Defence Research and Development Canada
Recherche et développement pour la défense Canada

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A specification for describing space-based ISR collection assets

Definitions, documentation, and application to mission planning software

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Defence Research and Development Canada
Reference Document
DRDC-RDDC-2018-D168
January 2019

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IMPORTANT INFORMATIVE STATEMENTS

Endorsement statement: This publication has been published by the Editorial Office of Defence Research and Development Canada, an agency of the Department of National Defence of Canada. Inquiries can be sent to: Publications.DRDC-RDDC@drdc-rddc.gc.ca.

Abstract

The Commercial Satellite Imagery Acquisition Planning System (CSIAPS), developed by Defence Research and Development Canada (DRDC), is a Research and Development (R&D) prototype system for multi-satellite collection planning and simulation. The database of collection assets in CSIAPS is formatted according to the Collection Asset Specification (CAS) data structure presented in this document. The CAS was developed to provide a common framework and database for describing remote sensing collection assets as well as the relationships between these assets. The CAS database, developed as a service on a service-oriented architecture, holds multiple technical parameters (e.g., spatial resolution, swath width, and polarization options) and administrative parameters (e.g., cost, lead time, latency, and license) for constellations, satellites, sensors, and data, as well as for the satellite owners and operators. The underlying data model for the CAS is designed to be sensor-agnostic, in order to hold information on a wide range of collection assets.

The objective of this report is to describe the development of the CAS data structure as well as document all of the parameters that the CAS contains. The overall data structure and its implementation as a graph-based knowledge ontology are discussed, and definitions for all of the nodes and property parameters in the CAS data structure are provided. The CAS is shown to provide machine interpretable definitions of key concepts in remote sensing, in addition to facilitating interoperability and sharing with partners through standardization of terminology. This work facilitated the migration of CSIAPS to a service-oriented architecture that can be accessed externally by other users and applications.

Significance for defence and security

Potential benefits of this work for the Canadian Armed Forces (CAF) include: increased quality and quantity of remote sensing opportunities; improved intelligence sharing, by having a data structure that can be exchanged as well as database that allies and partners can access; better discovery of asset cross-cueing opportunities; and lower overall cost, through the ability to choose lower-cost or free imagery that may also suit the task. Additionally, DRDC plans to share the CAS data model and the underlying database with the CAF and partner organizations through existing projects and ongoing agreements, thereby increasing interoperability among partners in the space-based Intelligence, Surveillance, and Reconnaissance (ISR) domain.

Résumé

Le Système de planification d'acquisition d'images de satellites commerciaux (SPAISC), conçu par Recherche et développement pour la défense Canada (RDDC), est un prototype de système de Recherche et développement (R&D) conçu pour la planification et la simulation de collectes multi-satellite. La base de données des ressources de collecte dans SPAISC est formatée conformément à la structure de données pour la spécification des ressources de collecte (SRC) présentée dans ce document, qui a été développée pour fournir un cadre commun et une base de données commune permettant de décrire les ressources de collecte de télédétection ainsi que les relations entre ces ressources. La base de données SRC, développée comme un service sur une architecture orientée service, contient plusieurs paramètres techniques (résolution spatiale, largeur de bande et options de polarisation, par exemple) et administratifs (coût, délai, latence et licence) pour les constellations, les satellites, les capteurs et les données, ainsi que pour les propriétaires et les opérateurs de satellites. Le modèle de données sous-jacent de la SRC est conçue pour être agnostique envers le type de capteur, afin de stocker des informations sur un large éventail de ressources de collecte.

L'objectif de ce rapport est de décrire le développement de la structure de données de la SRC et de documenter tous les paramètres que la SRC contient. La structure de données et son implémentation en tant qu'une ontologie de connaissances basée sur des graphes sont discutées, et des définitions pour tous les nœuds et paramètres de propriété de la structure de données de la SRC sont fournies. Il est également démontré que la SRC fournit des définitions interprétables par machine de concepts clés de la télédétection, en plus de faciliter l'interopérabilité et le partage d'information entre partenaires à travers la normalisation de la terminologie. Ce travail a facilité la migration du SPAISC vers une architecture orientée service accessible à l'externe par d'autres utilisateurs et applications.

Importance pour la défense et la sécurité

Les avantages potentiels pour les Forces armées canadiennes (FAC) comprennent : une augmentation dans la qualité et la quantité des opportunités de télédétection ; l'amélioration du partage des renseignements, grâce à une structure de données pouvant être échangée ainsi qu'une base de données accessible aux alliés et aux partenaires ; une meilleure façon de découvrir des opportunités de repérage croisé des ressources de collecte ; et des coûts nets moins élevés, grâce à la possibilité de choisir des images moins chères ou gratuites. De plus, RDDC partagera le modèle de données de la SRC et la base de données qui lui est associée avec les FAC et ses partenaires à travers des projets actuels et des ententes courantes, améliorant ainsi l'interopérabilité entre partenaires dans le domaine du renseignement, de la surveillance et de la reconnaissance (RSR) de l'espace.

Table of contents

Abstract . . . i

Significance for defence and security . . . i

Résumé . . . ii

Importance pour la défense et la sécurité . . . ii

Table of contents . . . iii

List of figures . . . viii

List of tables . . . ix

List of acronyms . . . x

Acknowledgements . . . xiii

1 Introduction . . . 1

2 Overall specification for the CAS data structure . . . 2

3 Collection Asset (CA) / Ressource de collecte (RC) . . . 6

3.1 CA Name / Nom de la RC . . . 6

3.2 Composition Tangibility / Tangibilité de la composition . . . 6

3.3 CA Exact Repeat Cycle / Cycle de répétition exacte de la RC . . . 7

3.4 CA Nominal Altitude / Altitude nominale de la RC . . . 7

4 Collection Asset Platform (CAP) / Plateforme de la ressource de collecte (PRC) 8

4.1 CAP Name / Nom de la PRC . . . 8

4.2 CAP Type / Type de PRC . . . 9

4.3 Catalogue Number / Numéro de catalogue . . . 9

4.4 Affiliation . . . 9

4.5 Operating Environment / Environnement opérationnel . . . 10

5 Service Provider / Fournisseur 10
5.1 Vendor / Vendeur 10
5.1.1 Name / Nom 10
5.1.2 Country / Pays 10
5.1.3 Alliance 11
5.2 Latency / Latence 11
5.3 Lead Time / Temps requis 11
6 Collection Asset Platform Operating Condition (CAPOC) / Condition opérationnelle de la plateforme de la ressource de collecte (COPRC) 12
6.1 CAPOC Exact Repeat Cycle / Cycle de répétition exacte de la COPRC . 12
6.2 CAPOC Nominal Altitude / Altitude nominale de la COPRC 12
6.3 Operating Status / Statut opérationnel 13
6.4 Duty Cycle / Cycle de service 13
6.5 Nominal Orbital Period / Période orbitale nominale 14
7 Sensor / Capteur 14
7.1 Sensor Name / Nom du capteur 14
7.2 Sensor Type / Type de capteur 15
7.3 Sensor Class / Classe du capteur 15
8 Sensing Device / Dispositif du capteur 16
8.1 Orientability / Orientabilité 16
8.2 Antenna Look Direction / Direction de regard de l’antenne 16
8.2.1 Squint / Mésalignement 17
9 Spectral Band / Bande spectrale 18
9.1 Band Name / Nom de la bande 18
9.2 Band Number / Numéro de la bande 19

9.3 Ground Sample Distance at Nadir / Distance inter-échantillon au sol au nadir 19

9.4 Frequency and Wavelength / Fréquence et longueur d'onde 19

10 Sensor Operating Condition (SOC) / Condition d'opération du capteur (COC) . . 20

10.1 Swath Size at Nadir / Grandeur du couloir au nadir 21

10.1.1 Length / Longueur 21

10.1.2 Width / Largeur 22

10.1.3 Aspect Ratio / Rapport de cadrage 22

10.2 Maximum Off-Nadir Angle / Angle maximale hors-nadir 23

10.3 Angle Range / Portée de l'angle 23

11 Sensor Operating Mode (SOM) / Mode d'opération du capteur (MOC) 23

11.1 Sensor On Time / Temps d'activité du capteur 24

11.2 Stereo Level / Niveau stéréo 24

11.3 Nominal Scene Size / Grandeur nominale de la scène 25

11.4 Polarization Mode / Mode de polarisation 25

11.4.1 Polarization Options / Options de polarisation 26

11.5 Maximum Azimuth Scene Size for Swath Oriented Product / Grandeur maximale en azimut de la scène pour un produit orienté en couloir 26

12 Sensor Operating Mode Position (SOMP) / Position du mode d'opération du capteur (PMOC) 27

13 Common Sensor Properties / Propriétés communes du capteur 27

13.1 SOC/SOM/SOMP Name / Nom du/de la COC/MOC/PMOC 27

13.2 SOC/SOM/SOMP Model Name / Nom du modèle du/de la COC/MOC/PMOC 28

13.3 SOC/SOM/SOMP Nominal Incidence Angle / Angle d'incidence nominal du/de la COC/MOC/PMOC 28

13.3.1 SOC/SOM/SOMP Cone Angle / Angle du cône du/de la COC/MOC/PMOC . . . 28
13.4 SOC/SOM/SOMP Clock Angle / Angle en horloge du/de la COC/MOC/PMOC . . . 29
14 Sensor Product (SP) / Produit du capteur (PC) . . . 29
14.1 Product Type / Type de produit . . . 30
14.1.1 Product Type Name / Nom du type de produit . . . 30
14.1.2 Geolocation Accuracy Without Ground Control Points / Précision de la géo-location sans points de contrôle terrestre . . . 30
14.1.3 Complex or Detected Data / Données complexes ou détectées . . . 30
14.1.4 Number of Looks / Nombre de regards . . . 31
14.1.5 Maximum Nominal Pixel Spacing / Espace nominale maximale entre pixels . . . 31
14.2 NIIRS . . . 31
14.2.1 Rating / Cote . . . 32
14.2.2 Scale / Échelle . . . 32
14.3 SP Nominal Incidence Angle / Angle d'incidence nominal du PC . . . 32
14.4 Nominal Resolution / Résolution nominale . . . 33
14.5 Polarization Mode / Mode de polarisation . . . 33
15 License / Licence . . . 33
15.1 License Type / Type de licence . . . 33
15.2 Cost per Scene / Coût par scène . . . 34
15.3 Currency / Devise . . . 34
16 Ship Detectability (SD) / Détectabilité des navires (DN) . . . 34
16.1 SD Angle / Angle de DN . . . 34
16.2 SD Polarization / Polarisation de DN . . . 35

16.3 SD Beam Number / Numéro du faisceau de DN 35

16.4 Minimum Detectable Ship Length (MDSL) / Longueur minimale détectable de navire (LMDN) 35

17 Other Tables 36

17.1 Affiliations 36

17.2 Acronyms 37

18 Discussion 38

19 Conclusion 39

References 41

Annex A: Computing frequency and wavelength parameters for spectral bands . . . 43

Annex B: Standard spectral bands 47

List of figures

Figure 1: Collection asset specification graph with nodes (filled boxes), edges (labelled arrows representing relationships between nodes), and properties (text connected to nodes or other properties). The French version of this graph is in Figure 2. 4

Figure 2: Graphe pour la spécification d'une ressource de collecte avec des noeuds (boîtes remplies), arcs (flèches avec texte, qui représentent les relations entre noeuds) et propriétés (texte relié à des noeuds ou à d'autres propriétés). Version française de la figure 1. 5

List of tables

Table A.1: Sequence of steps for obtaining all frequency and wavelength quantities for each way of specifying a spectral band. The numbers provide the order in which to obtain the parameter, beginning with 1 for the two given parameters whose values are known, 2 for the parameters that can be obtained in one step from the two given values, 3 for parameters that can be obtained from the given values plus the values found in Step 2, and so on. In each step, the equation used is specified in parentheses. Note that specifying or computing one of f_{max} or λ_{min} gives the other via Equation A.10, and similarly for f_{min} and λ_{max} through Equation A.11; hence, these pairs of parameters are listed together in the table. 46

Table B.1: Standard spectral bands defined by the Institute of Electrical and Electronics Engineers (IEEE). 48

Table B.2: Standard spectral bands defined by the International Telecommunication Union (ITU). 48

Table B.3: Standard spectral bands defined by the North Atlantic Treaty Organization (NATO). The designation for band N or O is mostly used by the U.S. military and by the Supreme Allied Commander Atlantic (SACLANT). The band definitions in this table supersede the older NATO designations listed in Table B.4; both are retained in CSIAPS for compatibility purposes. 49

Table B.4: Standard spectral bands formerly defined by the North Atlantic Treaty Organization (NATO). These definitions have been superseded by the designations in Table B.3, but are retained here for compatibility purposes. 49

Table B.5: Standard spectral bands defined for broadcasting by the European Union (EU). 50

Table B.6: Standard spectral bands defined for physical optics. Precise thresholds for these bands vary in the literature but are generally close in value [1]. 50

List of acronyms

21AT	Twenty First Century Aerospace Technology
ABSEA	Advanced class B Satellite Enabled AIS
AIS	Automatic Identification System
APT	Acquisition Planning Tool
ASI	Agenzia Spaziale Italiana
C-band	Compromise between the S-band and the L-band
CA	Collection Asset
CAF	Canadian Armed Forces
CAP	Collection Asset Platform
CAPOC	Collection Asset Platform Operating Condition
CAS	Collection Asset Specification
CAVIS	Cloud, Aerosol, Vapour, Ice, and Snow
CHRIS	Compact High Resolution Imaging Spectrometer
CSA	Canadian Space Agency
CSIAPS	Commercial Satellite Imagery Acquisition Planning System
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DRDC	Defence Research and Development Canada
DSTL	Defence Science and Technology Laboratory
EEC	Enhanced Ellipsoid Corrected product
EHF	Extremely High Frequency
ELF	Extremely Low Frequency
EO/IR	Electro-Optical/Infrared
ESA	European Space Agency
Fine Res	Fine Resolution
Full Res	Full Resolution
FVEY	Five Eyes
GCP	Ground Control Point
GEC	Geocoded Ellipsoid Corrected product
GEOINT	Geospatial Intelligence
GC	Government of Canada
GRD	Ground Range, Multi-look, Detected
GSD	Ground Sample Distance
HF	High Frequency
High Res	High Resolution
HSI	Hyperspectral Imaging
IEEE	Institute of Electrical and Electronics Engineers
IFF	Identification of Friend-or-Foe
IPOE	Intelligence Preparation of the Operational Environment
ISO	International Organization for Standardization
ISR	Intelligence, Surveillance, and Reconnaissance
ISS	International Space Station
ITU	International Telecommunications Union

JAXA	Japan Aerospace Exploration Agency
K	Kurz band (German for “short”)
Ka	Kurz-above band
KARI	Korean Aerospace Research Institute
KGS	Kazakhstan Gharysh Sapary
Ku	Kurz-under band
L-band	Long Wave band
LF	Low Frequency
LWIR	Long-Wave Infrared
M3MSat	Maritime Monitoring and Messaging Microsatellite
MDA	MacDonald, Dettwiler and Associates Ltd.
MSL	Mean Sea Level
Med Res	Medium Resolution
MEST	Ministry of Education, Science and Technology
MF	Medium Frequency
MGD	Multi-look Ground-range Detected product
MOU	Memorandum of Understanding
MSI	Multispectral Imaging
MSSR	Maratime Satellite Surveillance Radar
MWIR	Medium-Wave Infrared
NATO	North Atlantic Treaty Organization
NIIRS	National Imagery Interpretability Rating Scale
NIR	Near Infrared
NMEA	National Marine Electronics Association
NMSO	National Master Standing Offer
NTS	Nanosat Tracking Ships
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land imager
PAN	Panchromatic
PanSharp	Pan-Sharpened
PNOTS	Programa Nacional de Observación de la Tierra por Satélite
PROBA	Project for On-Board Autonomy
R-2	RADARSAT-2
R&D	Research and Development
RCM	RADARSAT Constellation Mission
RFI	Request For Information
RSC	Responsive Space Capabilities
S-band	Short Wave band
SACLANT	Supreme Allied Commander Atlantic
SAR	Synthetic Aperature Radar
SCF	ScanSAR Fine product
SCN	ScanSAR Narrow product
SCS	ScanSAR Sampled product
SE	Spatially Enhanced product

SGX	SAR Georeferenced Extra product
SHF	Super High Frequency
SLC	Single Look Complex product
SLF	Super Low Frequency
SOC	Sensor Operating Condition
SOM	Sensor Operating Mode
SOMP	Sensor Operating Mode Position
SP	Sensor Product
SPA	Swath Planner Application
SSC	Single Look Slant Range Complex product
Std Res	Standard Resolution
SWIR	Short-Wave Infrared
THF	Tremendously High Frequency or Terahertz
TIR	Thermal Infrared
TIRS	Thermal Infrared Sensor
UHF	Ultra High Frequency
ULF	Ultra Low Frequency
UV	Ultraviolet
VHF	Very High Frequency
VID	Video
VIIRS	Visible Infrared Imaging Radiometer Suite
VIS	Visible Spectrum
VLF	Very Low Frequency
VNIR	Visible and Near Infrared
Wide Res	Wide Resolution
X-band	Cross band

Acknowledgements

The authors would like to thank Jean Berger, Katerina Biron, Nicolas Duclos-Hindie, Chantal Lessard, Frédéric Morin, and Dana Rakus for their assistance.

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1 Introduction

The Commercial Satellite Imagery Acquisition Planning System (CSIAPS), developed by Defence Research and Development Canada (DRDC), is a Research and Development (R&D) prototype system for multi-satellite collection planning and simulation. CSIAPS may be used for applications in space-based Intelligence, Surveillance and Reconnaissance (ISR); Geospatial Intelligence (GEOINT); and Intelligence Preparation of the Operational Environment (IPOE) [2, 3].

CSIAPS finds satellite coverage opportunities by combining a database of satellite platforms and their key parameters with orbital modelling software (STK or Orekit) and a graphical user interface that lets the user specify their imaging requirements. CSIAPS uses in-house developed models for Synthetic Aperture Radar (SAR), Electro-Optical/Infrared (EO/IR), Thermal IR (TIR) and Automatic Identification System (AIS) sensors on commercial and civilian satellites. These models were developed by DRDC using information available in the open literature [4, 5, 6, 7, 8].

It can be challenging to model Collection Assets (CAs) (i.e., the satellite-sensor combinations best suited to a specific Request For Information, RFI) appropriately, given the large number and variety of such assets, and the significant range in their capabilities. For example, there is a choice of:

- Sensor type (e.g., SAR, EO/IR, or AIS);
- Imaging geometry (oblique versus nadir, high or low incidence angle, ascending or descending orbit, etc.);
- Sensor operating mode (e.g., spatial resolution versus swath width, multispectral versus panchromatic);
- Various options for SAR data (e.g., complex or real-valued data, polarization, interferometry); and
- Cost and license, which can vary significantly between available collection assets and the data products they can generate.

For its guidance expert system, CSIAPS uses inference rules that encode expertise from subject matter experts, and makes use of the automated reasoning capabilities in WISDOM, which is DRDC's R&D prototype of an intelligence production support system. WISDOM assists analysts and decision makers in developing their belief, opinion, judgment or prediction about situations. In CSIAPS and WISDOM, the database of collection assets is formatted according to the Collection Asset Specification (CAS) data structure. The objective of the CAS is to develop a common framework and database for describing remote sensing collection assets as well as the relationships between these assets. The CAS database, developed as a service on a service-oriented architecture, holds multiple technical parameters (e.g., spatial resolution, swath width, and polarization options) and administrative parameters (e.g., cost, lead time, latency, and license) for constellations, satellites, sensors, and data, as well as for the satellite owners and operators. The underlying data model for the CAS is designed to be sensor-agnostic, in order to hold information on a wide range of collection assets. In addition to the imaging systems discussed above, such assets could include deck-mounted ship sensors, or Identification of Friend-or-Foe (IFF) sensors mounted on aircraft.

The objective of this report is to describe the CAS and document all of the parameters it contains. The structure of this report as follows:

- Section 2 describes the CAS data structure.
- Sections 3–16 provide definitions of the nodes and property parameters in the CAS data structure.
- Section 17 describes other data tables used in tandem with the CAS.
- Section 18 provides a short discussion.
- Section 19 provides a few concluding remarks.

2 Overall specification for the CAS data structure

The CAS parameters have a formal naming convention for the properties and relationships (i.e., the ontology) that are defined in the specification. These parameters are organized as a graph data structure with nodes, edges (specifying directionality, functionality, and relationships) and properties. The advantages of using a graph data structure is that non-obvious connections between nodes can be found using graph theory and tools; additionally, it allows properties of objects and relationships between objects to be specified more naturally [9].

Figures 1 and 2 show the graph for the complete CAS in English and in French, respectively. Key terminology and concepts related to the CAS graph are as follows:

- Key objects and concepts are represented with *nodes* (filled boxes);
- Relationships between nodes are captured with *edges* (labelled arrows); and
- Individual attributes of nodes are called *properties* (text connected to nodes or other properties).

Note that properties may qualify any object (not just nodes) in the WISDOM graph data structure that has been selected for the implementation of the CAS management service in CSIAPS [9]. For example, properties of properties (i.e., sub-properties) are possible, and properties can also qualify (i.e., be attached to) edges in the graph.

The CAS model may be viewed as a type of knowledge ontology, as it defines:

- *Controlled vocabulary*, referring to terms with a specific meaning (represented in the graph with the words associated with nodes and properties);
- *Taxonomy*, referring to the relationships and the hierarchy that exist between various terms in the controlled vocabulary (represented in the graph by edges); and
- *Data properties*, referring to the properties of elements of the taxonomy (represented in the graph by properties).

Most of the remainder of this document (Sections 3–16) is dedicated to defining and describing the controlled vocabulary associated with the nodes and properties in Figures 1 and 2. Additionally, Section 17 describes other data tables that are used in tandem with the CAS to provide additional information, but which are not part of the CAS itself.

Figure 1: Collection asset specification graph with nodes (filled boxes), edges (labelled arrows representing relationships between nodes), and properties (text connected to nodes or other properties). The French version of this graph is in Figure 2.

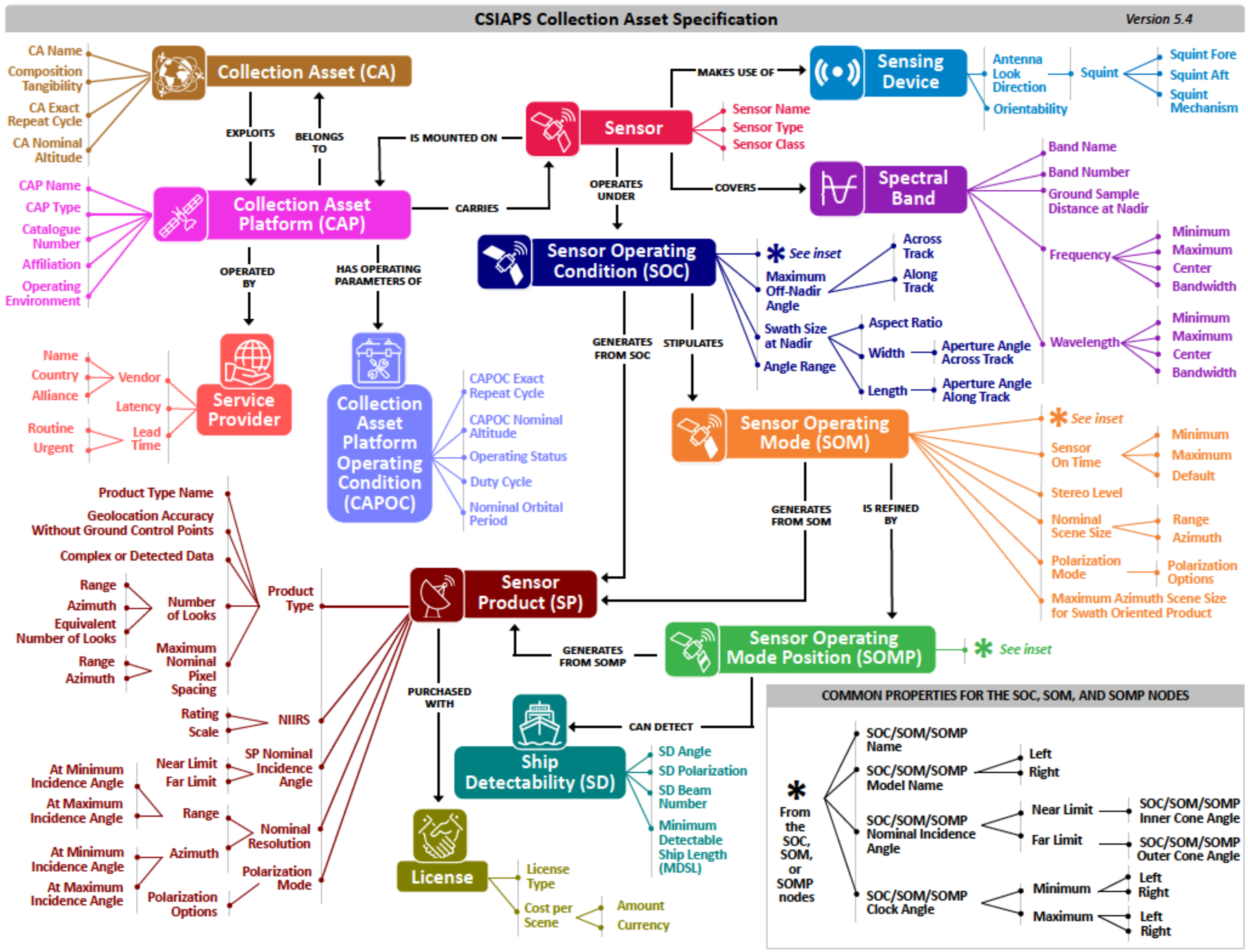
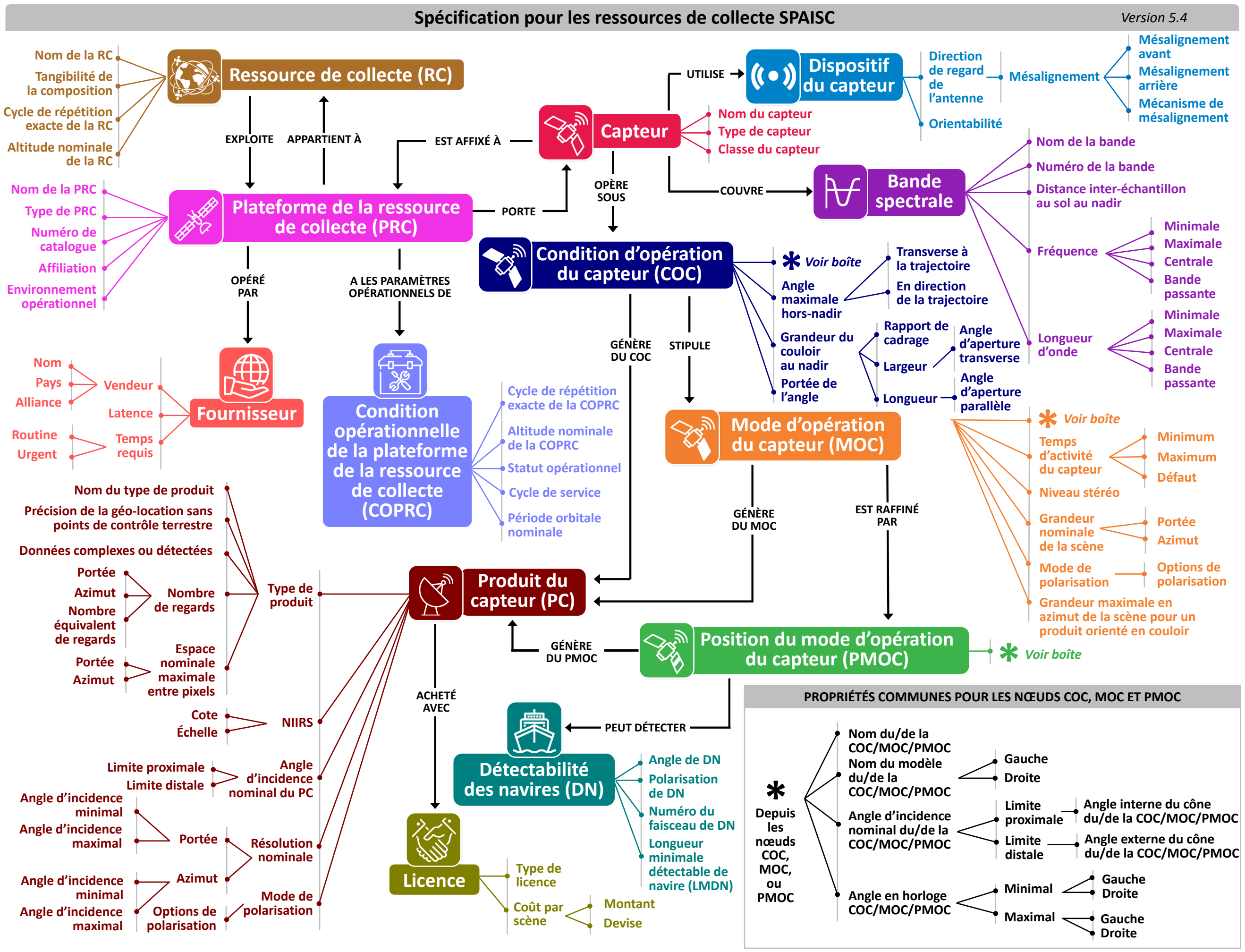


Figure 2: *Graphe pour la spécification d'une ressource de collecte avec des noeuds (boîtes remplies), arcs (flèches avec texte, qui représentent les relations entre noeuds) et propriétés (texte relié à des noeuds ou à d'autres propriétés). Version française de la figure 1.*



3 Collection Asset (CA) / Ressource de collecte (RC)

Collection Assets (CAs) are a central concept in CSIAPS, and can be thought of as a resource or a collection of resources that may be used to acquire intelligence. CAs are in turn formed of one or more Collection Asset Platforms (CAPs), which are defined in more detail in Section 4, page 8.

A CA node can have the following relationships:

- A CA may *exploit* a CAP; and
- A CAP may *belong to* a CA.

In the case of satellites, a CA might correspond to a constellation of satellites, while a CAP would correspond to an individual satellite in the constellation. The CA concept also extends to various types of CAPs, and indeed not all CAPs that belong to a CA need to be of the same type.

3.1 CA Name / Nom de la RC

Data type and units Text string

Constraints Must be non-empty and unique for each CA

Dependencies None

Sub-properties None

This property contains the name of the CA.

3.2 Composition Tangibility / Tangibilité de la composition

Data type and units Enumeration

Constraints Allowed values are: *Real*, *Vendor*, and *Virtual*; only applies to CAs that have CAPs with a Sensor of type SAR

Dependencies All other CAP properties (see description)

Sub-properties None

For CAs that contain only one CAP, the value of this property should be set to *real*. For CAs that contains multiple CAPs, this property describes the type of constellation that the CAPs form.

- In a real constellation, the CAPs that comprise it must have identical properties, except for their names and physical locations in orbit. In this case, it should not matter which CAP generates the requested sensor product, because all CAPs are considered to have identical sensors; in fact, it may not even be possible to request a specific CAP in a real constellation. The COSMO-SkyMed group of satellites are an example of this type of CA.
- A vendor-defined constellation is a set of CAPs operated by the same service provider, but which are different enough that they do not qualify as a real constellation in the sense defined previously. Often, it is the service provider that elects to refer to the CAPs as a constellation and chooses a name for the group, such as for marketing purposes. The WorldView group of satellites is an example of this type of constellation. This term could also apply to a previously real constellation in which the properties of one or more CAPs changes compared to the group, such as when a malfunction occurs in one satellite.
- A virtual constellation is any other grouping of CAPs that does not qualify as real or vendor-defined, including ad hoc constellations defined by users.

3.3 CA Exact Repeat Cycle / Cycle de répétition exacte de la RC

Data type and units Either a number (in days) or the text string *multi-valued*

Constraints If numeric, must be positive and non-zero; only applies to CAs with space-based CAPs (see Section 4.5, page 10)

Dependencies CAPOC Exact Repeat Cycle (see Section 6.1, page 12)

Sub-properties None

This property summarizes the repeat cycle of all CAPs within a CA. For CAs with one CAP, the value should be identical to the CAPOC Exact Repeat Cycle associated with the CA. If the CA contains multiple CAPs, then this property should be the same as their CAPOC Exact Repeat Cycle if this value is the same for all CAPs, and otherwise should be set to *multi-valued*.

3.4 CA Nominal Altitude / Altitude nominale de la RC

Data type and units Either a number (in kilometers) or the text string *multi-valued*

Constraints If numeric, must be positive and non-zero

Dependencies CAPOC Nominal Altitude (see Section 6.2, page 12)

Sub-properties None

This property summarizes the nominal altitude of all CAPs within a CA with respect to the Mean Sea Level (MSL). For CAs with one CAP, the value should be identical to the CAPOC Nominal Altitude associated with the CA. If the CA contains multiple CAPs, then this property should be the same as their CAPOC Nominal Altitude if this value is the same for all CAPs, and otherwise should be set to *multi-valued*.

4 Collection Asset Platform (CAP) / Plateforme de la ressource de collecte (PRC)

Collection Asset Platforms (CAPs) may be thought of as the smallest physically separable unit in a CA. A CAP may contain one or more sensors onboard, but typically these sensors cannot be physically separated from each other and must move as a unit. For example, in a constellation of satellites, a CAP refers to an individual satellite: the satellite may have more than one sensor on board, but all of these sensors must move as a group. Other examples of CAPs may include individual ships in a fleet, or an individual surveillance camera in a set of cameras.

A CAP node can have the following relationships:

- A CA (Section 3, page 6) *exploits* a CAP;
- A CAP *belongs to* a CA;
- A CAP may be *operated by* a Service Provider (Section 5, page 10);
- A CAP *has the operating parameters of* a CAP Operating Condition (CAPOC) node (Section 6, page 12);
- A CAP *carries* one or more Sensors (Section 7, page 14); and
- A Sensor *is mounted on* a CAP.

4.1 CAP Name / Nom de la PRC

Data type and units Text string

Constraints Must be non-empty and unique for each CAP

Dependencies CAPOC Nominal Altitude (see Section 6.2, page 12)

Sub-properties None

This property contains the name of the CAP.

4.2 CAP Type / Type de PRC

Data type and units Enumeration

Constraints Allowed values are: *Satellite*, *Aircraft*, and *UAV*

Dependencies None

Sub-properties None

This property describes the type of CAP. Possible types include satellites (objects in low-Earth orbit), aircraft (platforms mounted on manned aerial vehicles), and Unmanned Aerial Vehicles (UAVs) such as drones. The list of CAP types may expand in future versions of this specification.

4.3 Catalogue Number / Numéro de catalogue

Data type and units Numeric

Constraints Must be a valid entry in the catalogue of satellites maintained by USSPACECOM

Dependencies None

Sub-properties None

This property lists the unique satellite catalogue number associated with the CAP. The catalogue is maintained by USSPACECOM and was previously maintained by NORAD.

4.4 Affiliation

Data type and units Text string

Constraints The affiliations listed must match one of the names in the Affiliations table (see Section 17.1, page 36)

Dependencies All columns in the Affiliations table (see Section 17.1)

Sub-properties None

This property lists the primary stakeholders—typically government space agencies and satellite owner/operator companies—that are associated with a particular CAP. Multiple affiliations separated by commas may be listed. For example, the Sentinel-1 satellites are affiliated to the European Space Agency (ESA), and hence this property contains the single text string *ESA* for each platform in Sentinel-1. On the other hand, the CAP entry for RADARSAT-2 contains two affiliations listed as *CSA,MDA* where CSA stands for the Canadian Space Agency and MDA stands for MacDonald, Dettwiler and Associates Ltd. In all cases, each affiliation must correspond to one of the names in the Affiliations table described in Section 17.1.

4.5 Operating Environment / Environnement opérationnel

Data type and units Enumeration

Constraints Allowed values are: *Space*, *Air*, *Land*, *Water (surface)*, and *Water (underwater)*

Dependencies None

Sub-properties None

This property describes the type of environment that the CAP operates in. CSIAPS currently only supports space-based assets (for which the value of this property should be *Space*), but additional types may be supported in the future.

5 Service Provider / Fournisseur

This node describes a service provider that operates a particular CAP (see Section 4, page 8). Service Provider nodes may be associated to CAP nodes via an *operated by* relationship.

5.1 Vendor / Vendeur

This property provides information about the vendor operating the CAP, and has several sub-properties.

5.1.1 Name / Nom

Data type and units Text string

Constraints Must be non-empty and unique for each vendor entry

Dependencies None

Sub-properties None

This property contains the name of the vendor.

5.1.2 Country / Pays

Data type and units Text string

Constraints Must be a three-letter country code defined in the ISO 3166-1 standard

Dependencies None

Sub-properties None

This property contains the name of the country that the vendor is registered in or operates in; it should correspond to a three-letter “alpha-3” country code defined in the ISO 3166-1 standard.

5.1.3 Alliance

Data type and units Text string

Constraints None

Dependencies None

Sub-properties None

This property holds the name of the alliance to the vendor belongs. Multiple alliances may be listed, separated by commas. Common alliances of interest include:

- *ESA* for the European Space Agency;
- *FVEY* for the Five Eyes community; and
- *NATO* for organizations in countries that are members of the North Atlantic Treaty Organization (NATO).

5.2 Latency / Latence

Data type and units Numeric (in hours)

Constraints Must be positive or zero

Dependencies None

Sub-properties None

This property lists the service provider’s latency in hours, which refers to the time between when a target is imaged and the image is made available to the requestor. Note that this is distinct from lead time, which is defined in Section 5.3.

5.3 Lead Time / Temps requis

Data type and units Numeric (in hours)

Constraints Must be positive or zero

Dependencies None

Sub-properties *Routine*, *Urgent*

This property lists the service provider's lead time in hours. This refers to the minimum amount of advance notice that the service provider needs to act on an imaging request. For example, a lead time of 6 hours would mean that a request to image a target at 8 PM should be placed no later than 2 PM.

The Routine sub-property should contain the typical lead time of the service provider, while the Urgent sub-property provides space to enter a shorter lead time for more urgent requests if the service provider supports this capability (otherwise, the Urgent time should be set to the same value as the Routine time). Note that in some cases, a more urgent request may involve trade-offs such as increased cost or less choice of imaging modes.

6 Collection Asset Platform Operating Condition (CAPOC) / Condition opérationnelle de la plateforme de la ressource de collecte (COPRC)

This node contains various operating parameters that are associated to a particular CAP (see Section 4, page 8). CAPOC nodes are associated to CAP nodes via a *has operating parameters of* relationship.

6.1 CAPOC Exact Repeat Cycle / Cycle de répétition exacte de la COPRC

Data type and units Numeric (in days)

Constraints Must be positive and non-zero; only applies to CAPs of type *SAR* (see Section 4.2, page 9)

Dependencies None

Sub-properties None

The exact repeat cycle describes how long it takes a CAP to travel along one closed loop of its path and return to its starting point, whereupon it may image the same target under the exact same coherent illumination conditions. This value is useful for determining when it is next possible to image a target with exactly the same perspective, although in many cases, it is possible to image all or part of a target from a different perspective well before the exact repeat cycle. This parameter only applies to CAPs of the SAR type, which carry their own coherent illumination source.

6.2 CAPOC Nominal Altitude / Altitude nominale de la COPRC

Data type and units Numeric (in kilometers)

Constraints Must be positive and non-zero

Dependencies None

Sub-properties None

This property provides a nominal (average) value for the altitude of the CAP, relative to the Mean Sea Level (MSL). Note that the exact value of the altitude may vary due to other factors. For example, in the case of a satellite, the exact altitude is affected by local elevation, atmospheric drag, as well as how often and when the satellite operator chooses to boost the satellite.

6.3 Operating Status / Statut opérationnel

Data type and units Enumeration

Constraints Allowed values are: *Not launched*, *In commissioning*, *Operational*, *Temporarily unavailable*, and *Decommissioned*

Dependencies None

Sub-properties None

This property provides describes the status of the CAP in its life cycle. Possible values include:

- *Not launched* for platforms that are planned but not yet launched (such as RCM as of 2018);
- *In commissioning* for platforms that have just been launched and are being prepared for operational use;
- *Operational* for platforms that are available for remote sensing tasks and are operating normally;
- *Temporarily unavailable* for platforms that are currently non-operational (e.g. technical problems), but which are expected to become operational again in the future; and
- *Decommissioned* for platforms that were once operational, but are no longer available and will not be resuming operations in the future.

6.4 Duty Cycle / Cycle de service

Data type and units Numeric (in minutes)

Constraints Must be positive, non-zero, and not greater than the Nominal Orbital Period (see Section 6.5)

Dependencies Nominal Orbital Period (Section 6.5)

Sub-properties None

This property lists the duty cycle of the CAP, which refers to the amount of time that image acquisition can be performed during given period. In the case of a satellite, this corresponds to the number of minutes per orbit during which it is possible to image a target. This value cannot exceed the Nominal Orbital Period in Section 6.5.

6.5 Nominal Orbital Period / Période orbitale nominale

Data type and units Numeric

Constraints Must be positive, non-zero, and not less than the Duty Cycle (see Section 6.4)

Dependencies Duty Cycle (Section 6.4)

Sub-properties None

This property describes the time required to complete one orbit in the case of a satellite. For other CAPs that travel two or more times along a fixed, closed path, this may refer to the time taken to complete one loop of the path.

In the case of a satellite, this value cannot be less than the Duty Cycle in Section 6.4.

7 Sensor / Capteur

Sensors correspond to individual devices or instruments mounted on a CAP (see Section 4, page 8). A CAP may contain multiple sensors that each offer different imaging capabilities, but which all move as a group since they are part of the same physical platform. Sensor nodes may thus be related to CAP nodes via the following relationships:

- A CAP *carries* a Sensor (one or more); and
- A Sensor *is mounted on* a CAP.

7.1 Sensor Name / Nom du capteur

Data type and units Text string

Constraints Must be non-empty and unique for each sensor

Dependencies None

Sub-properties None

This property contains the name of the sensor. When a CAP contains only one sensor on board, often this name may be the same as the CAP name (see Section 4.1, page 8).

7.2 Sensor Type / Type de capteur

Data type and units Enumeration

Constraints Allowed values are: *SAR*, *AIS*, *EO/IR*, and *TIR*

Dependencies Sensor Class (Section 7.3)

Sub-properties None

This property describes the type of sensor. CSIAPS currently supports three types of sensor:

- Synthetic Aperture Radar (SAR);
- Automatic Identification System (AIS);
- Electro-Optical/Infrared (EO/IR); and
- Thermal Infrared (TIR).

More types may be added in the future. For each of the aforementioned types, the sensor capabilities are further clarified with the sensor class defined in Section 7.3.

7.3 Sensor Class / Classe du capteur

Data type and units Enumeration

Constraints Allowed values vary according to sensor type (Section 7.2); see the description below for more details

Dependencies Sensor Type (Section 7.2)

Sub-properties None

This value specifies the class of the sensor, which is a refinement of the sensor type defined in Section 7.2. The allowed values of this property depend on the sensor type.

- For SAR sensors, the class must describe the band, in the form of a standard band name as defined Annex B, suffixed with the text *-band* (e.g., *X-band*, *C-band*, or *S-band*).
- For AIS sensors, the allowed values are:
  - *A* (for a sensor that only supports class A AIS signals);
  - *B* (for a sensor that only supports class B AIS signals);
  - *A+B* (for a sensor that supports both classes of AIS signal).
- For EO/IR sensors, the allowed values are:

– *HSI* for hyperspectral imagers;
– *MSI* for multispectral imagers;
– *PAN* for panchromatic imagers;
– *MSI+PAN* for imagers that support both multi-spectral and panchromatic imaging;
– *TIR* for imagers that can capture thermal infrared; and
– *Video* for sensors that can capture video.

8 Sensing Device / Dispositif du capteur

Sensing Device nodes describe physical antenna properties of the sensors they are associated with. These nodes are related to Sensor nodes via a *makes use of* relationship.

8.1 Orientability / Orientabilité

Data type and units Enumeration

Constraints Allowed values are: *Fixed* and *Steerable*

Dependencies None

Sub-properties None

This property specifies whether the antenna is able to move (*Steerable*) or not (*Fixed*).

8.2 Antenna Look Direction / Direction de regard de l'antenne

Data type and units Enumeration

Constraints Allowed values are: *Left*, *Right*, *Both*, and *Nadir*

Dependencies None

Sub-properties *Squint / Mésalignement* (Section 8.2.1)

This property specifies the directions that the antenna is able to look in, relative to either true north (for a fixed platform) or to the direction of travel of the platform (e.g., for side-looking imaging radar). The value of *Both* is used for antennas that support both left and right look directions.

8.2.1 Squint / Mésalignement

Data type and units Enumeration

Constraints Allowed values are: *Yes* and *No*

Dependencies None

Sub-properties *Fore / Avant*, *Aft / Arrière*, *Mechanism / Mécanisme*

This property specifies whether or not an antenna is capable of squinting, which occurs when waves are transmitted in a plane other than the one normal to the antenna. This value should be set to *Yes* for antennas that support squinting, and *No* otherwise.

Fore / Avant

Data type and units Numeric (in degrees)

Constraints Must be a number between 0 (inclusively) and 90 (exclusively)

Dependencies *Squint / Mésalignement* (Section 8.2.1)

Sub-properties None

This property specifies the maximum squint angle in degrees towards the front (fore side) of the platform. The value of this property should be set to zero if the antenna does not support squinting.

Aft / Arrière

Data type and units Numeric (in degrees)

Constraints Must be a number between 0 (inclusively) and 90 (exclusively)

Dependencies *Squint / Mésalignement* (Section 8.2.1)

Sub-properties None

This property specifies the maximum squint angle in degrees towards the rear (aft side) of the platform. The value of this property should be set to zero if the antenna does not support squinting.

Mechanism / Mécanisme

Data type and units Enumeration

Constraints Allowed values are: *No squinting*, *Mechanical antenna squinting*, *Electronic antenna squinting*, and *Payload squinting*

Dependencies *Squint / Mésalignement* (Section 8.2.1)

Sub-properties None

This property specifies the mechanism employed by the antenna to perform squinting. The value of this property should be set to *No squinting* if the antenna does not support squinting.

9 Spectral Band / Bande spectrale

A spectral band refers to a frequency or a range of frequencies in the electromagnetic spectrum over which a sensor operates. Multiple spectral bands may be associated to a sensor node (Section 7, page 14), each via a *covers* relationship flowing from the sensor node to the spectral band node.

Definitions for several standard spectral bands are listed in Annex B. These include bands defined by the Institute of Electrical and Electronics Engineers (IEEE), the International Telecommunications Union (ITU), and the North Atlantic Treaty Organization (NATO). In this document, if the name of the organization is not specified when quoting a spectral band, it is assumed that the IEEE standard is being referenced (Table B.1).

9.1 Band Name / Nom de la bande

Data type and units Text string

Constraints Must be non-empty; also, the combination of this property and Band Number (Section 9.2) must be unique for each sensor

Dependencies None

Sub-properties None

This property specifies the name of the band. For EO/IR sensors, this name is often specified by the manufacturer to indicate either what kind of imaging the band may be suitable for (for example, *Coastal Aerosol* in the Sentinel-2A and Sentinel-2B CAPs, or *Coastal* in the WorldView-2 CAP), or else the approximate range of frequencies used (for example, *Red*, *Green*, and *Blue* in the Deimos-1 and Deimos-2 CAPs). Sometimes, the same band name is used for different frequency ranges; in this case, the band number (Section 9.2) may be used to distinguish which band is being referred to.

9.2 Band Number / Numéro de la bande

Data type and units Text string

Constraints Must be non-empty; also, the combination of this property and Band Name (Section 9.1) must be unique for each sensor

Dependencies None

Sub-properties None

This property assigns a number to the band. For EO/IR sensors, this number is often assigned by the manufacturer and is sometimes used to distinguish bands that cover different frequency ranges (Section 9.4) but have identical band names (Section 9.1). Bands are often numbered sequentially (1, 2, 3, . . .), but some manufacturers may deviate from this scheme (for example, the Sentintel-2A and Sentinel-2B platforms have a band numbered *8A*).

9.3 Ground Sample Distance at Nadir / Distance inter-échantillon au sol au nadir

Data type and units Numeric (in meters)

Constraints Must be positive or zero

Dependencies None

Sub-properties None

This property provides the ground sample distance that the sensor is capable of achieving when performing imaging in this spectral band looking towards nadir.

9.4 Frequency and Wavelength / Fréquence et longueur d'onde

Data type and units Numeric (in units of GHz for frequency, and nm for wavelength)

Constraints See description below

Dependencies None

Sub-properties *Minimum*, *maximum*, *center*, and *bandwidth* for both frequency and wavelength (eight sub-properties) / Valeurs *minimales*, *maximales*, *centrales*, et de *bande passante* pour la fréquence et pour la longueur d'onde (huit sous-propriétés)

The eight sub-properties within this property specify the frequency or range of frequencies covered by the spectral band. To do this, two parameters from the following list must be provided:

- Either minimum frequency or maximum wavelength (but not both simultaneously);
- Either maximum frequency or minimum wavelength (but not both simultaneously);
- Center frequency;
- Center wavelength;
- Frequency bandwidth; or
- Wavelength bandwidth.

There is also an additional condition that must be satisfied if the two parameters provided are the center frequency and the center wavelength (see Equation A.15, page 44 in Annex A). Once the two parameters are given, the equations in Annex A—and, in particular, the method described in Table A.1 of this Annex—may be used to compute the other six parameters. To specify a single frequency or wavelength, the value should be entered as the center of the band with a bandwidth of zero.

10 Sensor Operating Condition (SOC) / Condition d'opération du capteur (COC)

Sensor Operating Condition (SOC) nodes describe the imaging capabilities of an entire sensor. SOC nodes may be related to:

- Sensor nodes (Section 7, page 14) via an *operates under* relationship;
- Sensor Operating Mode (SOM) nodes (Section 11, page 23) via a *stipulates* relationship; and
- Sensor Product nodes (Section 14, page 29) via a *generates from SOC* relationship;

For sensors that consist of an array of elements, it is often the case that only a subset of these elements can be used at simultaneously to do imaging. The possible combinations of elements are described with SOM nodes (Section 11, page 23), while the individual elements themselves are described with Sensor Operating Mode Position (SOMP) nodes (Section 12, page 27).

SOC, SOM, and SOMP nodes all share several common properties that are described in Section 13 (page 27). This section describes other properties that are only associated with SOC nodes.

10.1 Swath Size at Nadir / Grandeur du couloir au nadir

This property contains information on the size of the swath when the sensor is pointing at nadir. There are three sub-properties: length (ℓ), width (w), and aspect ratio (r). Setting any two of these properties fixes the third via the relation

$$r = \frac{\ell}{w}. \tag{1}$$

10.1.1 Length / Longueur

Data type and units Numeric (in kilometers)

Constraints Must be positive and non-zero, and must obey Equation 1

Dependencies *Width / Largeur* (Section 10.1.2), *Aspect ratio / Rapport de cadrage* (Section 10.1.3)

Sub-properties *Aperture Angle Along Track / Angle d'aperture parallèle*

This property provides the length of the swath at nadir (ℓ in Equation 1), defined along the same direction that the sensor is moving in. For space-based satellites, this corresponds to the azimuth direction (i.e., along track).

Aperture Angle Along Track / Angle d'aperture parallèle

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 180 exclusively (cannot be exactly 0 or 180)

Dependencies *Length / Longueur* (Section 10.1.1), *CAPOC Nominal Altitude / Altitude nominale COPRC* (Section 6.2, page 12)

Sub-properties None

The along track aperture angle defines the angle swept by the sensor over the swath at nadir in the direction of the swath length. The angle in degrees may be computed using the formula

$$\theta_\ell = \left(\frac{180}{\pi}\right) \cdot 2 \arctan\left(\frac{\sin(\ell/2R)}{1 + h/R - \cos(\ell/2R)}\right), \tag{2}$$

where ℓ is the swath length at nadir (Section 10.1.1), h is the nominal altitude of the CAP carrying the sensor (Section 6.2, page 12) and R is the radius of the Earth (approximately 6378.137 km). The sensor thus spans aperture angles from $-\theta_\ell/2$ to $+\theta_\ell/2$ to cover the length of the swath at nadir.

10.1.2 Width / Largeur

Data type and units Numeric (in kilometers)

Constraints Must be positive and non-zero, and must obey Equation 1

Dependencies *Length / Longueur* (Section 10.1.1), *Aspect ratio / Rapport de cadrage* (Section 10.1.3)

Sub-properties *Aperture Angle Across Track / Angle d'aperture transverse*

This property provides the width of the swath at nadir (w in Equation 1), defined transversely to the direction that the sensor is moving in. For space-based satellites, this corresponds to the range direction (i.e., across track).

Aperture Angle Across Track / Angle d'aperture transverse

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 180 exclusively (cannot be exactly 0 or 180)

Dependencies *Width / Largeur* (Section 10.1.2), *CAPOC Nominal Altitude / Altitude nominale COPRC* (Section 6.2, page 12)

Sub-properties None

Analogously to the along-track aperture angle (Section 10.1.1, page 21), the across track aperture angle defines the angle swept by the sensor over the swath at nadir in the direction of the width. Similarly to Equation 2, the angle in degrees may be computed using the formula

$$\theta_w = \left(\frac{180}{\pi}\right) \cdot 2 \arctan\left(\frac{\sin(w/2R)}{1 + h/R - \cos(w/2R)}\right), \tag{3}$$

where w is the swath width at nadir (Section 10.1.2), h is the nominal altitude of the CAP carrying the sensor (Section 6.2, page 12) and R is the radius of the Earth (approximately 6378.137 km). The sensor thus spans aperture angles from $-\theta_w/2$ to $+\theta_w/2$ to cover the width of the swath at nadir.

10.1.3 Aspect Ratio / Rapport de cadrage

Data type and units Numeric (dimensionless)

Constraints Must be positive and non-zero, and must obey Equation 1

Dependencies *Length / Longueur* (Section 10.1.1), *Width / Largeur* (Section 10.1.2)

Sub-properties None

This property provides the swath aspect ratio at nadir, defined as the ratio of swath length and swath width per Equation 1.

10.2 Maximum Off-Nadir Angle / Angle maximale hors-nadir

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 90 inclusively

Dependencies None

Sub-properties *Along Track* and *Across Track* / *Transverse à la trajectoire* et *en direction de la trajectoire*

This property defines how much the sensor is able to move its central axis relative to nadir, in degrees. This property has two sub-properties: one for the along track direction, and another for the across track direction.

10.3 Angle Range / Portée de l'angle

Data type and units Enumeration

Constraints Allowed values are: *Full performance* and *Extended access*

Dependencies None

Sub-properties None

This property allows multiple ranges of imaging angles to be specified. Typically, the specifications for *Full performance* correspond to the normal operating regime of the sensor, for which the performance is guaranteed to meet a particular standard (e.g., a minimum resolution in the final product). On the other hand, *Extended access* specifies to the full capability of the sensor, but where performance may degrade beyond what is typically guaranteed.

As an example, the sensors on the TerraSAR-X and Tandem-X CAPs offer an incidence angle range (Section 13.3, page 28) of 18.2–49.5 degrees for most sensor products, but are physically capable of an incidence angle range of 13.2–53.3 degrees. In this scenario, the former, narrower range could be entered as *Full performance*, while the latter, wider range could be entered as *Extended access*.

11 Sensor Operating Mode (SOM) / Mode d'opération du capteur (MOC)

Sensor Operating Mode (SOM) nodes describe the imaging capabilities of a sensor when it is operating in a particular imaging mode. Often, this entails using only a subset of the full sensor capabilities described in an SOC node (Section 10, page 20).

SOM nodes may be related to:

- SOC nodes via a *stipulates* relationship;
- SOMP nodes (Section 12, page 27) via an *is refined by* relationship; and
- Sensor Product nodes (Section 14, page 29) via a *generates from SOM* relationship;

SOC, SOM, and SOMP nodes all share several common properties that are described in Section 13 (page 27). This section describes other properties that are only associated with SOC nodes.

11.1 Sensor On Time / Temps d'activité du capteur

Data type and units Numeric (in minutes)

Constraints Can be set to -1 for an unspecified value, and must otherwise be positive or zero; the maximum cannot be less than the minimum; the default value cannot be less than the minimum or greater than the maximum; and must be less than the Duty Cycle (Section 6.4, page 13)

Dependencies Duty Cycle (Section 6.4)

Sub-properties *Minimum*, *Maximum*, and *Default* / *Minimum*, *maximum* et *défaut*

This property describes the amount of time that the sensor is performing imaging (i.e., actively transmitting or receiving data) to acquire a specified data product. It is possible to specify minimum, maximum, and default values for this property. In all cases, the values must be less than the Duty Cycle (Section 6.4).

11.2 Stereo Level / Niveau stéréo

Data type and units Integer

Constraints Must be a positive whole number; can be zero as well

Dependencies None

Sub-properties None

This property specifies how many views of a particular scene can be acquired in a given SOM to build stereo imagery.

- A value of zero or one is referred to as *mono*, and means that only one view of a scene can be captured (no stereo capability);
- A value of two is referred to as *stereo*; and
- A value of three is referred to as *tri-stereo*.

Analogously to tri-stereo, a number of views of four or more may be referred to with a different prefix to the word "stereo" (e.g., *quad-stereo*, *penta-stereo*), but this terminology is not standard or in common usage.

11.3 Nominal Scene Size / Grandeur nominale de la scène

Data type and units Numeric (in kilometers)

Constraints Must be a positive and non-zero

Dependencies None

Sub-properties Range and Azimuth / Portée et azimut

This property describes the size of the scene that can nominally be obtained by imaging with a given SOM at nadir. The two sub-properties of this property provide the dimensions in the range and azimuth directions. The exact size of the scene obtained may vary from the nominal value according to other factors, such as the off-nadir angle (see Section 10.2, page 23).

11.4 Polarization Mode / Mode de polarisation

Data type and units Text string

Constraints Allowed values are: *Single*, *Dual*, *Quad*, *Compact*, and *;* for SAR sensors only

Dependencies None

Sub-properties Polarization Options / Options de polarisation (Section 11.4.1)

For SAR sensors, this property describes what polarization modes may be used when imaging with a given SOM:

- *Single*: single-channel transmit and single-channel receive;
- *Dual*: single-channel transmit and dual-channel receive;
- *Quad*: dual-channel transmit and dual-channel receive; and
- *Compact*: circular transmit and circular receive.

Other values may also be added as more polarization modes are developed. The Polarization Options sub-property further specifies the available polarizations (transmit and receive) within an available mode.

11.4.1 Polarization Options / Options de polarisation

Data type and units Text string

Constraints For SAR sensors only; must be consistent with the value of the *Polarization Mode* property; multiple values may be specified with a comma-separated list; see allowed values in description

Dependencies Polarization Mode (Section 11.4)

Sub-properties None

For SAR sensors, this property specifies what polarizations (transmit and receive) are available in a particular SOM. The value of this property must be consistent with the Polarization Mode setting, and multiple options for each polarization mode may be specified with a comma-separated list.

The allowed values of polarization options for each polarization mode are as follows:

- *Single*: *HH* (horizontal transmit, horizontal receive), *VV* (vertical transmit, vertical receive), *HV* (horizontal transmit, vertical receive), and *VH* (vertical transmit, vertical receive);
- *Dual*: *HH+HV*, *VV+VH*, and *HH+VV*;
- *Quad*: *HH+HV+VH+VV* (only one value allowed);
- *Compact*: *CL* (left-circular), *CR* (right-circular), and *CP* (circular with unspecified direction).

More information on polarization in SAR sensors may be found in the literature [10].

11.5 Maximum Azimuth Scene Size for Swath Oriented Product / Grandeur maximale en azimut de la scène pour un produit orienté en couloir

Data type and units Numeric (in kilometers)

Constraints Must be positive and non-zero

Dependencies None

Sub-properties None

This property describes the maximum size of the scene in the azimuth direction of the sensor, for those SOMs that generate swath-oriented image products.

12 Sensor Operating Mode Position (SOMP) / Position du mode d'opération du capteur (PMOC)

Sensor Operating Mode Position (SOMP) nodes describe the smallest individual imaging component of a sensor, such as one element of an array. Thus, a particular SOM (Section 11, page 23) typically uses some—but not necessarily all—of the SOMPs associated with a sensor, while the SOC node for a sensor often describes the full capability of all of the SOMPs for the sensor when taken together.

SOMP nodes may be related to:

- SOM nodes (Section 11, page 23) via an *is refined by* relationship;
- Sensor Product nodes (Section 14, page 29) via a *generates from SOMP* relationship; and
- Ship Detectability nodes (Section 16, page 34) via a *can detect* relationship.

SOC, SOM, and SOMP nodes all share several common properties that are described in Section 13 (page 27). The SOMP has no properties that are specifically associated with it and are not also common to SOC and SOM nodes. Hence, all of the properties for SOMP nodes appear in Section 13.

13 Common Sensor Properties / Propriétés communes du capteur

This section describes properties that are common to the SOC (Section 10, page 20, SOM (Section 11, page 23), and SOMP (Section 12, page 27) nodes.

13.1 SOC/SOM/SOMP Name / Nom du/de la COC/MOC/PMOC

Data type and units Text string

Constraints Must be non-empty and unique for each instance of this property

Dependencies None

Sub-properties None

This property provides the name of the SOC, SOM, or SOMP.

13.2 SOC/SOM/SOMP Model Name / Nom du modèle du/de la COC/MOC/PMOC

Data type and units Text string

Constraints Must be non-empty and unique for each instance of this property

Dependencies Antenna Look Direction (Section 8.2, page 16)

Sub-properties Left / Gauche, Right / Droite

This property gives the name of model associated with the SOC, SOM, or SOMP. In CSI-APS, these models refer to files used to store information about a SOC, SOM, or SOMP for the purposes of running orbit propagation simulations. Different file names may be specified for different antenna look directions (see Section 8.2, page 16) via the sub-properties of this property; currently, the specification supports having two different file names for the left and right look directions.

13.3 SOC/SOM/SOMP Nominal Incidence Angle / Angle d'incidence nominal du/de la COC/MOC/PMOC

Data type and units Numeric (in degrees)

Constraints For SAR sensors only; must be between 0 and 90 degrees inclusively, and the near limit cannot be greater than the far limit

Dependencies SOC/SOM/SOMP Cone Angle (Section 13.3.1)

Sub-properties Near Limit / Limite proximale, Far Limit / Limite distale

This property specifies the nominal incidence angle range for a SOC, SOM, or SOMP. The two sub-properties give the lower bound (near limit) and upper bound (far limit) of the angle range.

13.3.1 SOC/SOM/SOMP Cone Angle / Angle du cône du/de la COC/MOC/PMOC

Data type and units Numeric (in degrees)

Constraints Must be set according to Equation 4

Dependencies SOC/SOM/SOMP Nominal Incidence Angle (Section 13.3), CAPOC Nominal Altitude (Section 6.2, page 12)

Sub-properties Inner and Outer / Interne et externe

This sub-property provides the cone angle associated with the Nominal Incidence Angle for a given SOC, SOM, or SOMP. The formula relating the cone angle θ_c to an incidence angle θ_i (both in degrees) is

$$\theta_c = \left(\frac{180}{\pi}\right) \cdot \arcsin\left(\frac{R}{R+h} \cdot \sin\left(\frac{\pi}{180} \cdot \theta_i\right)\right), \tag{4}$$

where R is the radius of the Earth (approximately 6378.137 km) and h is the nominal altitude of the CAP carrying the sensor (Section 6.2, page 12). The Inner Cone Angle is a function of the Near Limit incidence angle, and the Outer Cone Angle is a function of the Far Limit incidence angle.

13.4 SOC/SOM/SOMP Clock Angle / Angle en horloge du/de la COC/MOC/PMOC

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 180 degrees for right, or between 180 and 360 degrees for left; minimum values cannot be greater than the corresponding maximum values

Dependencies None

Sub-properties Minimum Left, Minimum Right, Maximum Left, Maximum Right / Minimal à la gauche, minimal à la droite, maximal à la gauche, maximal à la droite

For conical sensors, the clock angles specify the range of sensor rotation about the boresight of the sensor, relative to the direction that the sensor is pointing (i.e., the azimuth direction in the case of satellites). Looking from above the sensor (i.e., down towards the imaging target in the case of a satellite), the clock angles span from 0 to 360 degrees in a clockwise direction, with values between 0 and 180 to the right of the sensor and 180 to 360 to the left.

SAR sensors are typically modelled with a small range of clock angles (for example, from 89.9 to 90.1 degrees) that form a thin wedge of a circle; this wedge then sweeps out a full swath as the satellite travels in the azimuth direction. On the other hand, the field of view for an AIS sensor is assumed to extend all the way to the horizon in any direction, and thus AIS sensors are typically modelled with clock angles from 0 to 360.

14 Sensor Product (SP) / Produit du capteur (PC)

Sensor Product (SP) nodes describe various properties relating to the image product that a sensor is capable of generating under particular conditions. SP nodes may be related to:

- SOC nodes (Section 10, page 20) via a *generates from SOC* relationship; and

- SOM nodes (Section 11, page 23) via a *generates from SOM* relationship; and
- SOMP nodes (Section 12, page 27) via a *generates from SOMP* relationship; and
- License nodes (Section 15, page 33) via a *purchased with* relationship.

14.1 Product Type / Type de produit

This property holds several sub-properties that describe the type of image product that a sensor can generate.

14.1.1 Product Type Name / Nom du type de produit

Data type and units Text string

Constraints Must be non-empty and unique for each entry

Dependencies None

Sub-properties None

This property provides the name of the product type.

14.1.2 Geolocation Accuracy Without Ground Control Points / Précision de la géo-location sans points de contrôle terrestre

Data type and units Numeric (in meters)

Constraints Must be positive and non-zero

Dependencies None

Sub-properties None

This property specifies the geolocation accuracy of the sensor product when no ground control points are used to refine the geolocation.

14.1.3 Complex or Detected Data / Données complexes ou détectées

Data type and units Enumeration

Constraints Allowed values are: *Complex* and *Detected*; for products from SAR sensors only

Dependencies None

Sub-properties None

For products from SAR sensors only, this property specifies whether the product data are supplied in complex-valued or real-values (i.e., detected) form.

14.1.4 Number of Looks / Nombre de regards

Data type and units Integer (Range and Azimuth), numeric (Equivalent Number of Looks)

Constraints For SAR sensors only; Range and Azimuth values must be at least one

Dependencies None

Sub-properties Range, Azimuth, Equivalent Number of Looks / Portée, azimut, nombre équivalent de regards

For SAR sensors, this property specifies the number of looks the sensor can provide and thus describes the degree of averaging applied to the SAR measurements. The number of looks may be reported in the range and azimuth directions, or as a single "equivalent" number of looks (which may be a fractional number).

14.1.5 Maximum Nominal Pixel Spacing / Espace nominale maximale entre pixels

Data type and units Numeric (in meters)

Constraints Must be a positive and non-zero

Dependencies None

Sub-properties Range and Azimuth / Portée et azimut

This property specifies the spacing between pixels in the sensor product, in both the range and azimuth directions.

14.2 NIIRS

The NATO Imagery Interpretability Rating Scale (NIIRS), as defined in NATO Standardization Agreement (STANAG) 7194, is a metric to quantify the degree of military-relevant information that could potentially be extracted through visual analysis of overhead (airborne or satellite) imagery. The NIIRS rating level has a correlation with spatial resolution, but other factors also come into play as well. These include (for the Radar NIIRS scale): incidence angle, radiometric resolution, the Noise Equivalent Sigma Zero (NESZ) and polarization mode (i.e., co- or cross-pol channels). Similar factors would apply to the Visible NIIRS scale. Two sub-properties specify the NIIRS value for a given sensor product: Rating and Scale.

14.2.1 Rating / Cote

Data type and units Numeric (NIIRS rating scale)

Constraints Must be a number between 0 and 9.9 inclusively; has precision only up to one decimal place

Dependencies NIIRS (Section 14.2)

Sub-properties None

The NIIRS consists of a numeric scale with ten rating levels (zero through nine), and can be specified to one-tenth of a rating level. On the NIIRS scale, a larger rating (e.g., 7.1) indicates greater information content, while a smaller rating (e.g., 3.7) indicates lesser information content, and a rating zero indicates no information at all (e.g., due to obscuration).

14.2.2 Scale / Échelle

Data type and units Enumeration

Constraints Allowed values are: *Radar*, *Visible*, *Multispectral*, *Infrared*, and *None*

Dependencies NIIRS (Section 14.2)

Sub-properties None

There is a separate NIIRS for imagery from each family of sensor. The scale names include:

- *Radar*, for a single-channel SAR image;
- *Visible*, for a panchromatic EO/IR image in the visible range;
- *Multispectral*, for a multi-channel EO/IR image in the visible and near-infrared range; and
- *Infrared*, for long-wavelength thermal emitted radiation.

14.3 SP Nominal Incidence Angle / Angle d'incidence nominal du PC

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 90 degrees inclusively, and the near limit cannot be greater than the far limit

Dependencies None

Sub-properties Near Limit / Limite proximale, Far Limit / Limite distale

This property specifies the nominal incidence angle range for a given sensor product. The two sub-properties give the lower bound (near limit) and upper bound (far limit) of the angle range.

14.4 Nominal Resolution / Résolution nominale

Data type and units Numeric (in meters)

Constraints Must be positive and non-zero

Dependencies None

Sub-properties Range at Minimum Incidence Angle / Portée à l'angle d'incidence minimal, Range at Maximum Incidence Angle / Portée à l'angle d'incidence maximal, Azimuth at Minimum Incidence Angle / Azimut à l'angle d'incidence minimal, Azimuth at Maximum Incidence Angle / Azimut à l'angle d'incidence maximal

This property gives the nominal spatial resolution that may be expected for a given sensor product. The four sub-properties specify lower and upper bounds in both the range and azimuth directions, depending on the incidence angle.

14.5 Polarization Mode / Mode de polarisation

This property and its Polarization Options sub-property are defined identically to SOM Polarization Mode and SOM Polarization Options; see Section 11.4, page 25.

15 License / Licence

License nodes specify what licenses are available for obtaining a particular sensor product. They are related to Sensor Product nodes (Section 14, page 29) via a *purchased with* relationship.

15.1 License Type / Type de licence

Data type and units Text string

Constraints None

Dependencies None

Sub-properties None

This property specifies the name or type of the license (for example, *National Master Standing Order, Class 1*).

15.2 Cost per Scene / Coût par scène

Data type and units Numeric (units specified in the Currency sub-property)

Constraints Must be positive or zero

Dependencies None

Sub-properties Currency / Devise

This property specifies the cost of obtaining an image under the specified license. The currency this cost is expressed in is specified in the Currency sub-property.

15.3 Currency / Devise

Data type and units Text string

Constraints Must be a valid currency code in the ISO-4217 standard

Dependencies None

Sub-properties None

This property specifies which currency the cost of the license is expressed in. The value of this property should correspond to one of the three-letter currency designators in the ISO-4217 standard for currencies.

16 Ship Detectability (SD) / Détectabilité des navires (DN)

Ship Detectability (SD) nodes provide data on the expected performance of a sensor in detecting ships in the ocean, by specifying a property known as the Minimum Detectable Ship Length (MDSL) under certain conditions, including the incidence angle of imaging and the polarization. The model currently used to determine MDSL values is described elsewhere [11]. SD nodes may be related to SOMP nodes Section 12, page 27 via a *can detect* relationship.

16.1 SD Angle / Angle de DN

Data type and units Numeric (in degrees)

Constraints Must be between 0 and 90 degrees, inclusively

Dependencies None

Sub-properties None

This property specifies the incidence angle of imaging.

16.2 SD Polarization / Polarisation de DN

Data type and units Text string

Constraints Must be one of the entries in Section 11.4, page 25

Dependencies Polarization Mode (Section 11.4)

Sub-properties None

This property specifies the polarization mode being used; it must correspond to one of the available modes for the sensor listed in Section 11.4, page 25.

16.3 SD Beam Number / Numéro du faisceau de DN

Data type and units Integer

Constraints Must be a beam number associated with the platform

Dependencies None

Sub-properties None

This property specifies the beam number, in cases where the MDSL changes as a function of which beam is being used to image the target. In cases where this distinction is not necessary, the value of this property may be set to one.

16.4 Minimum Detectable Ship Length (MDSL) / Longueur minimale détectable de navire (LMDN)

Data type and units Numeric (in meters)

Constraints Must be positive and non-zero

Dependencies None

Sub-properties None

This property gives the MDSL for a particular value of the angle, polarization, and beam number.

17 Other Tables

While most of the CAS may be described using the elements outlined in Section 2 and described in detail in Sections 3–16, some additional data tables that are not part of the graph are used in tandem with it to provide additional information. The contents of these additional data tables are described in this section.

17.1 Affiliations

The Affiliations table exists to hold names of organizations referred to elsewhere in the CAS, such as companies and government agencies. The columns in the Affiliations table are described below.

Name / Nom

Data type and units Text string

Constraints Must be non-empty and unique for each entry in the table

Dependencies None

Sub-properties None

This column contains the name of the organization, typically in short form so that it may be easily referred to elsewhere. From a database perspective, this column is intended to serve as the primary key of the Affiliations table.

Country / Pays

Data type and units Text string

Constraints Must be the name of a country

Dependencies None

Sub-properties None

This column contains the name of the country in which the organization is based.

Full Name / Nom complet

Data type and units Text string

Constraints None

Dependencies None

Sub-properties Full Name, English Name, French Name

This entry refers to three columns that contain the full name of the organization in:

- Its language of origin;
- In English; and
- In French.

Example entry

Below is an example entry in the Affiliations table.

Name DLR

Country Germany

Full Name Deutsches Zentrum für Luft- und Raumfahrt e.V.

English Name German Aerospace Centre

French Name Centre allemand pour l'aéronautique et l'astronautique

17.2 Acronyms

The Acronyms table is present to provide the expansion for acronyms that occur in the CAS. The acronyms used in the CAS are defined in the List of Acronyms of this document.

Term / Terme

Data type and units Text string

Constraints Must be non-empty and unique for each entry in the table

Dependencies None

Sub-properties None

This column contains the acronym to be defined. From a database perspective, this column is intended to serve as the primary key of the Acronyms table.

Acronym Expansion / Expansion de l'acronyme

Data type and units Text string

Constraints None

Dependencies None

Sub-properties None

This column contains the expanded definition of the acronym.

18 Discussion

The CAS data model presented in this report addresses several needs and challenges in remote sensing:

- The need to track many different parameters to find the best coverage opportunities that a particular collection asset can provide;
- The need to consider and optimize multiple factors that may be interrelated or in competition with one another (e.g., licensing agreements, cost, resolution, time constraints, computational resources); and
- The need to develop standardized terminology in order to build interoperable systems and communicate effectively with partner organizations and other stakeholders.

The CSIAPS CAS management service implements the CAS structure presented in this report and collects the required technical and administrative parameters in one place within its database. In past versions of CSIAPS (version 2.3 and earlier), these parameters were either hard-coded into CSIAPS or spread across a separate Microsoft SQL database, several Excel spreadsheets, and sensor model files in STK format. Hence, the CAS data structure and the corresponding management service described herein facilitate easy updating of key parameters.

As mentioned in Section 2, the CAS incorporates several features often associated with ontologies, including a controlled vocabulary, a taxonomy, and data properties. However, one additional feature of an ontology that the CAS currently does not possess are inference rules, which allow one to infer additional properties of an object based on known properties from the graph. An example of such an inference rule is: "If a Sensor node is associated with more than ten Spectral Band nodes, then the Sensor Type should be set to *HSI* (hyperspectral)." Augmenting the CAS by capturing subject matter knowledge in this way would enable the CAS to be used more effectively with the guidance expert system.

The CAS database is more complete for some CAs compared to others. Currently, the database is: mostly complete for the RADARSAT-2, RCM, and Sentinel-1 SAR satellites;

mostly complete for AIS satellites; and partially complete for other SAR satellites, EO/IR satellites, and TIR satellites. The CAS database is expected to grow when updated with information on newly launched/commissioned satellites, and the data model itself will evolve when new consumers of the CAS need access to additional parameters.

Ensuring the validity and reliability of the parameter values in the CAS database is an ongoing effort. In older versions of CSIAPS (versions 1.x and 2.x), sensor model parameters were validated by comparing them with actual image collections [2, 3], as well as with predictions from tools such as the Swath Planner Application (SPA) for RADARSAT-1, the Acquisition Planning Tool (APT) for RADARSAT-2, and the Savior multi-sensor planning tool for several EO/IR satellites. By contrast, the most recent version of CSIAPS (version 3.x) started the database of satellite and sensor parameters from scratch, using parameters sourced from technical documents and product specifications from manufacturers [4, 5, 6, 7, 8], as well as online databases such as eoPortal [12] and Space-Track [13]. Additionally, the CAS values for a subset of the SAR, EO/IR and AIS collection assets were compared with colleagues at the Fraunhofer Ernst Mach Institute in Germany as part of the Rim of the Pacific (RIMPAC) 2018 trial under the Micro-Satellite Military Utility (MSMU) Partnership Agreement (PA). As well, DRDC plans to have the CAS values for a subset of the SAR collection assets be validated by the satellite operators themselves, while under contract to DRDC.

The best practice for keeping the CAS up to date involves having a central repository, managed by DRDC or by a company under contract to DRDC, that is updated regularly to reflect new satellites and older de-commissioned satellites. As noted previously, the CAS would ideally be updated with information provided by the satellite operators, possibly under contract to DRDC or the Government of Canada (GC). For example, for a satellite operator to successfully be registered under the GC National Master Standing Offer (NMSO) for CSI, the operator could be required to provide values for all fields in the CAS, in a template provided by the GC.

19 Conclusion

In this work, a Collection Asset Specification (CAS) has been developed to provide a common framework for describing remote sensing collection assets. This is accomplished by developing an explicit specification of basic concepts, terminology, and relationships between them in the space-based ISR domain. The CAS data model has been used to implement the Commercial Satellite Imagery Acquisition Planning System (CSIAPS) collection asset parameters database as a service on a service-oriented architecture, and provides machine interpretable definitions in addition to facilitating interoperability and sharing.

This work will facilitate the migration of CSIAPS to a service-oriented architecture that can be accessed externally by other users and applications. The CAS model and database are expected to grow to include new collection assets, as well as evolve to include more parameters and new types of intelligence collection platforms. Effort will also be expended on maintaining and improving the reliability of the parameters in the database, and plans exist to implement contracts with the manufacturers themselves for updating the database directly. Finally, the CAS data model and the underlying database will be shared with the Canadian Armed Forces (CAF) and partner organizations through existing projects and ongoing agreements, thereby increasing interoperability among partners in the Intelligence, Surveillance, and Reconnaissance (ISR) domain.

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Annex A Computing frequency and wavelength parameters for spectral bands

In general, electromagnetic waves can be specified either in terms of a frequency f in Hertz, or a wavelength λ in metres. For a wave with a single frequency, the relationship between these two quantities is

$$c = f\lambda, \tag{A.1}$$

where $c = 2.99792458 \times 10^8$ m/s is the speed of light. A spectral band is defined as a collection of frequencies that can lie between a certain range of frequencies or wavelengths. There are two equivalent ways to specify a band: in terms of the minimum and maximum frequency or wavelength, or in terms of its central value (the midpoint between the minimum and maximum) and the bandwidth (the range between the minimum and the maximum). Hence, for a band whose frequencies range from f_{min} to f_{max}, the central frequency f_{c} and bandwidth f_{bw} are given by

$$f_{\text{c}} = \frac{f_{\text{min}} + f_{\text{max}}}{2}, \tag{A.2}$$

$$f_{\text{bw}} = f_{\text{max}} - f_{\text{min}}. \tag{A.3}$$

The equations to convert from center and bandwidth to minimum and maximum are

$$f_{\text{min}} = f_{\text{c}} - \frac{f_{\text{bw}}}{2}, \tag{A.4}$$

$$f_{\text{max}} = f_{\text{c}} + \frac{f_{\text{bw}}}{2}. \tag{A.5}$$

Analogous equations hold for the wavelengths that define the band:

$$\lambda_{\text{c}} = \frac{\lambda_{\text{min}} + \lambda_{\text{max}}}{2}, \tag{A.6}$$

$$\lambda_{\text{bw}} = \lambda_{\text{max}} - \lambda_{\text{min}}, \tag{A.7}$$

$$\lambda_{\text{min}} = \lambda_{\text{c}} - \frac{\lambda_{\text{bw}}}{2}, \tag{A.8}$$

$$\lambda_{\text{max}} = \lambda_{\text{c}} + \frac{\lambda_{\text{bw}}}{2}. \tag{A.9}$$

The relationships between frequencies and wavelengths for the minimum and maximum points of the range covered by the band follow from Equation A.1:

$$c = f_{\text{max}}\lambda_{\text{min}}, \tag{A.10}$$

$$c = f_{\text{min}}\lambda_{\text{max}}. \tag{A.11}$$

Thus, knowing one of f_{max} or λ_{min} specifies the other (via Equation A.10), and similarly for f_{min} and λ_{max} (via Equation A.11). All eight parameters (f_{min}, f_{max}, λ_{c}, λ_{bw}, λ_{min},

λ_{max}, λ_c, and λ_{bw}) must be positive real numbers. Moreover, only the two bandwidth values f_{bw} and λ_{bw} may be zero (the remaining six parameters must all be nonzero).

The aforementioned equations are sufficient to convert between wavelengths and frequencies in cases where at least one of the parameters provided is an endpoint of the range (minimum or maximum). These formulas also suffice when the band is specified as a center and a bandwidth, provided that both of these values are of the same type (i.e., both are frequencies or both are wavelengths). However, it is also possible—though admittedly less common—to specify a band as a combination of a center and a bandwidth of different types, or even as two center values or two bandwidths. In each of these cases, an additional formula is needed to obtain the remaining parameters in simple steps.

- f_{bw} and λ_{bw}: the central wavelength is given by

$$\lambda_c = \frac{1}{2}\sqrt{(\lambda_{bw})^2 + \frac{4c\lambda_{bw}}{f_{bw}}}, \tag{A.12}$$

  where f_{bw} and λ_{bw} must both be nonzero (if one is zero, the band has a single frequency and wavelength, which implies that both bandwidths must be zero, and that one of the other non-bandwidth parameters must also be specified);

- f_{bw} and λ_c: the bandwidth in wavelengths is given by

$$\lambda_{bw} = 2\left[\sqrt{(\lambda_c)^2 + \left(\frac{c}{f_{bw}}\right)^2} - \frac{c}{f_{bw}}\right], \tag{A.13}$$

  when $f_{bw} \neq 0$, while the trivial case of $f_{bw} = 0$ (zero bandwidth) results in $\lambda_{bw} = 0$;

- f_c and λ_c: the bandwidth in wavelengths is given by

$$\lambda_{bw} = 2\sqrt{(\lambda_c)^2 - \frac{c\lambda_c}{f_c}}, \tag{A.14}$$

  where the condition

$$f_c\lambda_c > c \tag{A.15}$$

  must hold for the values to specify a valid spectral band;

- f_c and λ_{bw}: the central wavelength is given by

$$\lambda_c = \frac{1}{2}\left[\sqrt{(\lambda_{bw})^2 + \left(\frac{c}{f_c}\right)^2} + \frac{c}{f_c}\right]. \tag{A.16}$$

The equations in the four cases just listed may be obtained by solving Equations A.2 through A.11 algebraically to obtain λ_{min} in terms of the parameters that are known, and then using either Equation A.6 or A.7 to obtain an analogous algebraic expression for λ_{max}. In each case, comparing these expressions to Equations A.8 and A.9 provides a formula for either λ_{c} or λ_{bw} (whichever is unknown).

In summary, to specify a spectral band:

- Two parameters must be provided from the following list: either f_{min} or λ_{max} (but not both simultaneously), either f_{max} or λ_{min} (but not both simultaneously), f_{c}, λ_{c}, f_{bw}, and λ_{bw};
- If the two parameters provided are f_{bw} and λ_{bw}, neither value can be zero (otherwise, both bandwidths are zero, and one of the other non-bandwidth parameters must be specified instead);
- If the two parameters provided are f_{c} and λ_{c}, the condition $f_{\text{c}}\lambda_{\text{c}} > c$ must hold for these values to specify a valid spectral band (in a computer implementation, it may also be worth including some room for rounding error when checking this condition, i.e. requiring $f_{\text{c}}\lambda_{\text{c}} > c + \epsilon$ where $\epsilon > 0$ is a tolerance value).

Once a spectral band is specified:

- Equations A.2 through A.12 may be used to obtain any of the remaining frequency and wavelength parameters for the band (f_{min}, f_{max}, f_{c}, f_{bw}, λ_{min}, λ_{max}, λ_{c}, and λ_{bw}), following the sequence of steps described in Table A.1;
- As soon as one of f_{min} or λ_{max} becomes known during in the method described in Table A.1 (including at the start of the method if either value was specified by the user), the other value can be obtained using Equation A.10;
- Similarly, once one of f_{min} and λ_{max} becomes known, the other value can be obtained using Equation A.11.

Table A.1: *Sequence of steps for obtaining all frequency and wavelength quantities for each way of specifying a spectral band. The numbers provide the order in which to obtain the parameter, beginning with 1 for the two given parameters whose values are known, 2 for the parameters that can be obtained in one step from the two given values, 3 for parameters that can be obtained from the given values plus the values found in Step 2, and so on. In each step, the equation used is specified in parentheses. Note that specifying or computing one of f_{max} or λ_{min} gives the other via Equation A.10, and similarly for f_{min} and λ_{max} through Equation A.11; hence, these pairs of parameters are listed together in the table.*

Given	f_{min} or λ_{max}	f_{max} or λ_{min}	f_{c}	λ_{c}	f_{bw}	λ_{bw}
(f_{min} or λ_{max}) and (f_{max} or λ_{min})	1 (given)	1 (given)	2 (A.2)	2 (A.6)	2 (A.3)	2 (A.7)
(f_{min} or λ_{max}) and f_{c}	1 (given)	3 (A.5)	1 (given)	4 (A.6)	2 (A.4)	4 (A.7)
(f_{min} or λ_{max}) and λ_{c}	1 (given)	3 (A.7)	4 (A.2)	1 (given)	4 (A.3)	2 (A.9)
(f_{min} or λ_{max}) and f_{bw}	1 (given)	3 (A.2)	2 (A.4)	4 (A.6)	1 (given)	4 (A.7)
(f_{min} or λ_{max}) and λ_{bw}	1 (given)	3 (A.6)	4 (A.2)	2 (A.9)	4 (A.3)	1 (given)
(f_{max} or λ_{min}) and f_{c}	2 (A.2)	1 (given)	1 (given)	3 (A.6)	2 (A.5)	3 (A.7)
(f_{max} or λ_{min}) and λ_{c}	2 (A.6)	1 (given)	3 (A.2)	1 (given)	3 (A.3)	2 (A.8)
(f_{max} or λ_{min}) and f_{bw}	2 (A.3)	1 (given)	2 (A.5)	3 (A.6)	1 (given)	3 (A.7)
(f_{max} or λ_{min}) and λ_{bw}	2 (A.7)	1 (given)	3 (A.2)	2 (A.8)	3 (A.3)	1 (given)
f_{c} and λ_{c}	3 (A.9)	3 (A.8)	1 (given)	1 (given)	4 (A.3)	2 (A.14)
f_{c} and f_{bw}	2 (A.4)	2 (A.5)	1 (given)	3 (A.6)	1 (given)	3 (A.7)
f_{c} and λ_{bw}	3 (A.9)	3 (A.8)	1 (given)	2 (A.16)	4 (A.3)	1 (given)
λ_{c} and f_{bw}	3 (A.9)	3 (A.8)	4 (A.2)	1 (given)	1 (given)	2 (A.13)
λ_{c} and λ_{bw}	2 (A.9)	2 (A.8)	3 (A.2)	1 (given)	3 (A.3)	1 (given)
f_{bw} and λ_{bw}	3 (A.9)	3 (A.8)	4 (A.2)	2 (A.12)	1 (given)	1 (given)

Annex B Standard spectral bands

This annex lists standard spectral bands (Section 9, page 18) included in the present specification, sourced from several standardizing organizations. Tables B.1–B.5 specify bands as frequencies between a minimum (f_{min}) and a maximum (f_{max}), while Table B.6 defines additional bands in terms of wavelengths between a minimum (λ_{min}) and a maximum (λ_{max}).

In this document, if the name of the organization is not specified when quoting a spectral band, it is assumed that the IEEE standard is being referenced (Table B.1).

Table B.1: *Standard spectral bands defined by the Institute of Electrical and Electronics Engineers (IEEE).*

Band name(s)	f_{min} (GHz)	f_{max} (GHz)
HF	0.003	0.030
VHF	0.03	0.30
UHF or P	0.3	1.0
L	1.0	2.0
S	2.0	4.0
C	4.0	8.0
X	8.0	12.0
Ku	12.0	18.0
K	18.0	26.5
Ka	26.5	40.0
V	40.0	75.0
W	75.0	110.0
G or mm	110.0	300.0

Table B.2: *Standard spectral bands defined by the International Telecommunication Union (ITU).*

Band name(s)	f_{min} (GHz)	f_{max} (GHz)
ELF or 1	0.000000003	0.000000030
SLF or 2	0.00000003	0.00000030
ULF or 3	0.0000003	0.0000030
VLF or 4	0.000003	0.000030
LF or 5	0.00003	0.00030
MF or 6	0.0003	0.0030
HF or 7	0.003	0.030
VHF or 8	0.03	0.30
UHF or 9	0.3	3.0
SHF or 10	3	30
EHF or 11	30	300
THF or THz	300	3,000

Table B.3: *Standard spectral bands defined by the North Atlantic Treaty Organization (NATO). The designation for band N or O is mostly used by the U.S. military and by the Supreme Allied Commander Atlantic (SACLANT). The band definitions in this table supersede the older NATO designations listed in Table B.4; both are retained in CSIAPS for compatibility purposes.*

Band name(s)	f_{min} (GHz)	f_{max} (GHz)
A	0.001	0.250
B	0.25	0.50
C	0.5	1.0
D	1	2
E	2	3
F	3	4
G	4	6
H	6	8
I	8	10
J	10	20
K	20	40
L	40	60
M	60	100
N or O	100	200

Table B.4: *Standard spectral bands formerly defined by the North Atlantic Treaty Organization (NATO). These definitions have been superseded by the designations in Table B.3, but are retained here for compatibility purposes.*

Band name(s)	f_{min} (GHz)	f_{max} (GHz)
I	0.100	0.150
G	0.150	0.225
P	0.225	0.390
L	0.39	1.55
S	1.55	3.90
C	3.9	6.2
X	6.2	10.9
Ku	10.9	20.0
Ka	20	36
Q	36	46
V	46	56
W	56	100

Table B.5: *Standard spectral bands defined for broadcasting by the European Union (EU).*

Band name(s)	f_{min} (GHz)	f_{max} (GHz)
I or 1	0.047	0.068
II or 2	0.088	0.108
III or 3	0.174	0.230
IV or 4	0.470	0.582
V or 5	0.582	0.862

Table B.6: *Standard spectral bands defined for physical optics. Precise thresholds for these bands vary in the literature but are generally close in value [1].*

Band name(s)	λ_{min} (nm)	λ_{max} (nm)
IR (Infrared)	700	1,000,000
LWIR (Long Wave IR) or TIR (Thermal IR)	8,000	15,000
MWIR (Medium Wave IR)	3,000	8,000
SWIR (Short Wave IR)	1,400	3,000
VNIR (Very Near IR)	400	1,400
NIR (Near IR)	700	1,400
VIS (Visible)	400	700
UV (Ultraviolet)	10	400
Red	620	750
Orange	590	620
Yellow	570	590
Green	495	570
Blue	450	495
Violet	380	450

DOCUMENT CONTROL DATA

*Security markings for the title, authors, abstract and keywords must be entered when the document is sensitive

1. ORIGINATOR (Name and address of the organization preparing the document. A DRDC Centre sponsoring a contractor's report, or a tasking agency, is entered in Section 8.) DRDC – Ottawa Research Centre 3701 Carling Avenue, Ottawa ON K1A 0Z4, Canada	2a. SECURITY MARKING (Overall security marking of the document, including supplemental markings if applicable.) CAN UNCLASSIFIED 2b. CONTROLLED GOODS NON-CONTROLLED GOODS DMC A

3. TITLE (The document title and sub-title as indicated on the title page.)

A specification for describing space-based ISR collection assets: Definitions, documentation, and application to mission planning software

4. AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used. Use semi-colon as delimiter)

Nandlall, S. D.; Secker, J.; Salciccioli, M. A.; Dessureault, D.; Roy, J.

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total pages, including Annexes, excluding DCD, covering and verso pages.)	6b. NO. OF REFS (Total cited in document.)
January 2019	64	13

7. DOCUMENT CATEGORY (e.g., Scientific Report, Contract Report, Scientific Letter)

Reference Document

8. SPONSORING CENTRE (The name and address of the department project or laboratory sponsoring the research and development.)

DRDC – Ottawa Research Centre
3701 Carling Avenue, Ottawa ON K1A 0Z4, Canada

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable contract number under which the document was written.)

10a. DRDC DOCUMENT NUMBER	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)
DRDC-RDDC-2018-D168	

11a. FUTURE DISTRIBUTION WITHIN CANADA (Approval for further dissemination of the document. Security classification must also be considered.)

Public release

11b. FUTURE DISTRIBUTION OUTSIDE CANADA (Approval for further dissemination of the document. Security classification must also be considered.)

12. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Use semi-colon as a delimiter.)

CSIAPS; Database; Specification; Satellite; Sensor; Beam

13. ABSTRACT/RÉSUMÉ (When available in the document, the French version of the abstract must be included here.)

The Commercial Satellite Imagery Acquisition Planning System (CSIAPS), developed by Defence Research and Development Canada (DRDC), is a Research and Development (R&D) prototype system for multi-satellite collection planning and simulation. The database of collection assets in CSIAPS is formatted according to the Collection Asset Specification (CAS) data structure presented in this document. The CAS was developed to provide a common framework and database for describing remote sensing collection assets as well as the relationships between these assets. The CAS database, developed as a service on a service-oriented architecture, holds multiple technical parameters (e.g., spatial resolution, swath width, and polarization options) and administrative parameters (e.g., cost, lead time, latency, and license) for constellations, satellites, sensors, and data, as well as for the satellite owners and operators. The underlying data model for the CAS is designed to be sensor-agnostic, in order to hold information on a wide range of collection assets.

The objective of this report is to describe the development of the CAS data structure as well as document all of the parameters that the CAS contains. The overall data structure and its implementation as a graph-based knowledge ontology are discussed, and definitions for all of the nodes and property parameters in the CAS data structure are provided. The CAS is shown to provide machine interpretable definitions of key concepts in remote sensing, in addition to facilitating interoperability and sharing with partners through standardization of terminology. This work facilitated the migration of CSIAPS to a service-oriented architecture that can be accessed externally by other users and applications.

Le Système de planification d’acquisition d’images de satellites commerciaux (SPAISC), conçu par Recherche et développement pour la défense Canada (RDDC), est un prototype de système de Recherche et développement (R&D) conçu pour la planification et la simulation de collectes multi-satellite. La base de données des ressources de collecte dans SPAISC est formatée conformément à la structure de données pour la spécification des ressources de collecte (SRC) présentée dans ce document, qui a été développée pour fournir un cadre commun et une base de données commune permettant de décrire les ressources de collecte de télédétection ainsi que les relations entre ces ressources. La base de données SRC, développée comme un service sur une architecture orientée service, contient plusieurs paramètres techniques (résolution spatiale, largeur de bande et options de polarisation, par exemple) et administratifs (coût, délai, latence et licence) pour les constellations, les satellites, les capteurs et les données, ainsi que pour les propriétaires et les opérateurs de satellites. Le modèle de données sous-jacent de la SRC est conçue pour être agnostique envers le type de capteur, afin de stocker des informations sur un large éventail de ressources de collecte.

L’objectif de ce rapport est de décrire le développement de la structure de données de la SRC et de documenter tous les paramètres que la SRC contient. La structure de données et son implémentation en tant qu’une ontologie de connaissances basée sur des graphes sont discutées, et des définitions pour tous les nœuds et paramètres de propriété de la structure de données de la SRC sont fournies. Il est également démontré que la SRC fournit des définitions interprétables par machine de concepts clés de la télédétection, en plus de faciliter l’interopérabilité et le partage d’information entre partenaires à travers la normalisation de la terminologie. Ce travail a facilité la migration du SPAISC vers une architecture orientée service accessible à l’externe par d’autres utilisateurs et applications.