EQ Simulator Output Event File Format

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Version 0.4

1. Overview

The event file lists all the earthquakes that occur during a simulation. There is a one-line *summary* for each event. Optionally, there may be a *slip map* which describes the distribution of slip over the fault surface during an event.

An event summary contains:

- An integer identification number.
- The magnitude.
- The starting time and duration of the event.
- The identification number of the fault section where the event occurred.
- The extent of the rupture, along strike and along depth.
- The hypocenter location, along strike and along depth.
- The area that ruptured.
- The mean slip.
- The seismic moment.
- Shear stress before and after the event.
- Normal stress before and after the event.

To create a slip map, you define a set of rectangular patches on the fault surface. For each patch, the file contains:

- The extent of the patch, along strike and along depth.
- The area that ruptured within the patch.
- The mean slip within the patch.
- The seismic moment within the patch.
- Shear stress before and after the event, within the patch.
- Normal stress before and after the event, within the patch.
- Optionally, a list of the element numbers that comprise the patch.

2. Earthquake Description

2.1. Events

Simulator output is organized into a series of *events*, each of which is an individual earthquake. The file includes a summary of each event.

The format described here allows a single event to span multiple fault sections.

2.2. Slip Maps

A *slip map* gives the distribution of slip over the fault surface, within a single event. Typically, slip maps are given only for a small fraction of events. To create a slip map, you lay out a set of rectangles on the fault surface, and give the amount of slip that occurred within each rectangle.

Optionally, you can include a list of the elements that make up each patch.

2.3. Coordinates

In the input geometry file document, you can find an explanation of our coordinate system. The fault system is divided into one or more *fault sections*, each of which can be either part of a fault or an entire fault. Any point on the fault surface has four coordinates: *latitude*, *longitude*, *depth*, and *DAS*. The term DAS stands for *distance along strike*. DAS is defined separately for each fault section, and represents how far along the fault strike a given point is located.

For output event files, the important concept is that for each fault section, the pair (DAS, depth) is a two-dimensional coordinate system for that section's fault surface.

Each fault section has a *section identification number* which we abbreviate as *SID*. So, any point anywhere in the fault system can be identified by the triple (SID, DAS, depth). We use the ordered triple (SID, DAS, depth) to specify the locations of earthquakes. Notice that these triples are completely independent of the mesh used to describe the fault system.

3. File Format

The output event file is a container, as described in the EQ Simulator Container Format. The container format lets us store different kinds of records in a single file.

3.1. Overall File Structure

The following table shows the overall structure of an output event file. Specific kinds of records are described later.

	Part	**Description**
1	Header	File header that contains the file signature, metadata, and record descriptors, as described in the container file specification.
2	Event list	Multiple lines that describe the earthquake events. Each event may be described by one line or several lines, depending on the level of detail desired.
3	End-of-file	One line that marks the end of the file, as described in the container file specification.

The signature for an output event file is "EQSim_Output_Event_2". The specification level of this document is 2. So, the first line of the file contains the following signature record:

```
101 EQSim_Output_Event_2 2
```

Refer to the container file specification for an explanation of signature and specification level.

4. Record Formats

The following table shows the standard kinds of data records for the output event file.

Kind	Name	Description
200	event_summary	Event summary record
201	slip_map	Slip map record
202	slip_element	Slip element record

These are all data records, which means that each record contains a series of data fields. Each kind of record is explained below.

The names "event_summary" and so forth must be listed in the descriptor part of the file header.

4.1. Event Summary Record

```
200 event_id magnitude time duration
    sid depth_lo depth_hi das_lo das_hi
    hypo_depth hypo_das area mean_slip moment
    shear_before shear_after normal_before normal_after
    comment_text
```

There is a summary record for each event. If any additional records are required to describe a particular event, they appear after the summary record.

Events must be listed in time order, that is, in the order in which they occurred. (If events overlap in time, they must be listed in the order in which they started.)

The record contains 18 data fields, described in the following table.

	Name	Type	Description
1	event_id	integer	A positive integer which identifies this event. Event numbers must appear in increasing order in the file. (The implication is that event numbers must be assigned in the order in which events start.) However, they are not required to be consecutive numbers.
2	magnitude	real	Event magnitude.

3	time	real	Time at which the event started, measured in seconds from the start of the simulation. Times should be written with the greatest possible precision (16 significant digits for double-precision floating-point variables) to allow sufficient accuracy for simulations that span many millions of years.
4	duration	real	The duration of the event, in seconds.
5	sid	integer	The section identification number, or SID, for the fault section on which the event occurred. See below for an explanation of what to do if an event spans multiple fault sections.
6	depth_lo	real	The lowest value of depth for the portion of the fault that ruptured, in meters.
7	depth_hi	real	The highest value of depth for the portion of the fault that ruptured, in meters.
8	das_lo	real	The lowest value of DAS (distance along strike) for the portion of the fault that ruptured, in meters.
9	das_hi	real	The highest value of DAS (distance along strike) for the portion of the fault that ruptured, in meters. Note that the values of das_lo and das_hi, taken together, describe the portion of the fault trace that lies above the event.
10	hypo_depth	real	The depth for the first point on the fault section to rupture (the hypocenter), in meters.
11	hypo_das	real	The DAS for the first point on the fault section to rupture (the hypocenter), in meters.
12	area	real	The total area of fault that ruptured, in square meters. Note this cannot be calculated from depth_lo, depth_hi, das_lo, and das_hi because in general the rupture does not fill the entire "rectangle" defined by those four values.
13	mean_slip	real	The mean slip in the event, in meters.
14	moment	real	Event moment, in Newton-meters.
15	shear_before	real	Shear stress before the event, in Pascal.
16	shear_after	real	Shear stress after the event, in Pascal.
17	normal_before	real	Normal stress before the event, in Pascal.
18	normal_after	real	Normal stress after the event, in Pascal.

The names “event_id” and so forth must be listed in the descriptor part of the file header.

As in any data record, the fields must be separated by one or more blank spaces. The *comment_text* is optional, but if included it must be separated from the last field by one or more blank spaces.

As in any data record, you can append additional fields after the fields listed above. Refer to the container file document for details. So, if your simulator can generate additional summary data, you can include the additional data in the file.

4.2. Multi-Section Events

If an event spans two or more fault sections, you should write it to the output event file as if it were two or more separate events.

Start by writing the summary record for the first section to rupture, followed by any additional records that pertain to the first section. Next, write the summary record for the second section to rupture, followed by any additional records that pertain to the second section. Continue until all ruptured sections are listed.

For multi-section events, the following considerations apply:

- Each summary record must contain the same *event_id*. Having the same identification number is the signal that they refer to a single event that spans multiple sections.

- Each summary record must contain the same *magnitude*, which is the total magnitude of the entire event.

- Each summary record must contain the same *time* and *duration*, which refer to the entire event.

- All other fields in the summary record refer just to the individual fault section. For example, the *moment* field contains the moment for the individual fault section; you must sum the *moment* values to obtain the total moment for the entire event.

- Sections are listed in the order they start to rupture. Therefore, in the first summary record, *hypo_das* and *hypo_depth* give the hypocenter of the entire event. In the second and subsequent summary records, they give the first point to rupture in the individual section.

4.3. Slip Map Record

```
201 depth_lo depth_hi das_lo das_hi
    area mean_slip moment
    shear_before shear_after normal_before normal_after
    element_id comment_text
```

Slip map records are used to give the distribution of slip and stress over the fault surface. You can choose which events, if any, have slip maps.

To create a slip map, you must partition the fault surface into a set of "rectangles" and give the amount of slip and stress in each rectangular partition. If your code uses a rectangular mesh, these "rectangles" might or might not be the actual computational mesh elements. In any case, it is your responsibility to select a set of "rectangles" of some appropriate size, and allocate slip from your computational elements (either rectangles or triangles) to the "rectangles" used in the slip map.

Each slip map record reports the amount of slip and stress in a single "rectangle" on the fault surface. You write a slip map by writing a series of slip map records, one for each "rectangle" where slip occurred. These records appear after the event summary record.

The record contains 12 data fields, described in the following table.

	Name	**Type**	**Description**
1	depth_lo	real	The lowest value of depth for this portion of the slip map, in meters.
2	depth_hi	real	The highest value of depth for this portion of the slip map, in meters.
3	das_lo	real	The lowest value of DAS (distance along strike) for this portion of the slip map, in meters.
4	das_hi	real	The highest value of DAS (distance along strike) for this portion of the slip map, in meters. Note that the values of depth_lo, depth_hi, das_lo, and das_hi, taken together, describe a "rectangular" portion of the fault surface.
5	area	real	The area of fault that ruptured within this "rectangle" in this event, in square meters. Note this cannot be calculated from depth_lo, depth_hi, das_lo, and das_hi because in general the rupture does not fill the entire "rectangle" defined by those four values.

6	mean_slip	real	The mean slip in this “rectangle” in this event, in meters.
7	moment	real	The moment in this “rectangle” in this event, in Newton-meters.
8	shear_before	real	Shear stress before the event, in this “rectangle”, in Pascal.
9	shear_after	real	Shear stress after the event, in this “rectangle”, in Pascal.
10	normal_before	real	Normal stress before the event, in this “rectangle”, in Pascal.
11	normal_after	real	Normal stress after the event, in this “rectangle”, in Pascal.
12	element_id	integer	An integer that gives information about what elements are included in this “rectangle”: • If zero, then no element information is provided. • If positive, then a single element in this “rectangle” ruptured. The value of element_id is the identification number of the element. • If negative, then several elements in this “rectangle” ruptured. The value of element_id is the negative of the number of elements. In this case, the slip map record must be immediately followed by a list of slip element records (kind 202) to list the identification numbers of the elements.

The names “depth_lo” and so forth must be listed in the descriptor part of the file header.

As in any data record, the fields must be separated by one or more blank spaces. The *comment_text* is optional, but if included it must be separated from the last field by one or more blank spaces.

As in any data record, you can append additional fields after the fields listed above. Refer to the container file document for details. So, if your simulator can generate additional data, you can include the additional data in the file.

4.4. Slip Element Record

```
202 element_id comment_text
```

Slip element records are used to list the identification numbers of the elements that make up a slip map entry.

When you create a slip map entry, you can optionally list the identification numbers of the corresponding elements. If a slip map entry corresponds to a single element, then you can insert the element identification number directly into the slip map record (kind 201). But if a slip map entry corresponds to multiple elements, and you want to list the elements, then you: (a) put the

number of elements into the slip map entry, and (b) write a list of slip element records, each listing one of the elements, immediately after the slip map record.

Each slip element record reports the identification number of one element. These records appear after the slip map record.

The record contains 1 data field, described in the following table.

	Name	Type	Description
1	element_id	integer	The identification number of an element. It is a positive integer. This is an element that ruptured in the current event, and is included in the current slip map entry.

The name "element_id" must be listed in the descriptor part of the file header.

As in any data record, the fields must be separated by one or more blank spaces. The *comment_text* is optional, but if included it must be separated from the last field by one or more blank spaces.

As in any data record, you can append additional fields after the fields listed above. Refer to the container file document for details. So, if your simulator can generate additional data, you can include the additional data in the file.

4.5. Guidelines for Reporting Stress

The summary and slip map records include fields for you to report the shear and normal stress, both before and after the event. In the summary record, you should report average stress values over the portion of the fault that slipped. In the slip map record, you should report average stress values over the portion of the "rectangle" that slipped.

Simulator codes may differ in their ability to report stress. Here are some guidelines:

- If your code tracks absolute values of shear and normal stress, you should report them.
- If your code tracks changes in shear and normal stress from some unspecified initial state, you should add your stress values to some assumed initial stress values. Preferably the assumed initial stresses would be obtained from the initial condition file.
- If your code only tracks shear stress, you should fill in the normal stress fields with some assumed values, preferably from the initial condition file.

- If your code tracks Coulomb stress, you should fill in the normal stress fields with some assumed values, preferably from the initial condition file. Then use the assumed normal stress, together with your Coulomb stress, to calculate shear stress and report that.

- If you can't report stress at all, fill in the stress fields with zeros.