175	
iodef-BulkObservable	176	
iodef-BulkObservableFormat	177	
iodef-BulkObservableList	178	
iodef-operator	179	
iodef-ext-operator	180	
iodef-euid-ref	181	
iodef-AttackPhaseID	182	

Table 4: Mapkeys

## 6. The IODEF Data Model (CDDL)

This section provides the IODEF data model. Note that mapkeys are described at the beginning of the CDDL data model for better readability.

```
start = iodef

;;; iodef.json: IODEF-Document

iodef-version = -24
iodef-lang = -23
```

iodef-format-id = -22  
iodef-private-enum-name = -21  
iodef-private-enum-id = -20  
iodef-Incident = -19  
iodef-AdditionalData = -18  
iodef-value = -17  
iodef-translation-id = -16  
iodef-name = -15  
iodef-dtype = -14  
iodef-ext-dtype = -13  
iodef-meaning = -12  
iodef-formatid = -11  
iodef-restriction = -10  
iodef-ext-restriction = -9  
iodef-observable-id = -8  
iodef-SoftwareReference = -7  
iodef-URL = -6  
iodef-Description = -5  
iodef-spec-name = -4  
iodef-ext-spec-name = -3  
iodef-purpose = -2  
iodef-ext-purpose = -1  
iodef-status = 0  
iodef-ext-status = 1  
iodef-IncidentID = 2  
iodef-AlternativeID = 3  
iodef-RelatedActivity = 4  
iodef-DetectTime = 5  
iodef-StartTime = 6  
iodef-EndTime = 7  
iodef-RecoveryTime = 8  
iodef-ReportTime = 9  
iodef-GenerationTime = 10  
iodef-Discovery = 11  
iodef-Assessment = 12  
iodef-Method = 13  
iodef-Contact = 14  
iodef-EventData = 15  
iodef-Indicator = 16  
iodef-History = 17  
iodef-id = 18  
iodef-instance = 19  
iodef-ThreatActor = 20  
iodef-Campaign = 21  
iodef-IndicatorID = 22  
iodef-Confidence = 23  
iodef-ThreatActorID = 24  
iodef-CampaignID = 25  
iodef-role = 26  
iodef-ext-role = 27  
iodef-type = 28  
iodef-ext-type = 29  
iodef-ContactName = 30  
iodef-ContactTitle = 31  
iodef-RegistryHandle = 32  
iodef-PostalAddress = 33  
iodef-Email = 34  
iodef-Telephone = 35  
iodef-Timezone = 36  
iodef-handle = 37  
iodef-registry = 38  
iodef-ext-registry = 39  
iodef-PAddress = 40  
iodef-EmailTo = 41  
iodef-TelephoneNumber = 42  
iodef-source = 43

iodef-ext-source = 44  
iodef-DetectionPattern = 45  
iodef-DetectionConfiguration = 46  
iodef-Application = 47  
iodef-Reference = 48  
iodef-AttackPattern = 49  
iodef-Vulnerability = 50  
iodef-Weakness = 51  
iodef-SpecID = 52  
iodef-ext-SpecID = 53  
iodef-ContentID = 54  
iodef-RawData = 55  
iodef-Platform = 56  
iodef-Scoring = 57  
iodef-ReferenceName = 58  
iodef-specIndex = 59  
iodef-ID = 60  
iodef-occurrence = 61  
iodef-IncidentCategory = 62  
iodef-Impact = 63  
iodef-SystemImpact = 64  
iodef-BusinessImpact = 65  
iodef-TimeImpact = 66  
iodef-MonetaryImpact = 67  
iodef-IntendedImpact = 68  
iodef-Counter = 69  
iodef-MitigatingFactor = 70  
iodef-Cause = 71  
iodef-severity = 72  
iodef-completion = 73  
iodef-ext-severity = 74  
iodef-metric = 75  
iodef-ext-metric = 76  
iodef-duration = 77  
iodef-ext-duration = 78  
iodef-currency = 79  
iodef-rating = 80  
iodef-ext-rating = 81  
iodef-HistoryItem = 82  
iodef-action = 83  
iodef-ext-action = 84  
iodef-DateTime = 85  
iodef-DefinedCOA = 86  
iodef-System = 87  
iodef-Expectation = 88  
iodef-RecordData = 89  
iodef-category = 90  
iodef-ext-category = 91  
iodef-interface = 92  
iodef-spoofed = 93  
iodef-virtual = 94  
iodef-ownership = 95  
iodef-ext-ownership = 96  
iodef-Node = 97  
iodef-NodeRole = 98  
iodef-Service = 99  
iodef-OperatingSystem = 100  
iodef-AssetID = 101  
iodef-DomainData = 102  
iodef-Address = 103  
iodef-Location = 104  
iodef-vlan-name = 105  
iodef-vlan-num = 106  
iodef-unit = 107  
iodef-ext-unit = 108  
iodef-system-status = 109

iodef-ext-system-status = 110  
iodef-domain-status = 111  
iodef-ext-domain-status = 112  
iodef-Name = 113  
iodef-DateDomainWasChecked = 114  
iodef-RegistrationDate = 115  
iodef-ExpirationDate = 116  
iodef-RelatedDNS = 117  
iodef-NameServers = 118  
iodef-DomainContacts = 119  
iodef-Server = 120  
iodef-SameDomainContact = 121  
iodef-ip-protocol = 122  
iodef-ServiceName = 123  
iodef-Port = 124  
iodef-Portlist = 125  
iodef-ProtoCode = 126  
iodef-ProtoType = 127  
iodef-ProtoField = 128  
iodef-ApplicationHeaderField = 129  
iodef-EmailData = 130  
iodef-IANAService = 131  
iodef-EmailFrom = 132  
iodef-EmailSubject = 133  
iodef-EmailX-Mailer = 134  
iodef-EmailHeaderField = 135  
iodef-EmailHeaders = 136  
iodef-EmailBody = 137  
iodef-EmailMessage = 138  
iodef-HashData = 139  
iodef-Signature = 140  
iodef-RecordPattern = 141  
iodef-RecordItem = 142  
iodef-FileData = 143  
iodef-WindowsRegistryKeysModified = 144  
iodef-CertificateData = 145  
iodef-offset = 146  
iodef-offsetunit = 147  
iodef-ext-offsetunit = 148  
iodef-Key = 149  
iodef-registryaction = 150  
iodef-ext-registryaction = 151  
iodef-KeyName = 152  
iodef-KeyValue = 153  
iodef-Certificate = 154  
iodef-X509Data = 155  
iodef-File = 156  
iodef-FileName = 157  
iodef-FileSize = 158  
iodef-FileType = 159  
iodef-AssociatedSoftware = 160  
iodef-FileProperties = 161  
iodef-scope = 162  
iodef-HashTargetID = 163  
iodef-Hash = 164  
iodef-FuzzyHash = 165  
iodef-DigestMethod = 166  
iodef-DigestValue = 167  
iodef-CanonicalizationMethod = 168  
iodef-FuzzyHashValue = 169  
iodef-AlternativeIndicatorID = 170  
iodef-Observable = 171  
iodef-uid-ref = 172  
iodef-IndicatorExpression = 173  
iodef-IndicatorReference = 174  
iodef-AttackPhase = 175

```

iodef-BulkObservable = 176
iodef-BulkObservableFormat = 177
iodef-BulkObservableList = 178
iodef-operator = 179
iodef-ext-operator = 180
iodef-euid-ref = 181
iodef-AttackPhaseID = 182

iodef = {
  iodef-version => text,
  ? iodef-lang => lang,
  ? iodef-format-id => text
  ? iodef-private-enum-name => text,
  ? iodef-private-enum-id => text,
  iodef-Incident => [+ Incident],
  ? iodef-AdditionalData => [+ ExtensionType]
}

duration = "second" / "minute" / "hour" / "day" / "month" /
"quarter" / "year" / "ext-value"
lang = "" / text .regexp "[a-zA-Z]{1,8}(-[a-zA-Z0-9]{1,8})*"

restriction = "public" / "partner" / "need-to-know" / "private" /
"default" / "white" / "green" / "amber" / "red" /
"ext-value"
SpecID = "urn:ietf:params:xml:ns:mile:mmdef:1.2" / "private"
IDtype = text .regexp "[a-zA-Z_][a-zA-Z0-9_.-]*"
IDREFType = IDtype
URLtype = uri
TimeZonetype = text .regexp "Z|([\\+|\\-])(0[0-9]|1[0-4]):[0-5][0-9]"
PortlistType = text .regexp
"[0-9]+(\\-[0-9]+)?(,[0-9]+(\\-[0-9]+)?)*"
action = "nothing" / "contact-source-site" / "contact-target-site" /
"contact-sender" / "investigate" / "block-host" /
"block-network" / "block-port" / "rate-limit-host" /
"rate-limit-network" / "rate-limit-port" / "redirect-traffic" /
"honey-pot" / "upgrade-software" / "rebuild-asset" /
"harden-asset" / "remediate-other" / "status-triage" /
"status-new-info" / "watch-and-report" / "training" /
"defined-coa" / "other" / "ext-value"

DATETIME = tdate

BYTE = eb64legacy

MLStringType = {
  iodef-value => text,
  ? iodef-lang => lang,
  ? iodef-translation-id => text
} / text

PositiveFloatType = float32 .gt 0

PAddressType = MLStringType

ExtensionType = {
  iodef-value => text,
  ? iodef-name => text,
  iodef-dtype => "boolean" / "byte" / "bytes" / "character" /
"date-time" / "ntpstamp" / "integer" / "portlist" / "real" /
"string" / "file" / "path" / "frame" / "packet" / "ipv4-packet" /
"json" / "ipv6-packet" / "url" / "csv" / "winreg" / "xml" /
"ext-value"
.default "string"
  ? iodef-ext-dtype => text,
  ? iodef-meaning => text,

```

```

? iodef-formatid => text,
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,
}

```

```

SoftwareType = {
? iodef-SoftwareReference => SoftwareReference,
? iodef-URL => [+ URLtype],
? iodef-Description => [+ MLStringType]
}

```

```

SoftwareReference = {
? iodef-value => text,
iodef-spec-name => "custom" / "cpe" / "swid" / "ext-value",
? iodef-ext-spec-name => text,
? iodef-dtype => "bytes" / "integer" / "real" / "string" / "xml" /
"ext-value" .default "string",
? iodef-ext-dtype => text
}

```

```

Incident = {
? iodef-purpose => "traceback" / "mitigation" / "reporting" /
"watch" / "other" / "ext-value",
? iodef-ext-purpose => text,
? iodef-status => "new" / "in-progress" / "forwarded" / "resolved" /
"future" / "ext-value",
? iodef-ext-status => text,
? iodef-lang => lang,
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,
iodef-IncidentID => IncidentID,
? iodef-AlternativeID => AlternativeID,
? iodef-RelatedActivity => [+ RelatedActivity],
? iodef-DetectTime => DATETIME,
? iodef-StartTime => DATETIME,
? iodef-EndTime => DATETIME,
? iodef-RecoveryTime => DATETIME,
? iodef-ReportTime => DATETIME,
iodef-GenerationTime => DATETIME,
? iodef-Description => [+ MLStringType],
? iodef-Discovery => [+ Discovery],
? iodef-Assessment => [+ Assessment],
? iodef-Method => [+ Method],
iodef-Contact => [+ Contact],
? iodef-EventData => [+ EventData],
? iodef-Indicator => [+ Indicator],
? iodef-History => History,
? iodef-AdditionalData => [+ ExtensionType]
}

```

```

IncidentID = {
? iodef-id => text,
? iodef-name => text,
? iodef-instance => text,
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text
}

```

```

AlternativeID = {
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
iodef-IncidentID => [+ IncidentID]
}

```

```

RelatedActivity = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-IncidentID => [+ IncidentID],
  ? iodef-URL => [+ URLtype],
  ? iodef-ThreatActor => [+ ThreatActor],
  ? iodef-Campaign => [+ Campaign],
  ? iodef-IndicatorID => [+ IndicatorID],
  ? iodef-Confidence => Confidence,
  ? iodef-Description => [+ text],
  ? iodef-AdditionalData => [+ ExtensionType]
}

ThreatActor = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-ThreatActorID => [+ text],
  ? iodef-URL => [+ URLtype],
  ? iodef-Description => [+ MLStringType],
  ? iodef-AdditionalData => [+ ExtensionType]
}

Campaign = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-CampaignID => [+ text],
  ? iodef-URL => [+ URLtype],
  ? iodef-Description => [+ MLStringType],
  ? iodef-AdditionalData => [+ ExtensionType]
}

Contact = {
  iodef-role => "creator" / "reporter" / "admin" / "tech" /
  "provider" / "user" / "billing" / "legal" / "irt" / "abuse" /
  "cc" / "cc-irt" / "leo" / "vendor" / "vendor-support" /
  "victim" / "victim-notified" / "ext-value",
  ? iodef-ext-role => text,
  iodef-type => "person" / "organization" / "ext-value",
  ? iodef-ext-type => text,
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-ContactName => [+ MLStringType],
  ? iodef-ContactTitle => [+ MLStringType],
  ? iodef-Description => [+ MLStringType],
  ? iodef-RegistryHandle => [+ RegistryHandle],
  ? iodef-PostalAddress => [+ PostalAddress],
  ? iodef-Email => [+ Email],
  ? iodef-Telephone => [+ Telephone],
  ? iodef-Timezone => TimeZonetype,
  ? iodef-Contact => [+ Contact],
  ? iodef-AdditionalData => [+ ExtensionType]
}

RegistryHandle = {
  iodef-handle => text,
  iodef-registry => "internic" / "apnic" / "arin" / "lacnic" /
  "ripe" / "afrinic" / "local" / "ext-value",
  ? iodef-ext-registry => text
}

PostalAddress = {
  ? iodef-type => "street" / "mailing" / "ext-value",
  ? iodef-ext-type => text,
  iodef-PAddress => PAddressType,
  ? iodef-Description => [+ MLStringType]
}

```

```

Email = {
  ? iodef-type => "direct" / "hotline" / "ext-value",
  ? iodef-ext-type => text,
  iodef-EmailTo => text,
  ? iodef-Description => [+ MLStringType]
}

Telephone = {
  ? iodef-type => "wired" / "mobile" / "fax" / "hotline" /
  "ext-value",
  ? iodef-ext-type => text,
  iodef-TelephoneNumber => text,
  ? iodef-Description => [+ MLStringType]
}

Discovery = {
  ? iodef-source => "nidsps" / "hips" / "siem" / "av" /
  "third-party-monitoring" / "incident" / "os-log" /
  "application-log" / "device-log" / "network-flow" /
  "passive-dns" / "investigation" / "audit" /
  "internal-notification" / "external-notification" /
  "leo" / "partner" / "actor" / "unknown" / "ext-value",
  ? iodef-ext-source => text,
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-Description => [+ MLStringType],
  ? iodef-Contact => [+ Contact],
  ? iodef-DetectionPattern => [+ DetectionPattern]
}

DetectionPattern = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-observable-id => IDtype,
  (iodef-Description => [+ MLStringType] //
    iodef-DetectionConfiguration => [+ text]),
  iodef-Application => SoftwareType
}

Method = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-Reference => [+ Reference],
  ? iodef-Description => [+ MLStringType],
  ? iodef-AttackPattern => [+ STRUCTUREDINFO],
  ? iodef-Vulnerability => [+ STRUCTUREDINFO],
  ? iodef-Weakness => [+ STRUCTUREDINFO],
  ? iodef-AdditionalData => [+ ExtensionType]
}

STRUCTUREDINFO = {
  iodef-SpecID => SpecID,
  ? iodef-ext-SpecID => text,
  ? iodef-ContentID => text,
  ? (iodef-RawData => [+ BYTE] // iodef-Reference => [+ Reference]),
  ? iodef-Platform => [+ Platform],
  ? iodef-Scoring => [+ Scoring]
}

Platform = {
  iodef-SpecID => SpecID,
  ? iodef-ext-SpecID => text,
  ? iodef-ContentID => text,
  ? iodef-RawData => [+ BYTE],
  ? iodef-Reference => [+ Reference]
}

```



```

}
Scoring = {
    iodef-SpecID => SpecID,
    ? iodef-ext-SpecID => text,
    ? iodef-ContentID => text,
    ? iodef-RawData => [+ BYTE],
    ? iodef-Reference => [+ Reference]
}

Reference = {
    ? iodef-observable-id => IDtype,
    ? iodef-ReferenceName => ReferenceName,
    ? iodef-URL => [+ URLtype],
    ? iodef-Description => [+ MLStringType]
}

ReferenceName = {
    iodef-specIndex => integer,
    iodef-ID => IDtype
}

Assessment = {
    ? iodef-occurrence => "actual" / "potential",
    ? iodef-restriction => restriction .default "private",
    ? iodef-ext-restriction => text,
    ? iodef-observable-id => IDtype,
    ? iodef-IncidentCategory => [+ MLStringType],
    iodef-Impact => [+ {iodef-SystemImpact => SystemImpact} /
        {iodef-BusinessImpact => BusinessImpact /
            {iodef-TimeImpact => TimeImpact} /
            {iodef-MonetaryImpact => MonetaryImpact} /
            {iodef-IntendedImpact => BusinessImpact}}],
    ? iodef-Counter => [+ Counter],
    ? iodef-MitigatingFactor => [+ MLStringType],
    ? iodef-Cause => [+ MLStringType],
    ? iodef-Confidence => Confidence,
    ? iodef-AdditionalData => [+ ExtensionType]
}

SystemImpact = {
    ? iodef-severity => "low" / "medium" / "high",
    ? iodef-completion => "failed" / "succeeded",
    iodef-type => "takeover-account" / "takeover-service" /
"takeover-system" / "cps-manipulation" / "cps-damage" /
"availability-data" / "availability-account" /
"availability-service" / "availability-system" / "damaged-system" /
"damaged-data" / "breach-proprietary" / "breach-privacy" /
"breach-credential" / "breach-configuration" / "integrity-data" /
"integrity-configuration" / "integrity-hardware" /
"traffic-redirection" / "monitoring-traffic" / "monitoring-host" /
"policy" / "unknown" / "ext-value" .default "unknown",
    ? iodef-ext-type => text,
    ? iodef-Description => [+ MLStringType]
}

BusinessImpact = {
    ? iodef-severity => "none" / "low" / "medium" / "high" / "unknown" /
"ext-value" .default "unknown",
    ? iodef-ext-severity => text,
    iodef-type => "breach-proprietary" / "breach-privacy" /
"breach-credential" / "loss-of-integrity" / "loss-of-service" /
"theft-financial" / "theft-service" / "degraded-reputation" /
"asset-damage" / "asset-manipulation" / "legal" / "extortion" /
"unknown" / "ext-value" .default "unknown",
    ? iodef-ext-type => text,
    ? iodef-Description => [+ MLStringType]
}

```

```

TimeImpact = {
  iodef-value => PositiveFloatType,
  ? iodef-severity => "low" / "medium" / "high",
  iodef-metric => "labor" / "elapsed" / "downtime" / "ext-value",
  ? iodef-ext-metric => text,
  ? iodef-duration => duration .default "hour",
  ? iodef-ext-duration => text
}

MonetaryImpact = {
  iodef-value => PositiveFloatType,
  ? iodef-severity => "low" / "medium" / "high",
  ? iodef-currency => text
}

Confidence = {
  iodef-value => float32,
  iodef-rating => "low" / "medium" / "high" / "numeric" / "unknown" /
"ext-value",
  ? iodef-ext-rating => text
}

History = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  iodef-HistoryItem => [+ HistoryItem]
}

HistoryItem = {
  iodef-action => action .default "other",
  ? iodef-ext-action => text,
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-observable-id => IDtype,
  iodef-DateTime => DATETIME,
  ? iodef-IncidentID => IncidentID,
  ? iodef-Contact => Contact,
  ? iodef-Description => [+ MLStringType],
  ? iodef-DefinedCOA => [+ text],
  ? iodef-AdditionalData => [+ ExtensionType]
}

EventData = {
  ? iodef-restriction => restriction .default "default",
  ? iodef-ext-restriction => text,
  ? iodef-observable-id => IDtype,
  ? iodef-Description => [+ MLStringType],
  ? iodef-DetectTime => DATETIME,
  ? iodef-StartTime => DATETIME,
  ? iodef-EndTime => DATETIME,
  ? iodef-RecoveryTime => DATETIME,
  ? iodef-ReportTime => DATETIME,
  ? iodef-Contact => [+ Contact],
  ? iodef-Discovery => [+ Discovery],
  ? iodef-Assessment => Assessment,
  ? iodef-Method => [+ Method],
  ? iodef-System => [+ System],
  ? iodef-Expectation => [+ Expectation],
  ? iodef-RecordData => [+ RecordData],
  ? iodef-EventData => [+ EventData],
  ? iodef-AdditionalData => [+ ExtensionType]
}

Expectation = {
  ? iodef-action => action .default "other",

```

```

? iodef-ext-action => text,
? iodef-severity => "low" / "medium" / "high",
? iodef-restriction => restriction .default "default",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,
? iodef-Description => [+ MLStringType],
? iodef-DefinedCOA => [+ text],
? iodef-StartTime => DATETIME,
? iodef-EndTime => DATETIME,
? iodef-Contact => Contact
}

System = {
? iodef-category => "source" / "target" / "intermediate" /
"sensor" / "infrastructure" / "ext-value",
? iodef-ext-category => text,
? iodef-interface => text,
? iodef-spoofed => "unknown" / "yes" / "no" .default "unknown",
? iodef-virtual => "yes" / "no" / "unknown" .default "unknown",
? iodef-ownership => "organization" / "personal" / "partner" /
"customer" / "no-relationship" / "unknown" / "ext-value",
? iodef-ext-ownership => text,
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,
iodef-Node => Node,
? iodef-NodeRole => [+ NodeRole],
? iodef-Service => [+ Service],
? iodef-OperatingSystem => [+ SoftwareType],
? iodef-Counter => [+ Counter],
? iodef-AssetID => [+ text],
? iodef-Description => [+ MLStringType],
? iodef-AdditionalData => [+ ExtensionType]
}

Node = {
(iodef-DomainData => [+ DomainData] //
iodef-Address => [+ Address]),
? iodef-PostalAddress => PostalAddress,
? iodef-Location => [+ MLStringType],
? iodef-Counter => [+ Counter]
}

Address = {
iodef-value => text,
iodef-category => "asn" / "atm" / "e-mail" / "ipv4-addr" /
"ipv4-net" / "ipv4-net-masked" / "ipv4-net-mask" / "ipv6-addr" /
"ipv6-net" / "ipv6-net-masked" / "mac" / "site-uri" /
"ext-value" .default "ipv6-addr",
? iodef-ext-category => text,
? iodef-vlan-name => text,
? iodef-vlan-num => integer,
? iodef-observable-id => IDtype
}

NodeRole = {
iodef-category => "client" / "client-enterprise" /
"client-partner" / "client-remote" / "client-kiosk" /
"client-mobile" / "server-internal" / "server-public" /
"www" / "mail" / "webmail" / "messaging" / "streaming" /
"voice" / "file" / "ftp" / "p2p" / "name" / "directory" /
"credential" / "print" / "application" / "database" /
"backup" / "dhcp" / "assessment" / "source-control" /
"config-management" / "monitoring" / "infra" / "infra-firewall" /
"infra-router" / "infra-switch" / "camera" / "proxy" /
"remote-access" / "log" / "virtualization" / "pos" / "scada" /

```

```

"scada-supervisory" / "sinkhole" / "honeypot" /
"anonymization" / "c2-server" / "malware-distribution" /
"drop-server" / "hop-point" / "reflector" /
"phishing-site" / "spear-phishing-site" / "recruiting-site" /
"fraudulent-site" / "ext-value",
  ? iodef-ext-category => text,
  ? iodef-Description => [+ MLStringType]
}

Counter = {
  iodef-value => float32,
  iodef-type => "count" / "peak" / "average" / "ext-value",
  ? iodef-ext-type => text,
  iodef-unit => "byte" / "mbit" / "packet" / "flow" / "session" /
"alert" / "message" / "event" / "host" / "site" / "organization" /
"ext-value",
  ? iodef-ext-unit => text,
  ? iodef-meaning => text,
  ? iodef-duration => duration .default "hour",
  ? iodef-ext-duration => text
}

DomainData = {
  iodef-system-status => "spoofed" / "fraudulent" /
"innocent-hacked" / "innocent-hijacked" / "unknown" / "ext-value",
  ? iodef-ext-system-status => text,
  iodef-domain-status => "reservedDelegation" / "assignedAndActive" /
"assignedAndInactive" / "assignedAndOnHold" /
"revoked" / "transferPending" / "registryLock" /
"registrarLock" / "other" / "unknown" / "ext-value",
  ? iodef-ext-domain-status => text,
  ? iodef-observable-id => IDtype,
  iodef-Name => text,
  ? iodef-DateDomainWasChecked => DATETIME,
  ? iodef-RegistrationDate => DATETIME,
  ? iodef-ExpirationDate => DATETIME,
  ? iodef-RelatedDNS => [+ ExtensionType],
  ? iodef-NameServers => [+ NameServers],
  ? iodef-DomainContacts => DomainContacts
}

NameServers = {
  iodef-Server => text,
  iodef-Address => [+ Address]
}

DomainContacts = {
  (iodef-SameDomainContact => text // iodef-Contact => [+ Contact])
}

Service = {
  ? iodef-ip-protocol => integer,
  ? iodef-observable-id => IDtype,
  ? iodef-ServiceName => ServiceName,
  ? iodef-Port => integer,
  ? iodef-Portlist => PortlistType,
  ? iodef-ProtoCode => integer,
  ? iodef-ProtoType => integer,
  ? iodef-ProtoField => integer,
  ? iodef-ApplicationHeaderField => [+ ExtensionType],
  ? iodef-EmailData => EmailData,
  ? iodef-Application => SoftwareType
}

ServiceName = {
  ? iodef-IANAService => text,

```

```

? iodef-URL => [+ URLtype],
? iodef-Description => [+ MLStringType]
}

```

```

EmailData = {
? iodef-observable-id => IDtype,
? iodef-EmailTo => [+ text],
? iodef-EmailFrom => text,
? iodef-EmailSubject => text,
? iodef-EmailX-Mailer => text,
? iodef-EmailHeaderField => [+ ExtensionType],
? iodef-EmailHeaders => text,
? iodef-EmailBody => text,
? iodef-EmailMessage => text,
? iodef-HashData => [+ HashData],
? iodef-Signature => [+ BYTE]
}

```

```

RecordData = {
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,
? iodef-DateTime => DATETIME,
? iodef-Description => [+ MLStringType],
? iodef-Application => SoftwareType,
? iodef-RecordPattern => [+ RecordPattern],
? iodef-RecordItem => [+ ExtensionType],
? iodef-URL => [+ URLtype],
? iodef-FileData => [+ FileData],
? iodef-WindowsRegistryKeysModified =>
    [+ WindowsRegistryKeysModified],
? iodef-CertificateData => [+ CertificateData],
? iodef-AdditionalData => [+ ExtensionType]
}

```

```

RecordPattern = {
  iodef-value => text,
  iodef-type => "regex" / "binary" / "xpath" /
"ext-value" .default "regex",
? iodef-ext-type => text,
? iodef-offset => integer,
? iodef-offsetunit => "line" / "byte" /
"ext-value" .default "line",
? iodef-ext-offsetunit => text,
? iodef-instance => integer
}

```

```

WindowsRegistryKeysModified = {
? iodef-observable-id => IDtype,
  iodef-Key => [+ Key]
}

```

```

Key = {
? iodef-registryaction => "add-key" / "add-value" / "delete-key" /
"delete-value" / "modify-key" / "modify-value" /
"ext-value",
? iodef-ext-registryaction => text,
? iodef-observable-id => IDtype,
  iodef-KeyName => text,
? iodef-KeyValue => text
}

```

```

CertificateData = {
? iodef-restriction => restriction .default "private",
? iodef-ext-restriction => text,
? iodef-observable-id => IDtype,

```

```

iodef-Certificate => [+ Certificate]
}

Certificate = {
  ? iodef-observable-id => IDtype,
  iodef-X509Data => BYTE,
  ? iodef-Description => [+ MLStringType]
}

FileData = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? iodef-observable-id => IDtype,
  iodef-File => [+ File]
}

File = {
  ? iodef-observable-id => IDtype,
  ? iodef-FileName => text,
  ? iodef-FileSize => integer,
  ? iodef-FileType => text,
  ? iodef-URL => [+ URLtype],
  ? iodef-HashData => HashData,
  ? iodef-Signature => [+ BYTE],
  ? iodef-AssociatedSoftware => SoftwareType,
  ? iodef-FileProperties => [+ ExtensionType]
}

HashData = {
  iodef-scope => "file-contents" / "file-pe-section" /
"file-pe-iat" / "file-pe-resource" / "file-pdf-object" /
"email-hash" / "email-headers-hash" / "email-body-hash" /
"ext-value",
  ? iodef-HashTargetID => text,
  ? iodef-Hash => [+ Hash],
  ? iodef-FuzzyHash => [+ FuzzyHash]
}

Hash = {
  iodef-DigestMethod => BYTE,
  iodef-DigestValue => BYTE,
  ? iodef-CanonicalizationMethod => BYTE,
  ? iodef-Application => SoftwareType
}

FuzzyHash = {
  iodef-FuzzyHashValue => [+ ExtensionType],
  ? iodef-Application => SoftwareType,
  ? iodef-AdditionalData => [+ ExtensionType]
}

Indicator = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  iodef-IndicatorID => IndicatorID,
  ? iodef-AlternativeIndicatorID => [+ AlternativeIndicatorID],
  ? iodef-Description => [+ MLStringType],
  ? iodef-StartTime => DATETIME,
  ? iodef-EndTime => DATETIME,
  ? iodef-Confidence => Confidence,
  ? iodef-Contact => [+ Contact],
  (iodef-Observable => Observable // iodef-uid-ref => IDREFType //
  iodef-IndicatorExpression => IndicatorExpression //
  iodef-IndicatorReference => IndicatorReference),
  ? iodef-NodeRole => [+ NodeRole],
  ? iodef-AttackPhase => [+ AttackPhase],

```

```

? iodef-Reference => [+ Reference],
? iodef-AdditionalData => [+ ExtensionType]
}

IndicatorID = {
  iodef-id => IDtype,
  iodef-name => text,
  iodef-version => text
}

AlternativeIndicatorID = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  iodef-IndicatorID => [+ IndicatorID]
}

Observable = {
  ? iodef-restriction => restriction .default "private",
  ? iodef-ext-restriction => text,
  ? (iodef-System => System // iodef-Address => Address //
    iodef-DomainData => DomainData //
    iodef-EmailData => EmailData //
    iodef-Service => Service //
    iodef-WindowsRegistryKeysModified =>
      WindowsRegistryKeysModified //
    iodef-FileData => FileData // iodef-CertificateData =>
      CertificateData //
    iodef-RegistryHandle => RegistryHandle // iodef-RecordData =>
      RecordData //
    iodef-EventData => EventData // iodef-Incident => Incident //
    iodef-Expectation => Expectation // iodef-Reference =>
      Reference //
    iodef-Assessment => Assessment //
    iodef-DetectionPattern => DetectionPattern //
    iodef-HistoryItem => HistoryItem //
    iodef-BulkObservable => BulkObservable //
    iodef-AdditionalData => [+ ExtensionType])
}

BulkObservable = {
  ? iodef-type => "asn" / "atm" / "e-mail" / "ipv4-addr" /
  "ipv4-net" / "ipv4-net-mask" / "ipv6-addr" / "ipv6-net" /
  "ipv6-net-mask" / "mac" / "site-uri" / "domain-name" /
  "domain-to-ipv4" / "domain-to-ipv6" /
  "domain-to-ipv4-timestamp" / "domain-to-ipv6-timestamp" /
  "ipv4-port" / "ipv6-port" / "windows-reg-key" / "file-hash" /
  "email-x-mailer" / "email-subject" / "http-user-agent" /
  "http-request-uri" / "mutex" / "file-path" / "user-name" /
  "ext-value",
  ? iodef-ext-type => text,
  ? iodef-BulkObservableFormat => BulkObservableFormat,
  iodef-BulkObservableList => text,
  ? iodef-AdditionalData => [+ ExtensionType]
}

BulkObservableFormat = {
  (iodef-Hash => Hash // iodef-AdditionalData => [+ ExtensionType])
}

IndicatorExpression = {
  ? iodef-operator => "not" / "and" / "or" / "xor" .default "and",
  ? iodef-ext-operator => text,
  ? iodef-IndicatorExpression => [+ IndicatorExpression],
  ? iodef-Observable => [+ Observable],
  ? iodef-uid-ref => [+ IDREFType],
  ? iodef-IndicatorReference => [+ IndicatorReference],

```

```

? iodef-Confidence => Confidence,
? iodef-AdditionalData => [+ ExtensionType]
}

IndicatorReference = {
  (iodef-uid-ref => IDREFType // iodef-euid-ref => text),
  ? iodef-version => text
}

AttackPhase = {
  ? iodef-AttackPhaseID => [+ text],
  ? iodef-URL => [+ URLtype],
  ? iodef-Description => [+ MLStringType],
  ? iodef-AdditionalData => [+ ExtensionType]
}

```

Figure 5: Data Model in CDDL

## 7. IANA Considerations

This document has no IANA actions.

## 8. Security Considerations

This document provides a mapping from XML IODEF defined in [RFC7970] to JSON, and Section 3.2 describes several issues that arise when converting XML IODEF and JSON IODEF. Though it does not provide any further security considerations other than the one described in [RFC7970], implementers of this document should be aware of those issues to avoid any unintended outcome.

## 9. References

### 9.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifier (URI): Generic Syntax", STD 66, RFC 3986, DOI 10.17487/RFC3986, January 2005, <<https://www.rfc-editor.org/info/rfc3986>>.
- [RFC4648] Josefsson, S., "The Base16, Base32, and Base64 Data Encodings", RFC 4648, DOI 10.17487/RFC4648, October 2006, <<https://www.rfc-editor.org/info/rfc4648>>.
- [RFC7049] Bormann, C. and P. Hoffman, "Concise Binary Object Representation (CBOR)", RFC 7049, DOI 10.17487/RFC7049, October 2013, <<https://www.rfc-editor.org/info/rfc7049>>.
- [RFC7203] Takahashi, T., Landfield, K., and Y. Kadobayashi, "An Incident Object Description Exchange Format (IODEF) Extension for Structured Cybersecurity Information", RFC 7203, DOI 10.17487/RFC7203, April 2014, <<https://www.rfc-editor.org/info/rfc7203>>.
- [RFC7970] Danyliw, R., "The Incident Object Description Exchange Format Version 2", RFC 7970, DOI 10.17487/RFC7970, November 2016, <<https://www.rfc-editor.org/info/rfc7970>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.



- [RFC8259] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", STD 90, RFC 8259, DOI 10.17487/RFC8259, December 2017, <<https://www.rfc-editor.org/info/rfc8259>>.
- [RFC8610] Birkholz, H., Vigano, C., and C. Bormann, "Concise Data Definition Language (CDDL): A Notational Convention to Express Concise Binary Object Representation (CBOR) and JSON Data Structures", RFC 8610, DOI 10.17487/RFC8610, June 2019, <<https://www.rfc-editor.org/info/rfc8610>>.

## 9.2. Informative References

- [JSON-SCHEMA] Wright, A., Andrews, H., and B. Hutton, "JSON Schema Validation: A Vocabulary for Structural Validation of JSON", Work in Progress, Internet-Draft, draft-handrews-json-schema-validation-02, 17 September 2019, <<https://tools.ietf.org/html/draft-handrews-json-schema-validation-02>>.

## Appendix A. Data Types Used in This Document

The CDDL prelude used in this document is mapped to JSON as shown in the table below.

CDDL Prelude	Use of JSON	Instance	Validation
bytes	n/a	string	tool available
text	string	string	unnecessary
tdate	n/a	string	date-time per Section 7.3.1 of [JSON-SCHEMA]
integer	n/a	number	integer
eb64legacy	n/a	string	tool available
uri	n/a	string	uri per Section 7.3.6 of [JSON-SCHEMA]
float32	float32	number	unnecessary

Table 5: CDDL Prelude Mapping in JSON

## Appendix B. The IODEF Data Model (JSON Schema)

This section provides a JSON schema [JSON-SCHEMA] that defines the IODEF data model defined in this document. Note that this section is informative.

```
{ "$schema": "https://json-schema.org/draft-04/schema#",
  "definitions": {
    "action": { "enum": ["nothing", "contact-source-site",
      "contact-target-site", "contact-sender", "investigate",
      "block-host", "block-network", "block-port",
      "rate-limit-host", "rate-limit-network",
      "rate-limit-port", "redirect-traffic", "honeypot",
      "upgrade-software", "rebuild-asset", "harden-asset",
      "remediate-other", "status-triage", "status-new-info",
      "watch-and-report", "training", "defined-coa", "other",
```

```

    "ext-value"]},
"duration": {"enum": ["second", "minute", "hour", "day",
    "month", "quarter", "year", "ext-value"]},
"SpecID": {
    "enum": ["urn:ietf:params:xml:ns:mile:mmdf:1.2",
    "private"]},
"lang": {
    "type": "string", "pattern":
        "^$|[a-zA-Z]{1,8}(-[a-zA-Z0-9]{1,8})*",
"purpose": {"enum": ["traceback", "mitigation",
    "reporting", "watch", "other", "ext-value"]},
"restriction": {"enum": ["public", "partner",
    "need-to-know", "private", "default", "white", "green",
    "amber", "red", "ext-value"]},
"status": {"enum": ["new", "in-progress", "forwarded",
    "resolved", "future", "ext-value"]},
"DATETIME": {"type": "string", "format": "date-time"},
"BYTE": {"type": "string"},
"PortlistType": {
    "type": "string", "pattern":
        "[0-9]+(\\-[0-9]+)?(,[0-9]+(\\-[0-9]+)?)*",
"TimeZonetype": {
    "type": "string", "pattern":
        "Z|[\\+\\-](0[0-9]|1[0-4]):[0-5][0-9]",
"URLtype": {
    "type": "string",
    "pattern":
        "^(([^:/?#]+):)?(//([^/?#]*))?([^?#]*(\\?([^#]*)
        ?(#(.*)?)?)",
"IDtype": {"type": "string", "pattern":
    "[a-zA-Z_][a-zA-Z0-9_.-]*"},
"IDREFType": {"$ref": "#/definitions/IDtype"},
"MLStringType": {
    "oneOf": [{ "type": "string",
        { "type": "object",
            "properties": {
                "value": {"type": "string"},
                "lang": {"$ref": "#/definitions/lang"},
                "translation-id": {"type": "string"}},
                "required": ["value"],
                "additionalProperties": false}}},
"PositiveFloatType": {"type": "number", "minimum": 0},
"PAddressType": {"$ref": "#/definitions/MLStringType"},
"ExtensionType": {
    "type": "object",
    "properties": {
        "value": {"type": "string"},
        "name": {"type": "string"},
        "dtype": {"enum": ["boolean", "byte", "bytes",
            "character", "json", "date-time", "ntpstamp",
            "integer", "portlist", "real", "string", "file",
            "path", "frame", "packet", "ipv4-packet",
            "ipv6-packet", "url", "csv", "winreg",
            "xml", "ext-value"], "default": "string"},
        "ext-dtype": {"type": "string"},
        "meaning": {"type": "string"},
        "formatid": {"type": "string"},
        "restriction": {
            "$ref": "#/definitions/restriction", "default":
                "private"},
        "ext-restriction": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDtype"}},
        "required": ["value", "dtype"],
        "additionalProperties": false},
"ExtensionTypeList": {
    "type": "array",

```

```

    "items": { "$ref": "#/definitions/ExtensionType" },
    "minItems": 1 },
  "SoftwareType": {
    "type": "object",
    "properties": {
      "SoftwareReference": {
        "$ref": "#/definitions/SoftwareReference" },
      "URL": {
        "type": "array",
        "items": { "$ref": "#/definitions/URLtype" },
        "minItems": 1 } },
      "Description": {
        "type": "array",
        "items": { "$ref": "#/definitions/MLStringType" },
        "minItems": 1 } },
    "required": [],
    "additionalProperties": false },
  "SoftwareReference": {
    "type": "object",
    "properties": {
      "value": { "type": "string" },
      "spec-name": { "enum": [ "custom", "cpe", "swid",
        "ext-value" ] },
      "ext-spec-name": { "type": "string" },
      "dtype": { "enum": [ "bytes", "integer", "real", "string",
        "xml", "ext-value" ], "default": "string" },
      "ext-dtype": { "type": "string" } },
    "required": [ "spec-name" ],
    "additionalProperties": false },
  "STRUCTUREDINFO": {
    "type": "object",
    "properties": {
      "SpecID": { "$ref": "#/definitions/SpecID" },
      "ext-SpecID": { "type": "string" },
      "ContentID": { "type": "string" },
      "RawData": {
        "type": "array",
        "items": { "$ref": "#/definitions/BYTE" },
        "minItems": 1
      },
    },
    "Reference": {
      "type": "array",
      "items": { "$ref": "#/definitions/Reference" },
      "minItems": 1
    },
  },
  "Platform": {
    "type": "array",
    "items": { "$ref": "#/definitions/Platform" },
    "minItems": 1
  },
  "Scoring": {
    "type": "array",
    "items": { "$ref": "#/definitions/Scoring" },
    "minItems": 1 } },
  "allOf": [
    { "required": [ "SpecID" ] },
    { "anyOf": [
      { "oneOf": [
        { "required": [ "Reference" ] },
        { "required": [ "RawData" ] } ] } ],
      { "not": { "required": [ "Reference", "RawData" ] } } ] },
    "additionalProperties": false },
  "Platform": {
    "type": "object",
    "properties": {
      "SpecID": { "$ref": "#/definitions/SpecID" },

```

```

    "ext-SpecID": {"type": "string"},
    "ContentID": {"type": "string"},
    "RawData": {
      "type": "array",
      "items": {"$ref": "#/definitions/BYTE"},
      "minItems": 1
    },
    "Reference": {
      "type": "array",
      "items": {"$ref": "#/definitions/Reference"},
      "minItems": 1
    },
    "required": ["SpecID"],
    "additionalProperties": false,
    "Scoring": {
      "type": "object",
      "properties": {
        "SpecID": {"$ref": "#/definitions/SpecID"},
        "ext-SpecID": {"type": "string"},
        "ContentID": {"type": "string"},
        "RawData": {
          "type": "array",
          "items": {"$ref": "#/definitions/BYTE"},
          "minItems": 1
        },
        "Reference": {
          "type": "array",
          "items": {"$ref": "#/definitions/Reference"},
          "minItems": 1
        },
        "required": ["SpecID"],
        "additionalProperties": false
      },
      "Incident": {
        "title": "Incident",
        "description": "JSON schema for Incident class",
        "type": "object",
        "properties": {
          "purpose": {"$ref": "#/definitions/purpose"},
          "ext-purpose": {"type": "string"},
          "status": {"$ref": "#/definitions/status"},
          "ext-status": {"type": "string"},
          "lang": {"$ref": "#/definitions/lang"},
          "restriction": {"$ref": "#/definitions/restriction",
            "default": "private"},
          "ext-restriction": {"type": "string"},
          "observable-id": {"$ref": "#/definitions/IDtype"},
          "IncidentID": {"$ref": "#/definitions/IncidentID"},
          "AlternativeID": {
            "$ref": "#/definitions/AlternativeID"},
          "RelatedActivity": {
            "type": "array",
            "items": {"$ref": "#/definitions/RelatedActivity"},
            "minItems": 1},
          "DetectTime": {"$ref": "#/definitions/DATETIME"},
          "StartTime": {"$ref": "#/definitions/DATETIME"},
          "EndTime": {"$ref": "#/definitions/DATETIME"},
          "RecoveryTime": {"$ref": "#/definitions/DATETIME"},
          "ReportTime": {"$ref": "#/definitions/DATETIME"},
          "GenerationTime": {"$ref": "#/definitions/DATETIME"},
          "Description": {
            "type": "array",
            "items": {"$ref": "#/definitions/MLStringType"},
            "minItems": 1},
          "Discovery": {
            "type": "array",
            "items": {"$ref": "#/definitions/Discovery"},
            "minItems": 1},
          "Assessment": {

```

```

    "type": "array",
    "items": {"$ref": "#/definitions/Assessment"},
    "minItems": 1},
  "Method": {
    "type": "array",
    "items": {"$ref": "#/definitions/Method"},
    "minItems": 1},
  "Contact": {
    "type": "array",
    "items": {"$ref": "#/definitions/Contact"},
    "minItems": 1},
  "EventData": {
    "type": "array",
    "items": {"$ref": "#/definitions/EventData"},
    "minItems": 1},
  "Indicator": {
    "type": "array",
    "items": {"$ref": "#/definitions/Indicator"},
    "minItems": 1},
  "History": {"$ref": "#/definitions/History"},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["IncidentID", "GenerationTime", "Contact",
    "purpose"],
  "additionalProperties": false},
"IncidentID": {
  "title": "IncidentID",
  "description": "JSON schema for IncidentID class",
  "type": "object",
  "properties": {
    "id": {"type": "string"},
    "name": {"type": "string"},
    "instance": {"type": "string"},
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"}},
  "required": ["id", "name"],
  "additionalProperties": false},
"AlternativeID": {
  "title": "AlternativeID",
  "description": "JSON schema for AlternativeID class",
  "type": "object",
  "properties": {
    "IncidentID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IncidentID"},
      "minItems": 1},
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"}},
  "required": ["IncidentID"],
  "additionalProperties": false},
"RelatedActivity": {
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "IncidentID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IncidentID"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "ThreatActor": {

```

```

    "type": "array",
    "items": {"$ref": "#/definitions/ThreatActor"},
    "minItems": 1},
  "Campaign": {
    "type": "array",
    "items": {"$ref": "#/definitions/Campaign"},
    "minItems": 1},
  "IndicatorID": {
    "type": "array",
    "items": {"$ref": "#/definitions/IndicatorID"},
    "minItems": 1},
  "Confidence": {"$ref": "#/definitions/Confidence"},
  "Description": {
    "type": "array",
    "items": {"type": "string"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
  "additionalProperties": false},
"ThreatActor": {
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "ThreatActorID": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList"}},
    "additionalProperties": false},
"Campaign": {
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "CampaignID": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList"}},
    "Contact": {
      "type": "object",
      "properties": {
        "role": {
          "enum": ["creator", "reporter", "admin", "tech",
            "provider", "user", "billing", "legal",
            "irt", "abuse", "cc", "cc-irt", "leo",
            "vendor", "vendor-support", "victim",

```

```

        "victim-notified", "ext-value"]},
    "ext-role": {"type": "string"},
    "type": {
        "enum": ["person", "organization", "ext-value"]},
    "ext-type": {"type": "string"},
    "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
    "ext-restriction": {"type": "string"},
    "ContactName": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
    "ContactTitle": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
    "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
    "RegistryHandle": {
        "type": "array",
        "items": {"$ref": "#/definitions/RegistryHandle"},
        "minItems": 1},
    "PostalAddress": {
        "type": "array",
        "items": {"$ref": "#/definitions/PostalAddress"},
        "minItems": 1},
    "Email": {
        "type": "array",
        "items": {"$ref": "#/definitions/Email"},
        "minItems": 1},
    "Telephone": {
        "type": "array",
        "items": {"$ref": "#/definitions/Telephone"},
        "minItems": 1},
    "Timezone": {"$ref": "#/definitions/TimeZonetype"},
    "Contact": {
        "type": "array",
        "items": {"$ref": "#/definitions/Contact"},
        "minItems": 1},
    "AdditionalData": {
        "$ref": "#/definitions/ExtensionTypeList"}},
    "required": ["role", "type"],
    "additionalProperties": false},
    "RegistryHandle": {
        "type": "object",
        "properties": {
            "handle": {"type": "string"},
            "registry": {
                "enum": ["internic", "apnic", "arin", "lacnic",
                    "ripe", "afrinic", "local", "ext-value"]},
            "ext-registry": {"type": "string"}},
        "required": ["handle", "registry"],
        "additionalProperties": false},
    "PostalAddress": {
        "type": "object",
        "properties": {
            "type": {
                "enum": ["street", "mailing", "ext-value"]},
            "ext-type": {"type": "string"},
            "PAddress": {"$ref": "#/definitions/PAddressType"},
            "Description": {
                "type": "array",
                "items": {"$ref": "#/definitions/MLStringType"},
                "minItems": 1}},

```

```

    "required": ["PAddress"],
    "additionalProperties": false},
  "Email": {
    "type": "object",
    "properties": {
      "type": {
        "enum": ["direct", "hotline", "ext-value"]},
      "ext-type": {"type": "string"},
      "EmailTo": {"type": "string"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1}},
    "required": ["EmailTo"],
    "additionalProperties": false},
  "Telephone": {
    "type": "object",
    "properties": {
      "type": {
        "enum": ["wired", "mobile", "fax", "hotline",
          "ext-value"]},
      "ext-type": {"type": "string"},
      "TelephoneNumber": {"type": "string"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1}},
    "required": ["TelephoneNumber"],
    "additionalProperties": false},
  "Discovery": {
    "type": "object",
    "properties": {
      "source": {
        "enum": ["nidps", "hips", "siem", "av",
          "third-party-monitoring", "incident", "os-log",
          "application-log", "device-log", "network-flow",
          "passive-dns", "investigation", "audit",
          "internal-notification", "external-notification",
          "leo", "partner", "actor", "unknown", "ext-value"]},
      "ext-source": {"type": "string"},
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
      "Contact": {
        "type": "array",
        "items": {"$ref": "#/definitions/Contact"},
        "minItems": 1},
      "DetectionPattern": {
        "type": "array",
        "items": {"$ref": "#/definitions/DetectionPattern"},
        "minItems": 1}},
    "required": [],
    "additionalProperties": false},
  "DetectionPattern": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "observable-id": {"$ref": "#/definitions/IDtype"},
      "Application": {"$ref": "#/definitions/SoftwareType"},
      "Description": {

```



```

        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
    "DetectionConfiguration": {
        "type": "array",
        "items": {"type": "string"},
        "minItems": 1}},
    "allOf": [
        {"required": ["Application"]},
        {"oneOf": [
            {"required": ["Description"]},
            {"required": ["DetectionConfiguration"]}]}],
    "additionalProperties": false},
    "Method": {
        "type": "object",
        "properties": {
            "restriction": {"$ref": "#/definitions/restriction",
                            "default": "private"},
            "ext-restriction": {"type": "string"},
            "Reference": {
                "type": "array",
                "items": {"$ref": "#/definitions/Reference"},
                "minItems": 1},
            "Description": {
                "type": "array",
                "items": {"$ref": "#/definitions/MLStringType"},
                "minItems": 1},
            "AttackPattern": {
                "type": "array",
                "items": {"$ref": "#/definitions/STRUCTUREDINFO"},
                "minItems": 1},
            "Vulnerability": {
                "type": "array",
                "items": {"$ref": "#/definitions/STRUCTUREDINFO"},
                "minItems": 1},
            "Weakness": {
                "type": "array",
                "items": {"$ref": "#/definitions/STRUCTUREDINFO"},
                "minItems": 1},
            "AdditionalData": {
                "$ref": "#/definitions/ExtensionTypeList"}},
        "required": [],
        "additionalProperties": false},
    "Reference": {
        "type": "object",
        "properties": {
            "observable-id": {"$ref": "#/definitions/IDtype"},
            "ReferenceName": {
                "$ref": "#/definitions/ReferenceName"},
            "URL": {
                "type": "array",
                "items": {"$ref": "#/definitions/URLtype"},
                "minItems": 1},
            "Description": {
                "type": "array",
                "items": {"$ref": "#/definitions/MLStringType"},
                "minItems": 1}},
        "required": [],
        "additionalProperties": false},
    "ReferenceName": {
        "type": "object",
        "properties": {
            "specIndex": {"type": "number"},
            "ID": {"$ref": "#/definitions/IDtype"}},
        "required": ["specIndex", "ID"],
        "additionalProperties": false},

```

```

"Assessment": {
  "type": "object",
  "properties": {
    "occurrence": { "enum": ["actual", "potential"] },
    "restriction": { "$ref": "#/definitions/restriction",
      "default": "private" },
    "ext-restriction": { "type": "string" },
    "observable-id": { "$ref": "#/definitions/IDtype" },
    "IncidentCategory": {
      "type": "array",
      "items": { "$ref": "#/definitions/MLStringType" },
      "minItems": 1 },
    "Impact": {
      "type": "array",
      "items": {
        "properties": {
          "SystemImpact": {
            "$ref": "#/definitions/SystemImpact" },
          "BusinessImpact": {
            "$ref": "#/definitions/BusinessImpact" },
          "TimeImpact": { "$ref": "#/definitions/TimeImpact" },
          "MonetaryImpact": {
            "$ref": "#/definitions/MonetaryImpact" },
          "IntendedImpact": {
            "$ref": "#/definitions/BusinessImpact" } },
        "additionalProperties": false },
      "minItems": 1
    },
    "Counter": {
      "type": "array",
      "items": { "$ref": "#/definitions/Counter" },
      "minItems": 1 },
    "MitigatingFactor": {
      "type": "array",
      "items": { "$ref": "#/definitions/MLStringType" },
      "minItems": 1 },
    "Cause": {
      "type": "array",
      "items": { "$ref": "#/definitions/MLStringType" },
      "minItems": 1 },
    "Confidence": { "$ref": "#/definitions/Confidence" },
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList" },
    "required": ["Impact"],
    "additionalProperties": false },
  "SystemImpact": {
    "type": "object",
    "properties": {
      "severity": { "enum": ["low", "medium", "high"] },
      "completion": { "enum": ["failed", "succeeded"] },
      "type": {
        "enum": ["takeover-account", "takeover-service",
          "takeover-system", "cps-manipulation", "cps-damage",
          "availability-data", "availability-account",
          "availability-service", "availability-system",
          "damaged-system", "damaged-data",
          "breach-proprietary", "breach-privacy",
          "breach-credential", "breach-configuration",
          "integrity-data", "integrity-configuration",
          "integrity-hardware", "traffic-redirection",
          "monitoring-traffic", "monitoring-host",
          "policy", "unknown", "ext-value" ] },
      "ext-type": { "type": "string" },
      "Description": {
        "type": "array",
        "items": { "$ref": "#/definitions/MLStringType" },

```

```

        "minItems": 1}},
    "required": ["type"],
    "additionalProperties": false},
    "BusinessImpact": {
        "type": "object",
        "properties": {
            "severity": {"enum":["none", "low", "medium", "high",
                "unknown", "ext-value"], "default": "unknown"},
            "ext-severity": {"type":"string"},
            "type": {"enum":["breach-proprietary",
                "breach-privacy", "breach-credential",
                "loss-of-integrity", "loss-of-service",
                "theft-financial", "theft-service",
                "degraded-reputation", "asset-damage",
                "asset-manipulation", "legal", "extortion",
                "unknown", "ext-value"]},
            "ext-type": {"type": "string"},
            "Description": {
                "type": "array",
                "items": {"$ref": "#/definitions/MLStringType"},
                "minItems": 1}},
        "required": ["type"],
        "additionalProperties": false},
    "TimeImpact": {
        "type": "object",
        "properties": {
            "value": {"$ref": "#/definitions/PositiveFloatType"},
            "severity": {"enum": ["low", "medium", "high"]},
            "metric": {"enum": ["labor", "elapsed", "downtime",
                "ext-value"]},
            "ext-metric": {"type": "string"},
            "duration": {
                "$ref": "#/definitions/duration", "default": "hour"},
            "ext-duration": {"type": "string"}},
        "required": ["value", "metric"],
        "additionalProperties": false},
    "MonetaryImpact": {
        "type": "object",
        "properties": {
            "value": {"$ref": "#/definitions/PositiveFloatType"},
            "severity": {"enum":["low", "medium", "high"]},
            "currency": {"type": "string"}},
        "required": ["value"],
        "additionalProperties": false},
    "Confidence": {
        "type": "object",
        "properties": {
            "value": {"type": "number"},
            "rating": {"enum": ["low", "medium", "high", "numeric",
                "unknown", "ext-value"]},
            "ext-rating": {"type":"string"}},
        "required": ["value", "rating"],
        "additionalProperties": false},
    "History": {
        "type": "object",
        "properties": {
            "restriction": {"$ref": "#/definitions/restriction",
                "default": "private"},
            "ext-restriction": {"type": "string"},
            "HistoryItem": {
                "type": "array",
                "items": {"$ref": "#/definitions/HistoryItem"},
                "minItems": 1}},
        "required": ["HistoryItem"],
        "additionalProperties": false},
    "HistoryItem": {

```

```

"type": "object",
"properties": {
  "action": {
    "$ref": "#/definitions/action", "default": "other"},
  "ext-action": {"type": "string"},
  "restriction": {"$ref": "#/definitions/restriction",
    "default": "private"},
  "ext-restriction": {"type": "string"},
  "observable-id": {"$ref": "#/definitions/IDtype"},
  "DateTime": {"$ref": "#/definitions/DATETIME"},
  "IncidentID": {"$ref": "#/definitions/IncidentID"},
  "Contact": {"$ref": "#/definitions/Contact"},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1},
  "DefinedCOA": {
    "type": "array",
    "items": {"type": "string"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["DateTime", "action"],
  "additionalProperties": false},
"EventData": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "Description": {"type": "array",
      "items": {"$ref": "#/definitions/MLStringType"}},
    "DetectTime": {"$ref": "#/definitions/DATETIME"},
    "StartTime": {"$ref": "#/definitions/DATETIME"},
    "EndTime": {"$ref": "#/definitions/DATETIME"},
    "RecoveryTime": {"$ref": "#/definitions/DATETIME"},
    "ReportTime": {"$ref": "#/definitions/DATETIME"},
    "Contact": {
      "type": "array",
      "items": {"$ref": "#/definitions/Contact"},
      "minItems": 1},
    "Discovery": {
      "type": "array",
      "items": {"$ref": "#/definitions/Discovery"},
      "minItems": 1},
    "Assessment": {"$ref": "#/definitions/Assessment"},
    "Method": {
      "type": "array",
      "items": {"$ref": "#/definitions/Method"},
      "minItems": 1},
    "System": {
      "type": "array",
      "items": {"$ref": "#/definitions/System"},
      "minItems": 1},
    "Expectation": {
      "type": "array",
      "items": {"$ref": "#/definitions/Expectation"},
      "minItems": 1},
    "RecordData": {
      "type": "array",
      "items": {"$ref": "#/definitions/RecordData"},
      "minItems": 1},
    "EventData": {
      "type": "array",
      "items": {"$ref": "#/definitions/EventData"},

```

```

    "minItems": 1},
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList"}},
    "required": [],
    "additionalProperties": false},
  "Expectation": {
    "type": "object",
    "properties": {
      "action": {
        "$ref": "#/definitions/action", "default": "other"},
      "ext-action": {"type": "string"},
      "severity": {"enum": ["low", "medium", "high"]},
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "default"},
      "ext-restriction": {"type": "string"},
      "observable-id": {"$ref": "#/definitions/IDtype"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
      "DefinedCOA": {
        "type": "array",
        "items": {"type": "string"},
        "minItems": 1},
      "StartTime": {"$ref": "#/definitions/DATETIME"},
      "EndTime": {"$ref": "#/definitions/DATETIME"},
      "Contact": {"$ref": "#/definitions/Contact"}},
      "required": [],
      "additionalProperties": false},
  "System": {
    "type": "object",
    "properties": {
      "category": {
        "enum": ["source", "target", "intermediate", "sensor",
          "infrastructure", "ext-value"]},
      "ext-category": {"type": "string"},
      "interface": {"type": "string"},
      "spoofed": {
        "enum": ["unknown", "yes", "no"], "default": "unknown"},
      "virtual": {
        "enum": ["yes", "no", "unknown"], "default": "unknown"},
      "ownership": {
        "enum": ["organization", "personal", "partner",
          "customer", "no-relationship", "unknown",
          "ext-value"]},
      "ext-ownership": {"type": "string"},
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "observable-id": {"$ref": "#/definitions/IDtype"},
      "Node": {"$ref": "#/definitions/Node"},
      "NodeRole": {
        "type": "array",
        "items": {"$ref": "#/definitions/NodeRole"},
        "minItems": 1},
      "Service": {
        "type": "array",
        "items": {"$ref": "#/definitions/Service"},
        "minItems": 1},
      "OperatingSystem": {
        "type": "array",
        "items": {"$ref": "#/definitions/SoftwareType"},
        "minItems": 1},
      "Counter": {
        "type": "array",
        "items": {"$ref": "#/definitions/Counter"},

```

```

    "minItems": 1},
  "AssetID": {
    "type": "array",
    "items": {"type": "string"},
    "minItems": 1},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["Node"],
  "additionalProperties": false},
"Node": {
  "type": "object",
  "properties": {
    "DomainData": {
      "type": "array",
      "items": {"$ref": "#/definitions/DomainData"},
      "minItems": 1},
    "Address": {
      "type": "array",
      "items": {"$ref": "#/definitions/Address"},
      "minItems": 1},
    "PostalAddress": {
      "$ref": "#/definitions/PostalAddress"},
    "Location": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Counter": {
      "type": "array",
      "items": {"$ref": "#/definitions/Counter"},
      "minItems": 1}},
  "anyOf": [
    {"required": ["DomainData"]},
    {"required": ["Address"]}
  ],
  "additionalProperties": false},
"Address": {
  "type": "object",
  "properties": {
    "value": {"type": "string"},
    "category": {
      "enum": ["asn", "atm", "e-mail", "ipv4-addr", "ipv4-net",
        "ipv4-net-masked", "ipv4-net-mask", "ipv6-addr",
        "ipv6-net", "ipv6-net-masked", "mac", "site-uri",
        "ext-value"], "default": "ipv6-addr"},
    "ext-category": {"type": "string"},
    "vlan-name": {"type": "string"},
    "vlan-num": {"type": "number"},
    "observable-id": {"$ref": "#/definitions/IDtype"}},
  "required": ["value", "category"],
  "additionalProperties": false},
"NodeRole": {
  "type": "object",
  "properties": {
    "category": {
      "enum": ["client", "client-enterprise",
        "client-partner", "client-remote", "client-kiosk",
        "client-mobile", "server-internal", "server-public",
        "www", "mail", "webmail", "messaging", "streaming",
        "voice", "file", "ftp", "p2p", "name", "directory",
        "credential", "print", "application", "database",
        "backup", "dhcp", "assessment", "source-control",
        "config-management", "monitoring", "infra",

```

```

        "infra-firewall", "infra-router", "infra-switch",
        "camera", "proxy", "remote-access", "log",
        "virtualization", "pos", "scada",
        "scada-supervisory", "sinkhole", "honeypot",
        "anonymization", "c2-server", "malware-distribution",
        "drop-server", "hop-point", "reflector",
        "phishing-site", "spear-phishing-site",
        "recruiting-site", "fraudulent-site",
        "ext-value"]},
    "ext-category": {"type": "string"},
    "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1}},
    "required": ["category"],
    "additionalProperties": false},
"Counter": {
    "type": "object",
    "properties": {
        "value": {"type": "number"},
        "type": {
            "enum": ["count", "peak", "average", "ext-value"]},
        "ext-type": {"type": "string"},
        "unit": {"enum": ["byte", "mbit", "packet", "flow",
            "session", "alert", "message", "event", "host",
            "site", "organization", "ext-value"]},
        "ext-unit": {"type": "string"},
        "meaning": {"type": "string"},
        "duration": {
            "$ref": "#/definitions/duration", "default": "hour"},
        "ext-duration": {"type": "string"}},
    "required": ["value", "type", "unit"],
    "additionalProperties": false},
"DomainData": {
    "type": "object",
    "properties": {
        "system-status": {
            "enum": ["spoofed", "fraudulent", "innocent-hacked",
                "innocent-hijacked", "unknown", "ext-value"]},
        "ext-system-status": {"type": "string"},
        "domain-status": {
            "enum": [ "reservedDelegation", "assignedAndActive",
                "assignedAndInactive", "assignedAndOnHold",
                "revoked", "transferPending",
                "registryLock", "registrarLock",
                "other", "unknown", "ext-value"]},
        "ext-domain-status": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "Name": {"type": "string"},
        "DateDomainWasChecked": {
            "$ref": "#/definitions/DATETIME"},
        "RegistrationDate": {
            "$ref": "#/definitions/DATETIME"},
        "ExpirationDate": {"$ref": "#/definitions/DATETIME"},
        "RelatedDNS": {
            "type": "array",
            "items": {"$ref": "#/definitions/ExtensionType"},
            "minItems": 1},
        "NameServers": {
            "type": "array",
            "items": {"$ref": "#/definitions/NameServers"},
            "minItems": 1},
        "DomainContacts": {
            "$ref": "#/definitions/DomainContacts"}},
    "required": ["Name", "system-status", "domain-status"],
    "additionalProperties": false},

```

```

"NameServers": {
  "type": "object",
  "properties": {
    "Server": {"type": "string"},
    "Address": {
      "type": "array",
      "items": {"$ref": "#/definitions/Address"},
      "minItems": 1}},
    "required": ["Server", "Address"],
    "additionalProperties": false},
  "DomainContacts": {
    "type": "object",
    "properties": {
      "SameDomainContact": {"type": "string"},
      "Contact": {
        "type": "array",
        "items": {"$ref": "#/definitions/Contact"},
        "minItems": 1}},
      "oneOf": [
        {"required": ["SameDomainContact"]},
        {"required": ["Contact"]}],
      "additionalProperties": false},
    "Service": {
      "type": "object",
      "properties": {
        "ip-protocol": {"type": "number"},
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "ServiceName": {"$ref": "#/definitions/ServiceName"},
        "Port": {"type": "number"},
        "Portlist": {"$ref": "#/definitions/PortlistType"},
        "ProtoCode": {"type": "number"},
        "ProtoType": {"type": "number"},
        "ProtoField": {"type": "number"},
        "ApplicationHeaderField": {
          "$ref": "#/definitions/ExtensionTypeList"},
        "EmailData": {"$ref": "#/definitions/EmailData"},
        "Application": {
          "$ref": "#/definitions/SoftwareType"}},
        "required": [],
        "additionalProperties": false},
      "ServiceName": {
        "type": "object",
        "properties": {
          "IANAService": {"type": "string"},
          "URL": {
            "type": "array", "items": {
              "$ref": "#/definitions/URLtype"}},
            "Description": {
              "type": "array",
              "items": {"$ref": "#/definitions/MLStringType"},
              "minItems": 1}},
            "required": [],
            "additionalProperties": false},
          "EmailData": {
            "type": "object",
            "properties": {
              "observable-id": {"$ref": "#/definitions/IDtype"},
              "EmailTo": {
                "type": "array",
                "items": {"type": "string"},
                "minItems": 1},
              "EmailFrom": {"type": "string"},
              "EmailSubject": {"type": "string"},
              "EmailX-Mailer": {"type": "string"},
              "EmailHeaderField": {
                "type": "array",

```



```

    "items": {"$ref": "#/definitions/ExtensionType"},
    "minItems": 1},
  "EmailHeaders": {"type": "string"},
  "EmailBody": {"type": "string"},
  "EmailMessage": {"type": "string"},
  "HashData": {
    "type": "array",
    "items": {"$ref": "#/definitions/HashData"},
    "minItems": 1},
  "Signature": {
    "type": "array",
    "items": {"$ref": "#/definitions/BYTE"},
    "minItems": 1}},
  "required": [],
  "additionalProperties": false},
"RecordData": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "DateTime": {"$ref": "#/definitions/DATETIME"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Application": {"$ref": "#/definitions/SoftwareType"},
    "RecordPattern": {
      "type": "array",
      "items": {"$ref": "#/definitions/RecordPattern"},
      "minItems": 1},
    "RecordItem": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "FileData": {
      "type": "array",
      "items": {"$ref": "#/definitions/FileData"},
      "minItems": 1},
    "WindowsRegistryKeysModified": {
      "type": "array",
      "items": {
        "$ref": "#/definitions/WindowsRegistryKeysModified"},
      "minItems": 1},
    "CertificateData": {
      "type": "array",
      "items": {"$ref": "#/definitions/CertificateData"},
      "minItems": 1},
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList"}},
    "required": [],
    "additionalProperties": false},
  "RecordPattern": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "type": {
        "enum": ["regex", "binary", "xpath", "ext-value"],
        "default": "regex"},
      "ext-type": {"type": "string"},
      "offset": {"type": "number"},

```

```

    "offsetunit": {"enum":["line", "byte", "ext-value"] ,
                  "default": "line"},
    "ext-offsetunit": {"type": "string"},
    "instance": {"type": "number"}},
    "required": ["value", "type"],
    "additionalProperties": false},
"WindowsRegistryKeysModified": {
    "type": "object",
    "properties": {
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "Key": {
            "type": "array",
            "items": {"$ref": "#/definitions/Key"},
            "minItems": 1}},
        "required": ["Key"],
        "additionalProperties": false},
"Key": {
    "type": "object",
    "properties": {
        "registryaction": {"enum": ["add-key", "add-value",
                                    "delete-key", "delete-value",
                                    "modify-key", "modify-value",
                                    "ext-value"]},
        "ext-registryaction": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "KeyName": {"type": "string"},
        "KeyValue": {"type": "string"}},
        "required": ["KeyName"],
        "additionalProperties": false},
"CertificateData": {
    "type": "object",
    "properties": {
        "restriction": {"$ref": "#/definitions/restriction",
                        "default": "private"},
        "ext-restriction": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "Certificate": {
            "type": "array",
            "items": {"$ref": "#/definitions/Certificate"},
            "minItems": 1}},
        "required": ["Certificate"],
        "additionalProperties": false},
"Certificate": {
    "type": "object",
    "properties": {
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "X509Data": {"$ref": "#/definitions/BYTE"},
        "Description": {
            "type": "array",
            "items": {"$ref": "#/definitions/MLStringType"},
            "minItems": 1}},
        "required": ["X509Data"],
        "additionalProperties": false},
"FileData": {
    "type": "object",
    "properties": {
        "restriction": {"$ref": "#/definitions/restriction"},
        "ext-restriction": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDtype"},
        "File": {
            "type": "array",
            "items": {"$ref": "#/definitions/File"},
            "minItems": 1}},
        "required": ["File"],
        "additionalProperties": false},
"File": {

```

```

"type": "object",
"properties": {
  "observable-id": {"$ref": "#/definitions/IDtype"},
  "FileName": {"type": "string"},
  "FileSize": {"type": "number"},
  "FileType": {"type": "string"},
  "URL": {
    "type": "array",
    "items": {"$ref": "#/definitions/URLtype"},
    "minItems": 1},
  "HashData": {"$ref": "#/definitions/HashData"},
  "Signature": {
    "type": "array",
    "items": {"$ref": "#/definitions/BYTE"},
    "minItems": 1},
  "AssociatedSoftware": {
    "$ref": "#/definitions/SoftwareType"},
  "FileProperties": {
    "type": "array",
    "items": {"$ref": "#/definitions/ExtensionType"},
    "minItems": 1}},
"required": [],
"additionalProperties": false},
"HashData": {
  "type": "object",
  "properties": {
    "scope": {"enum": ["file-contents", "file-pe-section",
      "file-pe-iat", "file-pe-resource", "file-pdf-object",
      "email-hash", "email-headers-hash", "email-body-hash",
      "ext-value"]},
    "HashTargetID": {"type": "string"},
    "Hash": {
      "type": "array",
      "items": {"$ref": "#/definitions/Hash"},
      "minItems": 1},
    "FuzzyHash": {
      "type": "array",
      "items": {"$ref": "#/definitions/FuzzyHash"},
      "minItems": 1}},
  "required": ["scope"],
  "additionalProperties": false},
"Hash": {
  "type": "object",
  "properties": {
    "DigestMethod": {"$ref": "#/definitions/BYTE"},
    "DigestValue": {"$ref": "#/definitions/BYTE"},
    "CanonicalizationMethod": {
      "$ref": "#/definitions/BYTE"},
    "Application": {
      "$ref": "#/definitions/SoftwareType"}},
  "required": ["DigestMethod", "DigestValue"],
  "additionalProperties": false},
"FuzzyHash": {
  "type": "object",
  "properties": {
    "FuzzyHashValue": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1},
    "Application": {"$ref": "#/definitions/SoftwareType"},
    "AdditionalData": {
      "$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["FuzzyHashValue"],
  "additionalProperties": false},
"Indicator": {
  "type": "object",

```

```

"properties": {
  "restriction": {"$ref": "#/definitions/restriction",
    "default": "private"},
  "ext-restriction": {"type": "string"},
  "IndicatorID": {"$ref": "#/definitions/IndicatorID"},
  "AlternativeIndicatorID": {
    "type": "array",
    "items": {
      "$ref": "#/definitions/AlternativeIndicatorID"},
    "minItems": 1},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1},
  "StartTime": {"$ref": "#/definitions/DATETIME"},
  "EndTime": {"$ref": "#/definitions/DATETIME"},
  "Confidence": {"$ref": "#/definitions/Confidence"},
  "Contact": {
    "type": "array",
    "items": {"$ref": "#/definitions/Contact"},
    "minItems": 1},
  "Observable": {"$ref": "#/definitions/Observable"},
  "uid-ref": {"$ref": "#/definitions/IDREFType"},
  "IndicatorExpression": {
    "$ref": "#/definitions/IndicatorExpression"},
  "IndicatorReference": {
    "$ref": "#/definitions/IndicatorReference"},
  "NodeRole": {
    "type": "array",
    "items": {"$ref": "#/definitions/NodeRole"},
    "minItems": 1},
  "AttackPhase": {
    "type": "array",
    "items": {"$ref": "#/definitions/AttackPhase"},
    "minItems": 1},
  "Reference": {
    "type": "array",
    "items": {"$ref": "#/definitions/Reference"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
"allof": [
  {"required": ["IndicatorID"]},
  {"oneOf": [
    {"required": ["Observable"]},
    {"required": ["uid-ref"]},
    {"required": ["IndicatorExpression"]},
    {"required": ["IndicatorReference"]}]}],
"additionalProperties": false},
"IndicatorID": {
  "type": "object",
  "properties": {
    "id": {"type": "string"},
    "name": {"type": "string"},
    "version": {"type": "string"}},
  "required": ["id", "name", "version"],
  "additionalProperties": false},
"AlternativeIndicatorID": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "IndicatorID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IndicatorID"},

```

```

    "minItems": 1}},
    "required": ["IndicatorID"],
    "additionalProperties": false},
  "Observable": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "System": {"$ref": "#/definitions/System"},
      "Address": {"$ref": "#/definitions/Address"},
      "DomainData": {"$ref": "#/definitions/DomainData"},
      "EmailData": {"$ref": "#/definitions/EmailData"},
      "Service": {"$ref": "#/definitions/Service"},
      "WindowsRegistryKeysModified": {
        "$ref": "#/definitions/WindowsRegistryKeysModified"},
      "FileData": {"$ref": "#/definitions/FileData"},
      "CertificateData": {
        "$ref": "#/definitions/CertificateData"},
      "RegistryHandle": {
        "$ref": "#/definitions/RegistryHandle"},
      "RecordData": {"$ref": "#/definitions/RecordData"},
      "EventData": {"$ref": "#/definitions/EventData"},
      "Incident": {"$ref": "#/definitions/Incident"},
      "Expectation": {"$ref": "#/definitions/Expectation"},
      "Reference": {"$ref": "#/definitions/Reference"},
      "Assessment": {"$ref": "#/definitions/Assessment"},
      "DetectionPattern": {
        "$ref": "#/definitions/DetectionPattern"},
      "HistoryItem": {"$ref": "#/definitions/HistoryItem"},
      "BulkObservable": {
        "$ref": "#/definitions/BulkObservable"},
      "AdditionalData": {
        "$ref": "#/definitions/ExtensionTypeList"}},
      "oneOf": [
        {"required": ["System"]},
        {"required": ["Address"]},
        {"required": ["DomainData"]},
        {"required": ["EmailData"]},
        {"required": ["Service"]},
        {"required": ["WindowsRegistryKeysModified"]},
        {"required": ["FileData"]},
        {"required": ["CertificateData"]},
        {"required": ["RegistryHandle"]},
        {"required": ["RecordData"]},
        {"required": ["EventData"]},
        {"required": ["Incident"]},
        {"required": ["Expectation"]},
        {"required": ["Reference"]},
        {"required": ["Assessment"]},
        {"required": ["DetectionPattern"]},
        {"required": ["HistoryItem"]},
        {"required": ["BulkObservable"]},
        {"required": ["AdditionalData"]}]],
      "additionalProperties": false},
    "BulkObservable": {
      "type": "object",
      "properties": {
        "type": {"enum": ["asn", "atm", "e-mail", "ipv4-addr",
          "ipv4-net", "ipv4-net-mask", "ipv6-addr", "ipv6-net",
          "ipv6-net-mask", "mac", "site-uri", "domain-name",
          "domain-to-ipv4", "domain-to-ipv6",
          "domain-to-ipv4-timestamp",
          "domain-to-ipv6-timestamp", "ipv4-port", "ipv6-port",
          "windows-reg-key", "file-hash", "email-x-mailer",
          "email-subject", "http-user-agent"],

```

```

        "http-request-url", "mutex", "file-path", "user-name",
        "ext-value"]},
    "ext-type": {"type": "string"},
    "BulkObservableFormat": {
        "$ref": "#/definitions/BulkObservableFormat"},
    "BulkObservableList": {"type": "string"},
    "AdditionalData": {
        "$ref": "#/definitions/ExtensionTypeList"}},
    "required": ["BulkObservableList"],
    "additionalProperties": false},
    "BulkObservableFormat": {
        "type": "object",
        "properties": {
            "Hash": {"$ref": "#/definitions/Hash"},
            "AdditionalData": {
                "$ref": "#/definitions/ExtensionTypeList"}},
        "oneOf": [
            {"required": ["Hash"]},
            {"required": ["AdditionalData"]}
        ],
        "additionalProperties": false},
    "IndicatorExpression": {
        "type": "object",
        "properties": {
            "operator": {
                "enum": ["not", "and", "or", "xor"], "default": "and"},
            "ext-operator": {"type": "string"},
            "IndicatorExpression": {
                "type": "array",
                "items": {
                    "$ref": "#/definitions/IndicatorExpression"},
                "minItems": 1},
            "Observable": {
                "type": "array",
                "items": {"$ref": "#/definitions/Observable"},
                "minItems": 1},
            "uid-ref": {
                "type": "array",
                "items": {"$ref": "#/definitions/IDREFTType"},
                "minItems": 1},
            "IndicatorReference": {
                "type": "array",
                "items": {
                    "$ref": "#/definitions/IndicatorReference"},
                "minItems": 1},
            "Confidence": {"$ref": "#/definitions/Confidence"},
            "AdditionalData": {
                "$ref": "#/definitions/ExtensionTypeList"}},
        "required": [],
        "additionalProperties": false},
    "IndicatorReference": {
        "type": "object",
        "properties": {
            "uid-ref": {"$ref": "#/definitions/IDREFTType"},
            "euid-ref": {"type": "string"},
            "version": {"type": "string"}},
        "oneOf": [
            {"required": ["uid-ref"]},
            {"required": ["euid-ref"]}
        ],
        "additionalProperties": false},
    "AttackPhase": {
        "type": "object",
        "properties": {
            "AttackPhaseID": {
                "type": "array",

```

```

    "items": {"type": "string"},
    "minItems": 1},
  "URL": {
    "type": "array",
    "items": {"$ref": "#/definitions/URLtype"},
    "minItems": 1},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false}},
"title": "IODEF-Document",
"description": "JSON schema for IODEF-Document class",
"type": "object",
"properties": {
  "version": {"type": "string"},
  "lang": {"$ref": "#/definitions/lang"},
  "format-id": {"type": "string"},
  "private-enum-name": {"type": "string"},
  "private-enum-id": {"type": "string"},
  "Incident": {
    "type": "array",
    "items": {"$ref": "#/definitions/Incident"},
    "minItems": 1},
  "AdditionalData": {
    "$ref": "#/definitions/ExtensionTypeList"}},
"required": ["version", "Incident"],
"additionalProperties": false}

```

Figure 6: JSON Schema

## Acknowledgments

We would like to thank Henk Birkholz, Carsten Bormann, Benjamin Kaduk, Alexey Melnikov, Yasuaki Morita, and Takahiko Nagata for their insightful comments on this document and CDDL.

## Authors' Addresses

Takeshi Takahashi  
 National Institute of Information and Communications Technology  
 4-2-1 Nukui-Kitamachi, Koganei, Tokyo  
 184-8795  
 Japan

Phone: +81 42 327 5862  
 Email: takeshi\_takahashi@nict.go.jp

Roman Danyliw  
 CERT, Software Engineering Institute, Carnegie Mellon University  
 4500 Fifth Avenue  
 Pittsburgh, PA  
 United States of America

Email: rdd@cert.org

Mio Suzuki  
 National Institute of Information and Communications Technology  
 4-2-1 Nukui-Kitamachi, Koganei, Tokyo  
 184-8795  
 Japan

Email: [mio@nict.go.jp](mailto:mio@nict.go.jp)