

# Technical Review of ERS and RADARSAT SAR CEOS Format for Geocoding and Terrain Correction Applications

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**Abstract :** This study introduces the CEOS (Committee for Earth Observing Satellites) standard format structure that is applicable to image formats of Earth observation systems, and describes several important parameters for post-process applications, especially in precise SAR geocoding and terrain correction application. ERS and RADARSAT were chosen as a representative case and the meaning and usage of various fields in LEADER file were investigated in detail from the viewpoint of SAR geocoding and terrain correction applications.

**Key Words :** CEOS, SAR, LEADER, ERS, RADARSAT

## 1. Introduction

This review provides a technical information containing the general introduction on the CEOS format and describing useful parameters which can be extracted from the CEOS header from the viewpoint of the Earth remote sensing applications processing (Man-Jo, 2000) and it is consisted of sections as follows: an introduction on the concept and structure of the CEOS format are reviewed in Section 2, CEOS format of the ERS PRI product (CEOS Format, 2000) is described in Section 3, CEOS format of the RADARSAT SGF product (RADARSAT CEOS Product Specification (RSI-GS-026), 1997) is described in Section 4, results developed are shown in Section 5, and

conclusions and comments are given in Section 6.

## 2. Overview of the CEOS Standard Format

### 1) Introduction

SAR (Synthetic Aperture Radar) data products from the various operational SAR instruments in orbit and to be launched in future are distributed to users in digital and analog print form. The media for the digital distribution cover 9-track magnetic tapes, HDDT (High Density Digital Tape) and various other devices including high-speed digital networks. Photographic media cover transparencies and prints in various sizes.

The standards for distribution in digital and analog form have been discussed and formalized by an international working group, consisting of technical experts in SAR processing methodology who were also conversant with formatting standards and procedures.

The CEOS was established in 1984, with membership open to international, or regional organizations responsible for a space-borne earth observation program (Garbuk and Gershenzon, 1997). The major objective was the enhancement of the benefits of space-borne Earth observations data, for CEOS members and for the international user community, to support both interdisciplinary and international applications. The CEOS working group on data (CEOS-WGD) was established to facilitate the use of data from earth observations and to standardize various aspects of data management, such as formats for archive and distribution, directories and inventories of available data sets, and networks for metadata and product access.

In particular, the subgroup on data formats has taken a strong coordination role in the development and maintenance of user product formats, which conform to a CEOS-recommended standard. The adaptation of this approach facilitates the ability to generate and read data products that are supplied by different agencies and from any different sensors. The prime goals of the CEOS-WGD format subgroup are to minimize the effort required to write and read data products from similar sensors on board different platforms, and to read data products from the same sensors which are supplied by different agencies.

The mechanism for archiving this is by maintaining standards for a family of formats, classes of sensors, among these classes being optical sensors (scanning or push-broom) and the general

case of SAR sensors. A permanent team of format experts, including representatives from other international standards organizations (such as the Consultative Committee on Space Data Systems, CCSDS) takes responsibility for the long-term maintenance and enhancement of the standard format family, and a temporary group of sensor experts assists in the development of approved recommended formats for a given sensor type. This is archived by establishing the minimum set of parameters required to encapsulate, describe and access data from all known or planned implementations of that specific sensor type.

This review introduces the CEOS standard format in general and describes several important parameters for applications processing, especially in precise SAR geocoding and terrain correction application.

## 2) Structure of the Standard Format

The standard format family incorporates the concept of a superstructure at four distinct levels, namely, volume, file, record and data field, which permits the precise structure of the dataset to be defined within the format itself.

Within the standard format family, the data files constituting one product are logically grouped on one or more tapes, and this grouping is referred to as a logical volume. The individual tapes are referred to as physical volumes. The family is sufficiently general to permit the storage of many logical volumes within one physical volume, or split one logical volume across several different physical volumes.

At the highest level of organization, a logical volume written in the standard format consists of an introductory file (the volume directory, which defines the logical and physical construction of the volume), the set of data files, and finally, a

terminating file (the null volume directory). In the case of multiple logical volumes constituting a volume set, the null volume directory is written only once, to terminate the set.

Within the volume directory file, the first record is a volume descriptor record. This is followed by one file pointer record, for each data file within the logical volume, which is used to define the logical construction of the referenced data file. This is optionally followed by one or more text records, which serve only as descriptive records stored in free-form alphanumeric format.

Within each data file, the first record is a file descriptor record containing detailed information on how to interpret the content of its constituent records. In addition, each file has associated with a file class, to identify the broad category to which the data belongs. Finally, within each data record, the first six fields (twelve bytes) are normally used to specify that record's sequence number within the file, some more specific record type coding information, and the length of the record. These overall concepts are exemplified in Fig. 1.

The CEOS recommendation for a SAR format has been defined to be applicable to a variety of radar sensors, and covers product definition, logical volume definition, file structure within a logical volume, file classes, record structure within a file, record types and data structure within a record. The definition of record structures is sufficiently general to cover many product types. Hence for implementation of specific product types, there may be many instances where values for specific fields are not relevant. In such cases, the fields are blank-filled (or zero-filled). When a complete record is not relevant, then the whole record is omitted from the file. For the general case, only three file types are required. They are the SAR LEADER FILE, the IMAGERY OPTIONS

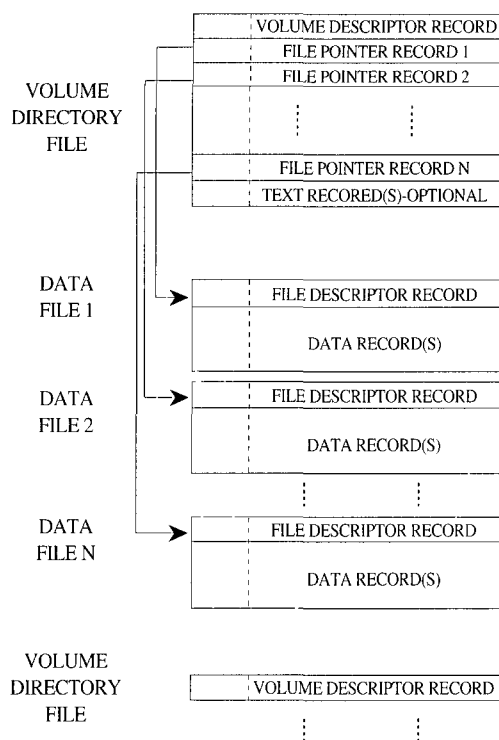


Fig. 1. General structure of CEOS Standard Format

FILE and the SAR TRAILER FILE.

### 3) SAR Leader File

As explained above, the exact contents of the SAR LEADER FILE are determined by the product type and sensor type combination. In the cases where the auxiliary data is inappropriate or the data is not available, the corresponding field of the file descriptor record variable segment, which itemizes the count and length of all possible record types in the file, has a zero record count and the records are not written to the SAR LEADER FILE.

In the instances where the auxiliary data to complete the record is not available until the end of the product generation process, the format allows the inclusion of these records in the SAR TRAILER FILE instead of the SAR LEADER FILE. Hence, the format definition of the auxiliary

Table 1. Record Types and Description

Record Types	Description
Data set summary	Information about the mission, data acquisition, sensor parameters and processing parameters used to generate the accompanying the SAR data set
Map projection data	Information about the geometric characteristics of the input (raw) and processed imagery data
Platform position data	State vectors (position and velocity) and orbit information for the platform
Attitude data	Attitude information of the sensor platform over the time spanning the SAR acquisition
Radiometric data	Transformation tables that relate data numbers in the image to a geophysical parameter of the target area (e.g. backscatter coefficient, soil moisture or soil roughness)
Radiometric compensation	Information about the range and azimuth radiometric correction applied to the data, including compensation for the antenna illumination pattern in the range direction and/or illumination variations in azimuth due to platform roll
Data quality summary	Quality information about the dataset
Data histogram	Sampled histograms, and statistics about the dataset as derived from the histograms
Range spectra	Spectra of the unprocessed raw data
Digital Elevation Model (DEM) descriptor	Description of the characteristics of the DEM used in the generation of the geocoded terrain height corrected SAR image data
Radar parameter data update	Updated radar parameters
Annotation data	Annotation which would accompany a photographic product of the same product
Detailed processing parameters	All processing parameters necessary to characterize the processor performance and operation. This record may be both sensor and processing facility dependent and its format may differ from one facility to another
Calibration data	Information used to calibrate the SAR instrument, from preflight sensor measurements and on-ground calibration
Ground Control Point (GCP)	Description of the GCPs used to adjust the initial system geometry and to assess the geometric quality of the geocoded SAR image data
Facility related data	A free format all information that is strictly related to the processing facility

information records is identical for SAR LEADER FILE and SAR TRAILER FILES.

The record types described in Table 1 can occur in either the SAR LEADER FILE or SAR TRAILER FILE.

#### 4) Imagery Options File

The SAR data is stored in a class imagery option file, as either unprocessed (raw) signal data, processed image data or enhanced SAR data.

#### 5) SAR Trailer File

As explained in the SAR LEADER FILE section, the basic building blocks for the file and record construction for the SAR TRAILER FILE are identical to those for the SAR LEADER FILE.

In next two sections, the CEOS product format

Table 2. General Structure of ERS PRI Product

Product Component	Record Size
Volume Directory File	
Volume Descriptor Record	360 bytes
Leader File Pointer Record	360 bytes
Data Set File Pointer Record	360 bytes
Text Record	360 bytes
Leader File	
File Descriptor Record	720 bytes
Data Set Summary File	1886 bytes
Map Projection Record	1620 bytes
Platform Position Record	variable
Facility Related Data Record General Type	12288 bytes
Facility Related Data Record PCS Quality Type	12288 bytes
Data Set File	
File Descriptor Record	16012 bytes
Image Data Records	16012 bytes
Null Volume File	
Volume Descriptor Record	360 bytes

which ERS and RADARSAT use is described in detail.

### 3. ERS PRI Product Format

As a representative example of SAR sensor, in this section, the CEOS SAR product format of ERS is shown. According to the format specification, parameters which are useful for applications processing, especially in SAR geocoding and terrain correction, are identified and explained its

importance in applications processing.

#### 1) General Structure

Table 2 shows the general structure of the ERS PRI product and its record size.

#### 2) Selected Parameters

In this section, parameters which are useful for applications processing, especially in SAR geocoding and terrain correction, are identified and its importance in applications processing is explained. The format column in the following

Table 3. ERS SAR Leader File / Data Set Summary Record

Field	Bytes	Format	Description	Unit
16	165-180	A16	Ellipsoid designator	
17	181-196	F16.7	Ellipsoid semi-major axis	km
18	197-212	F16.7	Ellipsoid semi-minor axis	km
19	213-228	F16.7	Earth mass * gravitational constant (M*G)	kg.m/s <sup>2</sup>
21	245-260	F16.7	Ellipsoid J2 parameter	
22	261-276	F16.7	Ellipsoid J3 parameter	
23	277-292	F16.7	Ellipsoid J4 parameter	
35	445-452	A8	Orbit number	
40	485-492	F8.3	Incidence angle at scene centre as derived from sensor platform orientation	degrees
41	493-500	F8.3	Radar frequency	GHz
42	501-516	F8.3	Radar wavelength	meters
57	711-726	F16.7	Range sampling rate	MHz
74	935-950	F16.7	Pulse repetition frequency (PRF) (actual value)	Hz
81	1047-1062	A16	Processing facility identifier	
88	1175-1190	F16.7	Nominal number of looks processed in azimuth	looks
89	1191-1206	F16.7	Nominal number of looks processed in range	looks
97	1351-1366	F16.7	Nominal resolution in range (3-db width)	meters
98	1367-1382	F16.7	Nominal resolution in azimuth (3-db width)	meters
108	1527-1534	A8	Time direction indicator along pixel direction	
109	1535-1542	A8	Time direction indicator along line direction	
121	1687-1702	F16.7	Line spacing	meters
122	1703-1718	F16.7	Pixel spacing	meters
126/1	1767-1782	F16.7	Zero-Doppler range time(two-way) of first range pixel	millisec
126/2	1783-1798	F16.7	Zero-Doppler range time(two-way) of center range pixel	millisec
126/3	1799-1814	F16.7	Zero-Doppler range time(two-way) of last range pixel	millisec
126/4	1815-1838	A24	Zero-Doppler azimuth time(two-way) of first azimuth pixel (UTC) <dd-MMM-yyyy\$hh:mm:ss.ttt>	
126/5	1839-1862	A24	Zero-Doppler azimuth time(two-way) of center azimuth pixel (UTC) <dd-MMM-yyyy\$hh:mm:ss.ttt>	
126/6	1863-1886	A24	Zero-Doppler azimuth time(two-way) of last azimuth pixel (UTC) <dd-MMM-yyyy\$hh:mm:ss.ttt>	

Table 4. ERS SAR Leader File / Map Projection Data Record

Field	Bytes	Format	Description	Unit
8	29-60	A32	Map projection descriptor	
9	61-76	I16	Number of pixels per line of image	pixels
10	77-92	I16	Number of lines	lines
11	93-108	F16.7	Nominal inter-pixel distance in output scene	meters
12	109-124	F16.7	Nominal inter-line distance in output scene	meters
20	237-268	A32	Name of reference ellipsoid	
21	269-284	F16.7	Semi-major axis of reference ellipsoid	km
22	285-300	F16.7	Semi-minor axis of reference ellipsoid	km
68	1073-1088	F16.7	1st line, 1st pixel geodetic latitude (positive for north latitude)	degrees
69	1089-1104	F16.7	1st line, 1st pixel geodetic longitude (negative for west longitude)	degrees
70	1105-1120	F16.7	1st line, last pixel geodetic latitude (positive for north latitude)	Degrees
71	1121-1136	F16.7	1st line, last pixel geodetic longitude (negative for west longitude)	Degrees
72	1137-1152	F16.7	Last line, last pixel geodetic latitude (positive for north latitude)	Degrees
73	1153-1168	F16.7	Last line, last pixel geodetic longitude (negative for west longitude)	Degrees
74	1169-1184	F16.7	Last line, 1st pixel geodetic latitude (positive for north latitude)	Degrees
75	1185-1200	F16.7	Last line, 1st pixel geodetic longitude (negative for west longitude)	Degrees

Table 5. ERS SAR Leader File / Platform Position Data Record

Field	Bytes	Format	Description	Unit
14	141-144	I4	Number of data points (up to 64)	
15	145-148	I4	Year of data point <YYYY>	
16	149-152	I4	Month of data point <\$\$MM>	
17	153-156	I4	Day of data point <\$\$DD>	
18	157-160	I4	Day in the year <GMT> (1st Jan. = day 1)	
19	161-182	D22.15	Seconds of day of data	
20	183-204	D22.15	Time interval between data points	
21	205-268	A64	Reference coordinate system	
22	269-290	D22.15	Greenwich mean hour angle	
23	291-306	F16.7	Along track position error	
24	307-322	F16.7	Across track position error	
25	323-338	F16.7	Radial position error	
29	387-452	3D22.15	1st data point - position vector X 1st data point - position vector Y 1st data point - position vector Z	
30	453-518	3D22.15	1st data point - velocity vector X' 1st data point - velocity vector Y' 1st data point - velocity vector Z'	
31	519-584	3D22.15	2nd data point - position vector X 2nd data point - position vector Y 2nd data point - position vector Z	
32	585-650	3D22.15	2nd data point - velocity vector X' 2nd data point - velocity vector Y' 2nd data point - velocity vector Z'	

Table 6. ERS SAR Leader File / Facility Related Data Record [General Type]

Field	Bytes	Format	Description	Unit
56	583-598	F16.7	Incidence angle at first range pixel (at mid-azimuth)	
57	599-614	F16.7	Incidence angle at center range pixel (at mid-azimuth)	
58	615-630	F16.7	Incidence angle at lat range pixel (at mid-azimuth)	
62	663-678	F16.7	Absolute calibration constant K (scalar)	
63	679-694	F16.7	Upper bound calibration constant K (+0.75db)	
64	695-710	F16.7	Lower bound calibration constant K (-0.75db)	
65	711-726	F16.7	Estimated noise-equivalent	
140	1855-1934	4E20.10	<p>4 coefficients of the ground range to slant range conversion polynomial</p> <ul style="list-style-type: none"> <li>For the vmp, the coefficients can be used to calculate the range time of the output range sample as a function of ground range as follows:  <math display="block">T_n = (C_0 + C_1 G_n + C_2 G_n^2 + C_3 G_n^3) / F_r + T_0</math> where,  <math>G_n</math> is ground range of sample n from first range sample in meters.  <math>F_r</math> is range sampling frequency in Hz.  <math>T_0</math> is the range time of the first output range sample.</li> <li>For the bangkok processor, the coefficients can be used to calculate the slant range sample corresponding to the output range sample as a function of ground range as follows:  <math display="block">S_n = C_0 + C_1 G_n + C_2 G_n^2 + C_3 G_n^3</math> where,  <math>G_n</math> is ground range sample number.  <math>S_n</math> is the corresponding slant range sample.</li> </ul>	
141	1935-2034	5E20.10	<p>5 coefficients of the antenna elevation pattern polynomial</p> <ul style="list-style-type: none"> <li>For the vmp, the coefficients can be used to calculate the antenna elevation pattern as a function of range time as follows:  <math display="block">A_t = C_0 + C_1 t + C_2 t^2 + C_3 t^3 + C_4 t^4</math> where,  <math>A_t</math> is in dB.  <math>t</math> is the range time relative to the polynomial origin in seconds.</li> <li>For the bangkok processor, the coefficients can be used to calculate the antenna elevation pattern as a function of range pixel look angle as follows:  <math display="block">A_l = C_0 + C_1 t + C_2 t^2 + C_3 t^3 + C_4 t^4</math> where,  <math>A_l</math> is in natural value from 1 to 0.  <math>t</math> is the range pixel look angle in degrees.</li> </ul>	
142	2035-2050	E16.7	Range time of origin of antenna pattern polynomial	

tables is specified using FORTRAN format specifier.

example and all the numbers shown here are extracted from the COES header of the SGF image.

## 4. RADARSAT SGF Product Format

### 1) General Structure

A RADARSAT SGF image is used as an

### 2) Selected Parameters

In this section, parameters which are useful for RADARSAT SAR geocoding and terrain

Table 7. General Structure of RADARSAT SGF Product

Product Component	Record Size
Volume Directory File	
Volume Descriptor Record	360 bytes
Leader File Pointer Record	360 bytes
Text Record	360 bytes
Leader File	
File Descriptor Record	720 bytes
Data Set Summary File	4096 bytes
Data Quality Summary	1620 bytes
Signal Data Histogram	16920 bytes
Processed Data (16bit) Histogram	16920 bytes
Processing Parameters	7726 bytes
Map Projection Record	1620 bytes
Platform Position Record	8960 bytes
Attitude Data	8960 bytes
Radiometric Data	9860 bytes
Radiometric Compensation Data	16836 bytes
Data Set File	
File Descriptor Record	16252 bytes
Signal Data	variable
Processed Data	variable
Trailer File	
File Descriptor Record	720 bytes
Data Set Summary File	4096 bytes
Data Quality Summary	1620 bytes
Signal Data Histogram	16920 bytes
Processed Data (8bit) Histogram	16920 bytes
Processing Parameters	7726 bytes
Attitude Data	8960 bytes
Radiometric Data	9860 bytes
Radiometric Compensation Data	16836 bytes
Null Volume File	
Volume Descriptor Record	360 bytes

correction, are identified and explained for its importance in geocoding and terrain correction applications.

## 5. Examples

In order to extract the necessary parameters from the CEOS header easily, a utility program has been developed. This was written using Visual Basic for Application (VBA) of Windows Excel. Fig. 2 shows the user interface of the program and an example output.

Another program to extract the image from the Product Data Set File has been developed using IDL. Table 13 contains the information about the ERS image to be extracted and Fig. 3 shows the extracted scene.

## 6. Conclusions

From the viewpoint of the post-process application and development, it is important to understand the various parameters which are used during the post-process stage.

In this study, the specific product format of ERS and RADARSAT based on CEOS Standard Format is investigated in detail, main parameters

Table 8. RADARSAT SAR Leader File / Data Quality Summary Record

Field	Bytes	Format	Description	Unit
11	31-46	F16.7	Nominal integrated side lobe ratio (ISLR)	dB
12	47-62	F16.7	Nominal peak side lobe ration (PSLR)	dB
17	127-142	F16.7	Nominal slant range resolution	meters
18	143-158	F16.7	Nominal azimuth resolution	meters
19	159-174	F16.7	Nominal radiometric resolution	dB
76	1343-1358	F16.7	Nominal noise equivalent	dB
77	1359-1374	F16.7	Nominal equivalent number of looks	looks



Table 9. RADARSAT SAR Leader File / Detailed Processing Parameters Record

Field	Bytes	Format	Description	Unit
424	4883-4886	I4	Number of SRGR coefficients sets	
425	4887-4907	A21	SRGR update date/time	
426-431	4908-5003	6E16.7	SRGR coefficients This can be used to calculate the slant range of range sample as a function of ground range.	

Table 10. RADARSAT SAR Leader File / Platform Position Data Record

Field	Bytes	Format	Description	Unit
14	141-144	I4	Number of data points (up to 64)	
15	145-148	I4	Year of data point <YYYY>	
16	149-152	I4	Month of data point <\$\$MM>	
17	153-156	I4	Day of data point <\$\$DD>	
18	157-160	I4	Day in the year <GMT> (1st Jan. = day 1)	
19	161-182	D22.15	Seconds of day of data	
20	183-204	D22.15	Time interval between data points	second
21	205-268	A64	Reference coordinate system	
22	269-290	D22.15	Greenwich mean hour angle	degree
23	291-306	F16.7	Along track position error	meters
24	307-322	F16.7	Across track position error	meters
25	323-338	F16.7	Radial position error	meters
26	339-354	F16.7	Along track velocity error	meters
27	355-370	F16.7	Across track velocity error	meters
28	371-386	F16.7	Radial velocity error	meters
29	387-452	3D22.15	Data point position	meters
30	453-518	3D22.15	Data point velocity	mm/sec
31-156	519-8834		Repeat fields 29 to 30, 63 times	

Table 11. RADARSAT SAR Leader File / Radiometric Compensation Data Record

Field	Bytes	Format	Description	Unit
15	85-92	I8	Number of beam table entries	
16	93-4188	256F16.7	Elevation gain beam profile	
17	4189-4204	A16	Beam type	
18	4205-4220	F16.7	Look angle of beam table center	
19	4221-4236	F16.7	Increment between beam table entries	

Table 12. RADARSAT SAR Leader File / Processed Data Record

Field	Bytes	Format	Description	Unit
13	37-40	B4	Acquisition year	
14	41-44	B4	Acquisition day of year	
15	45-48	B4	Acquisition seconds of day	millisec
20	57-60	B4	Pulse repetition frequency	Hz
22	65-68	B4	Slant range to first pixel	meters
24	73-76	B4	Slant range to last pixel	meters
39	133-136	B4	First pixel latitude (millionths of degree)	degrees
40	137-140	B4	Center pixel latitude (millionths of degree)	degrees
41	141-144	B4	Last pixel latitude (millionths of degree)	degrees
42	145-148	B4	First pixel longitude (millionths of degree)	degrees
43	149-152	B4	Center pixel longitude (millionths of degree)	degrees
44	153-156	B4	Last pixel longitude (millionths of degree)	degrees

Table 13. Information of Sample Image

Sensor	ERS-1 AMI (Active Microwave Instrument)	
Orbit	5802 (Descending)	
Acquisition Time	25th August 1992	02:16:21.00
Scene Center	37.3964 N	126.5909 E
Product	SAR.PRI	
Number of Lines	5248	
Number of Pixels	5120	
Line Spacing	20.0 m	
Pixel Spacing	20.0 m	

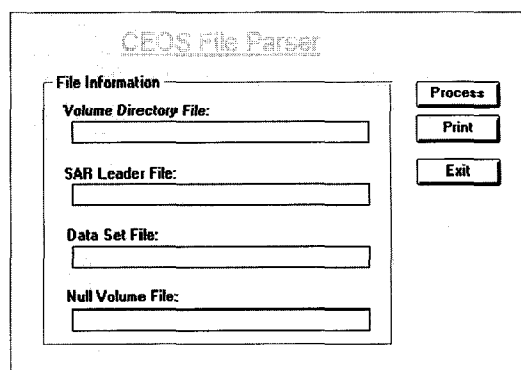


Fig. 2. User Interface of the CEOS Parsing Program



Fig. 3. The Extracted Scene

for post-process are highlighted, and two utility programs are implemented as shown in Fig. 2.

With those tools, it is easy and speedy to extract the header information and to utilize at later processing stage, especially in SAR geocoding processing.

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