

## NASA-Sponsored U.S. FGDC Remote Sensing Standards

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**ABSTRACT** NASA has sponsored the development of two FGDC remote sensing related standards, the FGDC Content Standard for Remote Sensing Swath Data and the FGDC Content Standard for Digital Geospatial Metadata: Extensions for Remote Sensing Metadata. The primary objective of the swath standard is to define the content for swath type of remote sensing data, thereby providing a solid basis from which to develop interoperable data formats for this common form of remote sensing data. The standard defines the minimal content requirements for a swath and the relationships among its individual components. It also discusses the treatment of optional supporting information within a swath. The standard provides a common framework for organizing a wide range of remotely sensed data, ranging from scanning, profiling, staring, or push-broom type remote sensing instruments, whether they be ground-based, shipboard, airborne, or space-borne. The remote sensing metadata standard is the extensions of the FGDC geospatial metadata standard. The purpose of these extensions is to provide a common terminology and set of definitions for documenting geospatial data obtained by remote sensing, within the framework of the *FGDC Content Standard for Digital Geospatial Metadata*. These *Remote Sensing Extensions* are to provide additional information particularly relevant to remote sensing: the geometry of the measurement process, the properties of the measuring instrument, the processing of raw readings into geospatial information, and the distinction between metadata applicable to an entire collection of data and those applicable only to component parts. Creating these extensions allow the accurate description of geospatial data derived from remote sensing measurements using a standard FGDC form. While the swath standard has already been approved by FGDC, the remote sensing metadata standard is being developed currently. We welcome comments and inputs from the international remote sensing community for the improvements of the draft remote sensing metadata standard.

**KEY WORDS** Geographic Information Standards, FGDC, Remote Sensing, Swath Data, Metadata, NSDI

### 1. Introduction

The Federal Geographic Data Committee (FGDC) was established under U.S. President Executive Order 12906, dated April 13, 1994, to coordinate the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 15 federal agencies that make up the FGDC are developing the NSDI in cooperation with organizations from state, local, and tribal governments, the academic community, and the private sector [FGDC, 1997a].

As defined in the FGDC Standards Reference Model, FGDC classifies standards into several categories. One of the categories of standards is data standards. Most FGDC standards are of this type. Data standards describe geographic objects, features or items that are collected, automated, or affected by activities or functions of agencies. There are five types of data standards defined by FGDC. One of them is data content standards, which provides semantic definitions of a set of objects and the relationship between the objects [FGDC, 1997b].

NASA, as a member of FGDC, has sponsored the development of two FGDC standards dealing with remote sensing data; the FGDC Content Standard for Remote Sensing Swath Data (subsequently called the Swath Standard), and the FGDC Content Standard for Digital Geospatial Metadata--Extensions for Remote Sensing Metadata (subsequently called the Remote Sensing Metadata Extensions or Standard). This paper describes these two standards and discusses NASA's future plan for developing remote sensing-related standards.

### 2. The Swath Standard

Swath is one of very common types of remote sensing data. The primary objective of the swath standard is to define the minimal content requirements for remote sensing swath data, thereby providing a solid basis from which to develop interoperable data formats for this common form of remote sensing data. It also discusses the treatment of optional supporting information within a swath. By developing such a standard, NASA hopes to achieve the following goals:

1. To provide a common conceptual framework for encoding swath and swath-like data,
2. To encourage inter-use of swath and swath-like data through implementation of transfer standards within the conceptual framework,
3. To use participatory involvement in the standard development to reach out to non-federal organizations, which will encourage broadly based application of the standard.

The Swath Standard supports the development of the NSDI by providing a common framework for organizing a wide range of remotely sensed data. The standard is useful for data from scanning, profiling, staring, or push-broom type remote sensing instruments, whether they be ground based, shipboard, airborne, or space-borne.

The Swath Standard defines the swath concept, the minimal components of a swath, and the relationships among the components [FGDC, 1999]. The swath standard inherits heavily from NASA EOSDIS swath concept [Ilg et al., 1995; Di et al., 1996; Demcsak, 1997; Wynne et al., 1997]. The following sections summarize the swath standard.

### 2.1. The Swath Concept

The swath concept is based on a typical satellite swath, where an instrument takes a series of scans approximately perpendicular to the ground track of the satellite as it moves along that ground track.

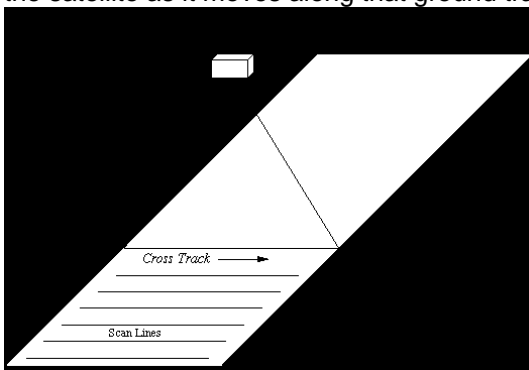


Figure1. Physical view of a simple swath: a time-ordered series of scan lines

Figure 1 shows this traditional *physical* view of a swath. For some instruments, the term swath is used to refer to a single scan of the instrument's various detectors. For the purposes of this standard, however, a series of one or more scans is considered to form a swath.

The *data* view of a swath is one where the data is ordered by *time* or a *time-like variable* (e.g., scan line counter). The data stored for every time entry can consist of time, geolocation (e.g., latitude, longitude), scalar values, 1D arrays of values (e.g.,

scan lines or profiles), or 2D arrays of values (e.g., multiple channel scan lines or profiles). Figure 2 shows a conceptual example.

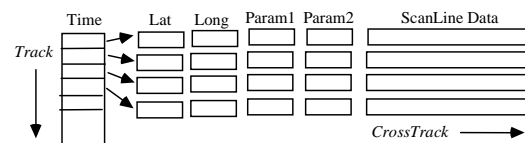


Figure 2. Data view of a swath: a time-ordered series of scalars and arrays

In this figure, each Time value has associated with it a Latitude and Longitude, two scalar values (Param1, Param2), and a 1D array containing ScanLine Data. Conceptually, each named item can be considered as a separate array. For example, in the figure above, Time would be a 1D array, as would Lat, Long, Param1, and Param2. The ScanLine Data would be a 2D array.

The concepts of 'Track' and 'Cross-Track' dimensions are fundamental to the swath model. The 'Track' dimension (which sometimes is referred to as 'along track') is defined as the dimension where time or a time-like variable increases or decreases monotonically. The 'Cross-Track' dimension, if used, defines an on-ground dimension perpendicular to the Track dimension. These two dimensions are fundamental because geolocation services depend on knowing which array dimensions correspond to the 'track' and 'cross-track' conceptual dimensions. Other conceptual dimensions, such as 'detector,' 'band,' 'channel,' and 'parameter' also can be defined. But since these dimensions are not used for geolocation services, this standard does not standardize their usage.

Table 1 shows required and optional conceptual dimensions for *scanning* instruments. Table 2 shows the same information for *profiling* instruments, and Table 3 shows the same information for a *combination scanning-profiling* instrument, such as TRMM Precipitation RADAR.

To apply these concepts to a particular instrument, the producer must determine the appropriate dimensions to use and arrange them in an acceptable order (see comments in Tables 1, 2 and 3). The names of the dimensions are meant only as points of reference. The data producer defines the actual names of the dimensions assigned within a swath structure.

### 2.2. The Components of a Swath

There are three components to establishing a swath structure:

1. the sensor data,

2. the geolocation information, and
3. the relationships between data and geolocation.

The elementary computer data structures for storing both the sensor data and the geolocation information are tables, arrays, or combinations of the two. A single swath structure can contain any number of *Tables* and *Multidimensional Arrays*. There is however one type of information that is special: *geolocation information*. In a swath, geolocation information can be stored as a table, as a series of arrays, or as a combination of a table and arrays. For example, It is legal to store Latitude and Longitude for every grid location (two

2D arrays, one for Latitude, one for Longitude), and also a Time value for every scanline (one 1D table). It is required that every swath contains some geolocation component.

These possible components are also summarized in Table 4. A particular swath may have multiple instances (or no instances) of any of these different components, except the geolocation objects. There cannot be more than one geolocation table and there should be a minimum of geolocation arrays in a single swath (having one table *and* a few arrays is okay).

Table 1. Dimension definitions for a generic scanning instrument

Dimension	Description	Comments
Track	Parallel to the ground track of the satellite	Required
Cross-Track	Perpendicular to the ground track of the satellite and parallel to the surface of the Earth	Required
Detector	Number of footprints per dwell	Optional
Band or Channel	Generally used for lower level data that has not been processed into science parameters	Optional; Band and Parameter are mutually exclusive
Parameter	No physical mapping; generally used for higher level data that has been processed into science parameters	Optional; Band and Parameter are mutually exclusive

Table 2. Dimension definitions for a generic profiling instrument

Dimension	Description	Comments
Track	Parallel to the ground track of the satellite	Required; must be the first declared dimension
Profile	Perpendicular to the ground track of the satellite and vertical with respect to the Earth	Required; ordering is unimportant; equivalent to atmospheric level
Detector	Number of foot prints per dwell	Optional; ordering is unimportant
Band or Channel	Generally used for lower level data that has not been processed into science parameters	Optional; ordering is unimportant; Band and Parameter are mutually exclusive
Parameter	No physical mapping; generally used for higher level data that has been processed into science parameters	Optional; ordering is unimportant; Band and Parameter are mutually exclusive

Table 3. Dimension definitions for a generic scanning-profiling instrument

Dimension	Description	Comments
Track	Parallel to the ground track of the satellite	Required
CrossTrack	Perpendicular to the ground track of the satellite and parallel to the surface of the Earth	Required
Profile	Perpendicular to the ground track of the satellite and "vertical" with respect to the Earth	Required; equivalent to atmospheric level
Detector	Number of foot prints per dwell	Optional
Band or Channel	Generally used for lower level data that has not been processed into science parameters	Optional; Band and Parameter are mutually exclusive
Parameter	No physical mapping; generally used for higher level data that has been processed into science parameters	Optional; Band and Parameter are mutually exclusive

Table 4. Possible Components of a Swath Structure

Component Type	Dim.	Comments
Geolocation Field	1D/2D	Time, Scan Number, Track Counter
Data Field	ND	Scalar values per Track entry
2D Data Array (scanner)	2D	Scan Lines per Track entry
2D Data Array (profiler)	2D	Profiles per Track entry
3D Data Array (scanner)	3D	Multiple Scan Lines per Track entry
3D Data Array (profiler)	3D	Multiple Profiles per Track entry
Geolocation relationships	N/A	Metadata defining the relationship between the data and the geolocation data

### 2.3 Defining a Swath

The reason for creating a common swath structure is to be able to provide common services on swaths that are instrument independent. For example, subsetting and subsampling by geolocation could be provided on data stored in a swath structure, independent of the instrument and product the data represents. Of course, the same services *could* be provided on the data even if it is not stored according to the swath conventions. However, the code to supply those services would have to be custom written for every instrument product.

These services all revolve around geolocation information (time, latitude, longitude, etc.). The primary considerations for the swath structure, therefore, concern these variables, what their format is, their dimensionality, and what the relationship is between other data arrays and the geolocation table and/or array(s).

#### 2.3.1 Sensor Data

Sensor data is the major component of the swath data; it records some aspects of information about the status of the Earth. Normally, sensor data will be processed by scientific algorithms for retrieving useful information. The sensor data, as stored in digital form, has the following characteristics:

1. Data type. The swath standard does not specify specific data types for sensor data. Some examples of data types that can be used are:
  - ASCII representation of numerical values
  - 8, 16, 32 and n-bit ( $n > 0$ ) binary integers.
  - 32 and 64 bit binary floats
2. Data structure. The data itself can be stored in tables or multidimensional arrays in the swath. The only limitation is that the slowest varied dimension (or the only dimension, in the case of a table) is the *Track* dimension.
3. Data unit
  - digital numbers (DN) of the sensor unit,
  - a physical unit, e.g., wind speed in m/s,
  - a transformed value of a physical unit, or

- a transformed value of the sensor digital numbers

#### 2.3.2. Geolocation

In a swath structure, one or more of the following methods must be used to provide geolocation information:

- Time/Location
- Analytic fit
- Attitude/Ephemeris data for spacecraft or airborne platforms.

When geolocation information for a swath structure is provided in Time/Location form, at least one of the following geolocation parameters must be provided:

- *Date/Time*
- *Latitude and Longitude* pairs
- *Colatitude and Longitude* pairs

Some combinations of *Time*, *Longitude*, and either *Latitude* or *Colatitude* are allowed in a swath. Besides the above-mentioned ones, the standard allows data producers to add any other geolocation information into a swath. Figure 3 shows a geolocation table that contains Time, Latitude, and Longitude columns for geolocation information per scan line.

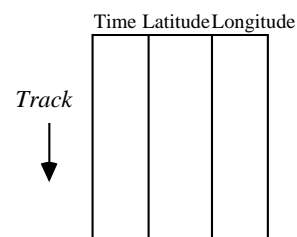


Figure 3. Geolocation Table with 1D Geolocation Information Included

For cases where geolocation exists for every Track, Cross-Track location, the Time, Latitude, and Longitude arrays should be two-dimensional. Figure 4 shows two 2D arrays of Latitude and Longitude, which for convenience have been combined into a single 3D array.

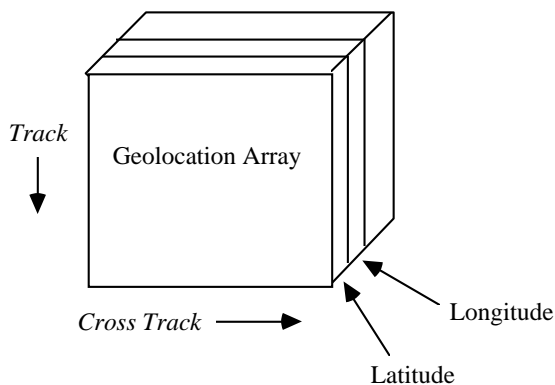


Figure 4. Geolocation Array containing Latitude and Longitude planes

When the geolocation information is presented in the form of a function that gives latitude or colatitude and longitude as a function of data array index coordinates (Cross-Track and Track), the required information depends on the form of the function. The function may be a polynomial or some other function of the coordinate array position ( $x, y$ ). For polynomial function, the standard only requires to state that the functional fit is to a polynomial and give the values of the polynomial coefficients. When the geolocation information uses other functional forms, then the form of the function, definitions of any coefficients or terms, and the values of those coefficients should be provided.

When attitude and ephemeris data are provided for a swath structure describing measurements from satellite or airborne platforms, the following information is required to enable the user to calculate both geolocation and viewing geometry for the measurements:

- Date/Time
- Platform attitude roll, pitch, and yaw angles ( $\xi_r, \xi_p, \xi_y$ )
- Platform position vector ( $x, y, z$ )

The data set may provide the platform attitude and position information directly or it may contain other information from which attitude and position can be calculated. Platform velocity vector ( $u, v, w$ ) is operational since it can be calculated from the position vector and time. The arrangement of attitude and ephemeris data is the same as that of the time/location geolocation method.

### 2.3.3. The Relationship between Geolocation and Sensor Data

The next step is to match up the data elements with the geolocation parameters. This is done by mapping dimensions of the data elements to the "Track" and "Cross-Track" dimensions of the geolocation parameters. In order to define the

relationship between Geolocation data and sensor data, two items have to be defined:

- 1) Dimension definition. It defines a dimension of geolocation data or sensor data. It has to be defined for each dimension in both geolocation data and the sensor data. The dimension definition consists of two parts:
  - Dimension Name: The name of a dimension. The name could be a string of ASCII characters up to 256 characters.
  - Dimension Size: The size of a dimension. It should be encoded in either Binary or ASCII integers.
- 2) Dimension mappings. The dimension mapping defines the relationship between geolocation dimensions and the data dimensions. A dimension mapping should consist of the following four parts:
  - Data Dimension: the name of the dimension of the data object being mapped.
  - Geolocation Dimension: the name of the dimension the geolocation object is being mapped to.
  - Offset: the offset into the data array along Data Dimension where the first geolocation value applies. A negative value indicates that the offset is instead applied to Geolocation Dimension, which is useful in cases where the geolocation object is larger than the data object.
  - Increment: the increment along Data Dimension for which there is geolocation data in the Geolocation object. A negative value indicates that the increment is applied along GeoDimension, which is useful in cases where the geolocation object is larger than the data object.

This standard does not specify which mechanism to be used to encode the mappings. It will depend on the encoding standard of this content standard to specify an encoding method.

### 3. The Draft Remote Sensing Metadata Standard

The FGDC Content Standard for Digital Geospatial Metadata [FGDC, 1998] defines common geospatial metadata that provide information for prospective users to determine the following information about a geospatial data set: its availability, its fitness for an intended use, and the means of accessing and successfully transferring it. Because of its generality, the standard may not meet the metadata needs for specific geospatial domains.

In January 1999, NASA submitted a proposal to FGDC for developing the remote sensing metadata extensions that would define remote sensing specific metadata within the framework of the

FGDC metadata standard [NASA, 1999]. The FGDC Standard Working Group (SWG) approved the proposal after 30 days of public review of the proposal. SWG assigned the project of developing the standard to the FGDC Imagery Subgroup. The subgroup then formed a NASA-led core development team with members from U.S. federal agencies, industries, and universities in June 1999. Currently the team has developed the draft standard that is being reviewed by members of the imagery subgroup. It is expected that the draft standard will be subjected to many modifications before it becomes an official FGDC standard.

The purpose of *Remote Sensing Extensions* is to provide additional information particularly relevant to remote sensing: the geometry of the measurement process, the properties of the measuring instrument, the processing of raw readings into geospatial information, and the distinction between metadata applicable to an entire collection of data and those applicable only to component parts. For that purpose, the draft *Remote Sensing Extensions* establish the names, definitions, and permissible values for new data elements and the compound elements of which they are the components. These new elements are placed within the structure of the *FGDC Metadata Content Standard*, allowing the combination of the original standard and the new extensions to be treated as a single entity. The draft *Remote Sensing Extensions* do not specify either the means by which this information is organized in a computer system for data transfer or the means by which this information is transmitted, communicated, or presented to the user. This standard is intended to support the collection and processing of geospatial metadata for data derived from remote sensing. It is intended to be useable by all levels of government and the private sector and not intended to reflect an implementation design.

#### 4. Future Plan

NASA plans to continuously play an active role in the development of FGDC standards related to remote sensing. Based on the FGDC directive for the standard approval processes [FGDC, 1997c], the current draft metadata standard will be reviewed by members of the Imagery Subgroup. The draft will be modified based on members' comments. After the Imagery Subgroup is satisfied with the draft, the subgroup will recommend the draft standard to the Standard Working Group. SWG will review the draft standard and send comments back to the Imagery Subgroup for revisions. The draft standard then will be published on the Federal Register and the FGDC Web site and sent out through the FGDC

mailing lists for a three-month public review. Comments from the public review will be forwarded to the Imagery Subgroup and authors of the draft standard. Based on comments from the public and SWG members, SWG will decide whether or not to recommend the standard to FGDC's Coordination Group for endorsement. Once the FGDC Coordination Group and then the FGDC Steering Committee endorse the Swath Standard, it will become an FGDC standard. We expect that the draft will become an official FGDC standard around October 2000 if everything goes smoothly. During the standard approval processes, especially during the three-month public review period, the public has many opportunities to participate in the development and review of the Remote Sensing Metadata Standard. Both NASA and FGDC Imagery Subgroup welcome such participation.

Besides the development of the FGDC remote sensing metadata standard, NASA is planning to develop other remote sensing related standards for FGDC, such as the encoding standard for the swath data, the content standard for remote sensing grid data, and the content standard for remotely sensed point measurement. We also plan to integrate both the FGDC swath standard and the remote sensing metadata standard into the ISO TC/211 Geographic Information Standards through cooperation with the ISO TC/211 Imagery Components project.

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