BIDS Extension Proposal 10 (BEP010): intracranial Electroencephalography (iEEG)

version 0.10

NOTE: This google doc is no longer actively maintained. It has been moved into the bids-specification repository for further comment and eventual merge into the BIDS specification. If you have comments or questions, please open an issue on the BIDS specification repo.

Here's a link to the latest BIDS specification: https://bids-specification.readthedocs.io/en/latest/01-introduction.html

Here's a link to the Pull Request for the iEEG specification extension: https://github.com/bids-standard/bids-specification/pull/108

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This document contains a draft for the iEEG-BIDS data structure. It is a community effort to define standards in data / metadata storage for the field of iEEG. This is a working document in draft stage and any comments are welcome.

This specification is an extension of BIDS, and general principles are shared. The specification should work for many different settings and facilitate the integration with other imaging methods.

To see the original BIDS specification, see this link. This document inherits all components of the original specification (e.g., how to store imaging data, events, stimuli and behavioral data), and should be seen as an extension of it, not a replacement.

[examples can be pushed here https://github.com/bids-standard/bids-examples/tree/bep010_ieeg/]

1. Table of contents

2. Preliminary clarifications

This specification extends the Brain Imaging Data Structure (BIDS) Specification for integration of intracranial electroencephalography (iEEG) data, including both surface recordings (electrocorticography, ECoG), depth recordings, such as stereo EEG (sEEG), and recordings done with deep brain stimulation (DBS) electrodes. Most core principles of the original BIDS-fMRI and BIDS-MEG specifications are inherited by the iEEG specification, though some special considerations and additional fields are noted below.

Please refer to general BIDS specification document for context and general guidelines (definitions, units, directory structure, missing values, stimulus and event information, etc.).:
https://docs.google.com/document/d/1HFUkAEE-pB-angVcYe6pf_-fVf4sCpOHKesUvfb8Grc

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

The terminology that will be used is inherited from fMRI/MEG and includes the following. Note that these are descriptive labels, and their definition can be tailored for specific use cases (e.g., recordings not undertaken in a controlled environment like a hospital):

- Dataset, subject, session, data acquisition, data type, task, event, and run are all defined as in the general BIDS specification.
- **Electrode -** A single point of contact between the acquisition system and the recording site (e.g., scalp, neural tissue, ...). Multiple electrodes can be organized as caps (for EEG), arrays, grids, leads, strips, probes, shafts, etc.
- **Channel -** A single analog digital converter in the recording system that regularly samples the value of a transducer, which results in a signal being represented as a time series in the data. This can be connected to two electrodes (to measure the potential difference between them), a magnetic field or magnetic

gradient sensor, temperature sensor, accelerometer, etc.

Three preliminary example BIDS-iEEG examples can be found on:
https://github.com/bids-standard/bids-examples/tree/bep010_ieeg

Examples of electrical stimulation are further discussed below.

2.1 A note on missing information

The goal of the BIDS-iEEG specification is to explicitly and transparently describe the relevant information needed to understand a dataset and replicate results. As iEEG is often collected in a chaotic or uncontrolled environment, in some instances information that is "required" in the BIDS-iEEG specification may be missing. In this case, set the value of this information to the string: "n/a". We **strongly discourage this practice if possible**, but recognize that in some cases this information is simply not there.

3. iEEG-BIDS

Unprocessed iEEG data must be stored in one of the supported file formats. This file only contains the *raw* electrophysiological data (the original data format straight from the amplifier can be stored in an optional `/sourcedata/` folder as well, see bids 1.0.2 section 3.4). All metadata needed to correctly interpret the measured data must be stored in the .json and .tsv files. The allowed file formats for the raw data are still under discussion and feedback is appreciated (section 3.1).

We encourage users to provide the meta information extracted from the manufacturer specific data files in the sidecar JSON file. This allows for easy searching and indexing of key metadata elements without needing to parse the various proprietary (typically binary) native data files. Other relevant files should be included alongside the iEEG data. For iEEG recordings, this includes for example the position of electrodes, 3D anatomical brain images, surface renderings, and operative photos.

BIDS contains "required", "recommended" and "optional" fields. These are indicated throughout the document. Required/recommended fields are indicated by **(required/recommended)**. Square brackets `[_example.]` indicate OPTIONAL fields. The BIDS validator can take these into account.

As in MRI-BIDS, the following apply:

1) All specifications of paths need to use forward slashes.

2) The inheritance principle applies: any metadata file (.json, .tsv, etc.) may be defined at any directory level. The values from the top level are inherited by all lower levels unless they are overridden by a file at the lower level. For details see fMRI-BIDS section 3.5:
(https://docs.google.com/document/d/1HFUkAEE-pB-angVcYe6pf_-fVf4sCpOHKesUvfb8Grc)

3.1. File formats for the raw data

The iEEG community uses a variety of formats for storing raw data, and there is no single standard that every

researcher uses. The BIDS-iEEG specification is meant to enable open, sharable, and reproducible datasets, and unprocessed iEEG data must be stored in an **open file format** (https://en.wikipedia.org/wiki/Open_format). To determine the formats to support, the BIDS-iEEG community conducted a survey asking researchers which formats they use, and which they'd be willing to use. Formats to allow were chosen based off their pre-existing usage in the community as well as being generic, well-defined, language-agnostic, and performant. More information about the survey can be found at this link.

The allowed file formats are divided into two groups: *recommended* formats that are open, well-defined standards, and *accepted* formats that are common in the community. In general, it is discouraged to use *accepted* formats over *recommended* formats, particularly because there are conversion scripts available in most analytics languages to convert data into *recommended* formats. Below are lists of each group of allowed data formats in BIDS-iEEG.

Future versions of BIDS may extend (or shrink) this list of supported file formats. File formats for future consideration MUST have open access documentation, MUST have open source implementation for both reading and writing in at least two programming languages and SHOULD be widely supported in multiple software packages. Other formats that may be considered in the future should have a clear added advantage over the existing formats and should have wide adoption in the BIDS-iEEG community.

Recommended Formats

- European Data Format (.edf) (https://www.edfplus.info/)
- Brainvision (.vhdr/.eeg/.vmrk) (https://www.brainproducts.com/, see the FieldTrip documentation for more information on Brainvision http://www.fieldtriptoolbox.org/getting_started/brainvision)

Allowed Formats

- Neurodata Without Borders (.nwb) (https://github.com/NeurodataWithoutBorders/pynwb). Included to facilitate interactions with NWB, another open data format for neuroscience data.
- EEGlab (.set, .fdt) Included because a survey indicated that it is very often used by the community.
- MEF3 (.mef) (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4956586/, github org: https://github.com/msel-source, specification and links: http://msel.mayo.edu/codes.html, Python reader: https://www.google.com/url?q=https://github.com/ICRC-BME/PySigView&sa=D&ust=1540234072960000&usg=AFQjCNEBg8ua_qEc7U3OsK0lh-iXn94mWQ). Included because it can include FDA-approved encryption of patient information in video format.

3.2. iEEG Template

The following section describes the structure of files, folders, and their naming conventions for the BIDS-iEEG specification. Note that some parts of this overlap with the broader BIDS specification and are not unique to BIDS-iEEG and that for optional files only a few common examples are given.

```
% required: essential to be BIDS compliant (i.e., MUST as per RFC2199)
% recommended: gives a warning if not present (i.e., SHOULD as per RFC2199)
% [] indicates optional: no warning if missing (i.e., MAY as per RFC2199)

sub-<label>/
  [ses-<label>]/
  [sub-<label>_scans.tsv]                                          % optional
```

```
  anat/
       sub-<label>[_ses-<label>]_T1w.nii[.gz]                          % recommend
       ...
 [ses-<label>]/
  [sub-<label>_scans.tsv]                                              % optional
  anat/
       sub-<label>[_ses-<label>]_T1w.nii[.gz]                          % recommend
       [sub-<label>[_ses-<label>]_CT.nii[.gz]]                         % optional
       ...
  ieeg/
       sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>]_ieeg.<allowed_extension>   % required
       sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>]_ieeg.json                  % required
       sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>]_channels.tsv               % required
       [sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>]_events.tsv]                % optional


%%% electrode contact metadata %%%
       sub-<label>[_ses-<label>][_space-<label>]_electrodes.tsv        % required
       sub-<label>[_ses-<label>][_space-<label>]_coordsystem.json      % required
       [sub-<label>[_ses-<label>][_space-<label>]_photo.jpg]           % optional

%%% continuous physiological and stimulus recordings, per section 8.6 off the general BIDS
specification %%%
       [sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>][_recording-<label>]_physio.tsv.gz] % optional
       [sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>][_recording-<label>]_physio.json]   % optional
       [sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>][_recording-<label>]_stim.tsv.gz]   % optional
       [sub-<label>[_ses-<label>]_task-<task_label>[_acq-<label>]
             [_run-<index>][_space-<label>][_recording-<label>]_stim.json]     % optional

%%% surface reconstructions for electrodes go in the “derivatives” folder. A relative path
has to be stored in the _coordinatesystem.json. This is an example, but the derivatives
are not strictly part of the BIDS-iEEG spec, but it is shown here as surface visualization
is extremely common in the iEEG community.%%%
derivatives/<pipeline_name>/
       sub-<label>/
         [ses-<label>]/
             anat/sub-<label>[_ses-<label>]_T1w_pial.R.surf.gii        % recommend
```

The iEEG template can include iEEG data of any kind, including but not limited to task-based, resting state, sleep and CCEP recordings. File labelling follows the same general rules as outlined for “8.4. Task (including resting state) imaging data” of the The Brain Imaging Data Structure (BIDS) Specification, with the only differences being that:

1. The “rec” (reconstruction algorithm) label does not apply and is omitted.

2. The "_bold" suffix is replaced with "_ieeg"
3. The .nii[.gz] extension is replaced with an allowed extension (see list of allowed extensions in section 3.1)
4. Similar to the MEG-BIDS format, a "_proc" (processed) label can be added for processing on a recording device, such as e.g., real-time processing for a closed loop DBS device.
5. A *CT* can be stored in the anatomy folder as:

```
sub-<label>/
    [ses-<label>]/
anat/sub-<label>[_acq-<label>][_ses-<label>]_CT.nii
```

6. Similar to the BIDS derivatives, the surface reconstructions are stored in the derivatives folder:

```
/derivatives/<pipeline_name>/
       sub-<label>/
          [ses-<label>]/
             anat/sub-<label>[_ses-<label>]_T1w_hemi-R_pial.surf.gii
```

See Appendix I to see particular examples for different iEEG data formats.

3.3. RUN specific files

A number of files may be included alongside each iEEG recording data file (i.e., for every run of data collection). These files contain information that can often be partially extracted from the raw data files. By having this information in the json/tsv files as well, it facilitates querying large collections of iEEG datasets. These include:

1. ***_ieeg.json:** A JSON document containing metadata about the iEEG recording data file.
2. ***_channels.tsv:** A .tsv file listing amplifier metadata such as channel names, types, sampling frequency, and other information. Note that this may include non-electrode channels such as trigger channels.
3. ***_events.tsv**: A .tsv file listing the event latency and description.

For behavioral data acquired independently or alongside the iEEG, MEG, or MRI recording, see section "8.7 Behavioral experiments (with no MRI)" of the The Brain Imaging Data Structure (BIDS) Specification.

3.3.1. Sidecar JSON document (*_ieeg.json)

General fields, shared with MRI-BIDS, MEG-BIDS and EEG-BIDS:

MUST be present:

`TaskName`	REQUIRED. Name of the task (for resting state use the "rest" prefix). No two tasks should have the same name. Task label is derived from this field by removing all non alphanumeric ([a-zA-Z0-9]) characters. Note this does not have to be a "behavioral task" that subjects perform, but can reflect some information about the conditions present when the data was acquired (e.g., "rest", "seizure", or "sleep").

SamplingFrequency	REQUIRED. Sampling frequency (in Hz) of all the iEEG channels in the recording (e.g., 2400). All other channels should have frequency specified as well in the channels.tsv file.
PowerLineFrequency	REQUIRED. Frequency (in Hz) of the power grid where the iEEG recording was done (i.e., 50 or 60).
SoftwareFilters	REQUIRED. List of temporal software filters applied or ideally key:value pairs of pre-applied filters and their parameter values. (n/a if none). E.g., "{'HighPass': {'HalfAmplitudeCutOffHz': 1, 'RollOff: '6dB/Octave'}}".

SHOULD be present:
For consistency between studies and institutions, we encourage users to extract the values of these fields from the actual raw data. Whenever possible, please avoid using ad-hoc wording.

DCOffsetCorrection	RECOMMENDED. A description of the method (if any) used to correct for a DC offset. If the method used was subtracting the mean value for each channel, use "mean".
HardwareFilters	RECOMMENDED. List of hardware (amplifier) filters applied with key:value pairs of filter parameters and their values.
Manufacturer	RECOMMENDED. Manufacturer of the amplifier system (e.g., "TDT, Blackrock").
ManufacturersModelName	RECOMMENDED. Manufacturer's designation of the iEEG amplifier model.
TaskDescription	RECOMMENDED. Longer description of the task.
Instructions	RECOMMENDED. Text of the instructions given to participants before the recording. This is especially important in context of resting state and distinguishing between eyes open and eyes closed paradigms.
CogAtlasID	RECOMMENDED. URL of the corresponding Cognitive Atlas Task term.
CogPOID	RECOMMENDED. URL of the corresponding CogPO term.
InstitutionName	RECOMMENDED. The name of the institution in charge of the equipment that produced the composite instances.

InstitutionAddress	RECOMMENDED. The address of the institution in charge of the equipment that produced the composite instances.
DeviceSerialNumber	RECOMMENDED. The serial number of the equipment that produced the composite instances. A pseudonym can also be used to prevent the equipment from being identifiable, as long as each pseudonym is unique within the dataset.
ECOGChannelCount	RECOMMENDED. Number of iEEG surface channels included in the recording (e.g., 120).
SEEGChannelCount	RECOMMENDED. Number of iEEG depth channels included in the recording (e.g., 8).
EEGChannelCount	RECOMMENDED. Number of scalp EEG channels recorded simultaneously (e.g., 21).
EOGChannelCount	RECOMMENDED. Number of EOG channels.
ECGChannelCount	RECOMMENDED. Number of ECG channels.
EMGChannelCount	RECOMMENDED. Number of EMG channels.
MiscChannelCount	RECOMMENDED. Number of miscellaneous analog channels for auxiliary signals.
TriggerChannelCount	RECOMMENDED. Number of channels for digital (TTL bit level) triggers.
RecordingDuration	RECOMMENDED. Length of the recording in seconds (e.g., 3600).
RecordingType	RECOMMENDED. Defines whether the recording is “continuous” or “epoched”; this latter limited to time windows about events of interest (e.g., stimulus presentations, subject responses etc.)
EpochLength	RECOMMENDED. Duration of individual epochs in seconds (e.g., 1) in case of epoched data. If recording was continuous, leave out the field.
SubjectArtefactDescription	RECOMMENDED. Freeform description of the observed subject artefact and its possible cause (e.g., “door open”, ”nurse walked into room at 2 min”, ”seizure at 10 min”). If this field is left empty, it will be interpreted as absence of artifacts.
SoftwareVersions	RECOMMENDED. Manufacturer’s designation of the acquisition software.

Specific iEEG fields:

iEEGReference	REQUIRED. General description of the reference scheme used and (when applicable) of location of the reference electrode in the raw recordings (e.g., "left mastoid", "bipolar", "T01" for electrode with name T01, "intracranial electrode on top of a grid, not included with data", "upside down electrode"). If different channels have a different reference, this field should have a general description and the channel specific reference should be defined in the _channels.tsv file.
ElectrodeManufacturer	RECOMMENDED. can be used if all electrodes are of the same manufacturer (e.g., AD-TECH, DIXI). If electrodes of different manufacturers are used, please use the corresponding table in the _electrodes.tsv file.
ElectrodeManufacturersModelName	RECOMMENDED. If different electrode types are used, please use the corresponding table in the _electrodes.tsv file.
iEEGGround	RECOMMENDED. Description of the location of the ground electrode ("placed on right mastoid (M2)").
iEEGPlacementScheme	RECOMMENDED. Freeform description of the placement of the iEEG electrodes. Left/right/bilateral/depth/surface (e.g., "left frontal grid and bilateral hippocampal depth" or "surface strip and STN depth" or "clinical indication bitemporal, bilateral temporal strips and left grid").
iEEGElectrodeGroups	RECOMMENDED. Field to describe the way electrodes are grouped into strips, grids or depth probes e.g., {'grid1': "10x8 grid on left temporal pole", 'strip2': "1x8 electrode strip on xxx"}.
[ElectricalStimulation]	OPTIONAL. Boolean field to specify if electrical stimulation was done during the recording (options are "true" or "false"). Parameters for event-like stimulation should be specified in the _events.tsv file (see example underneath).
[ElectricalStimulationParameters]	OPTIONAL. Free form description of stimulation parameters, such as frequency, shape etc. Specific onsets can be specified in the _events.tsv file. Specific shapes can be described here in freeform text.

Example:


```
{
        "TaskName":"visual",
        "Manufacturer":"Tucker Davis Technologies",
        "ManufacturersModelName":"n/a",
        "TaskDescription":"visual gratings and noise patterns",
        "Instructions":"look at the dot in the center of the screen and press the button when it
        changes color",
        "CogAtlasID":"n/a",
        "CogPOID":"n/a",
        "InstitutionName":"Stanford Hospital and Clinics",
        "InstitutionAddress":"300 Pasteur Dr, Stanford, CA 94305",
        "DeviceSerialNumber":"n/a",
        "EEGChannelCount":0,
        "EOGChannelCount":0,
        "ECGChannelCount":0,
        "EMGChannelCount":0,
        "MiscChannelCount":0,
        "TriggerChannelCount":0,
        "PowerLineFrequency":60,
        "RecordingDuration":233.639,
        "RecordingType":"continuous",
        "SubjectArtefactDescription":"",
        "ECOGChannelCount":118,
        "SEEGChannelCount":0,
        "iEEGPlacementScheme":"right occipital temporal surface",
        "iEEGReference":"left mastoid",
        "Stimulation":false
```


Note that the date time information should be stored in the Study key file (scans.tsv), see section 3.4.1. Scans.tsv. As it is indicated there, date time information should be expressed in the following format YYYY-MM-DDThh:mm:ss (ISO8601 date-time format). For example: 2009-06-15T13:45:30. It does not need to be fully detailed, depending on REB/IRB policy.

3.3.2 Channels description table (*_channels.tsv)

A channel is one time series recorded with the recording system (for example, there can be a bipolar channel, recorded from two electrodes or contact points on the tissue). Although this information can often be extracted from the iEEG recording, listing it in a simple .tsv document makes it easy to browse or search (e.g., searching for recordings with a sampling frequency of >=1000 Hz). The two required columns are channel name and type. Channels should appear in the table in the same order they do in the iEEG data file. Any number of additional columns may be provided to provide additional information about the channels. Note that electrode positions should not be added to this file but to *_electrodes.tsv.

Required fields

Differences with MEG-BIDS are highlighted in grey.

`name`	REQUIRED. Label of the channel, only contains letters and numbers. The label must correspond to _electrodes.tsv name and all ieeg type channels are required to have a position. The reference channel name MUST be provided in the reference column.
`type`	REQUIRED. Type of channel, see below for adequate keywords in this field.
`units`	REQUIRED. Physical unit of the value represented in this channel, e.g., V for Volt, specified according to the SI unit symbol and possibly prefix symbol (e.g., mV, µV), see the BIDS spec (section 15 Appendix V: Units) for guidelines for Units and Prefixes.
`low_cutoff`	REQUIRED. Frequencies used for the low pass filter applied to the channel in Hz. If no low pass filter was applied, use `n/a`. Note that anti-alias is a low pass filter, specify its frequencies here if applicable.
`high_cutoff`	REQUIRED. Frequencies used for the high pass filter applied to the channel in Hz. If no high pass filter applied, use `n/a`.

Recommended and optional fields

`reference`	RECOMMENDED. Specification of the reference (e.g., 'mastoid', 'ElectrodeName01', 'intracranial', 'CAR', 'other', 'n/a'). If the channel is not an electrode channel (e.g., a microphone channel) use `n/a`.
`group`	RECOMMENDED. Which group of channels (grid/strip/seeg/depth) this channel belongs to. This is relevant because one group has one cable-bundle and noise can be shared. This can be a name or number. Note that any groups specified in `_electrodes.tsv` must match those present here.
`sampling_frequency`	OPTIONAL. Sampling rate of the channel in Hz.
`description`	OPTIONAL. Brief free-text description of the channel, or other information of interest (e.g., position (e.g., "left lateral temporal surface", etc.).
`notch`	OPTIONAL. Frequencies used for the notch filter applied to the channel, in Hz. If no notch filter applied, use `n/a`.

status	OPTIONAL. Data quality observed on the channel (good/bad). A channel is considered bad if its data quality is compromised by excessive noise. Description of noise type SHOULD be provided in [status_description].
status_description	OPTIONAL. Freeform text description of noise or artifact affecting data quality on the channel. It is meant to explain why the channel was declared bad in [status].

Example

sub-01_channels.tsv:

name	type	units	low_cutoff	high_cutoff	reference	group	sampling_frequency	description	notch	status	status_description
LT01	ECOG	µV	300	0.1	mastoid	LTG	1000	lateral_temporal_surface	n/a	good	n/a
LT02	ECOG	µV	300	0.1	mastoid	LTG	1000	lateral_temporal_surface	n/a	bad	broken
H01	SEEG	µV	300	0.1	mastoid	HST	1000	hippocampal_depth	n/a	bad	line noise
ECG1	ECG	µV	n/a	0.1	ECG2	4	1000	ecg_channel	60	good	n/a
TR1	TRIG	n/a	n/a	n/a	n/a	5	1000	ana_trigger	n/a	good	n/a

Restricted keyword list for field `type`

See section 8.4.2 in general BIDS for an extensive list. Only **bold** types are suggested iEEG additions.

- `EEG`: Electrode channel from electroencephalogram
- `ECOG`: Electrode channel from electrocorticogram (intracranial)
- `SEEG`: Electrode channel from stereo-electroencephalogram (intracranial)
- `DBS`: Electrode channel from deep brain stimulation (intracranial)
- `VEOG`: Vertical EOG (electrooculogram)
- `HEOG`: Horizontal EOG
- `EOG`: Generic EOG channel if HEOG or VEOG information not available
- `ECG`: ElectroCardioGram (heart)

- `EMG:` ElectroMyoGram (muscle)
- `TRIG:` System Triggers
- `AUDIO:` Audio signal
- `PD:` Photodiode
- `EYEGAZE:` Eye Tracker gaze
- `PUPIL:` Eye Tracker pupil diameter
- `MISC:` Miscellaneous
- `SYSCLOCK:` System time showing elapsed time since trial started
- `ADC:` Analog to Digital input
- `DAC:` Digital to Analog output
- `OTHER:` Any other type of channel
- **`REF:`** **Reference channel**

Free text examples for field `description`

- intracranial, stimulus, response, vertical EOG, horizontal EOG, skin conductance, eyetracker

Examples of type and description fields:

name	type	description
VEOG	EOG	vertical EOG
LO01	SEEG	frontal surface
FDI	EMG	left first dorsal interosseous
UDIO001	TRIG	analogue trigger
AUDIO001	MISC	envelope of audio signal (raw audio goes as a '.tsv.gz' as a physiological or other continuous recording, general BIDS 8.6)

3.3.2. Task events (*_events.tsv)

Task events are part of the general BIDS (see section 8.5 from The Brain Imaging Data Structure (BIDS) Specification). We add some examples here about storing data recorded during electrical stimulation of the electrodes.

Template:

```
sub-<label>/[ses-<_label>]/
   ieeg/
      <matches>_events.tsv
```

Where `<matches>` corresponds to task file name. For example: `sub-control01_task-nback`

Required fields

`onset`	REQUIRED. Onset in seconds.

duration	REQUIRED. Duration in seconds.
trial_type	REQUIRED. Examples: "electrical_stimulation" for trials with electrical stimulation on the intracranial electrodes, "passive listening" for trials where a subject passively hears a stimulus.

Optional fields

sample	OPTIONAL. Onset of the event with respect to the digitization of the signal.
value	OPTIONAL. Corresponds to the value of a marker of the event, for example the value of a TTL trigger as incorporated in a TRIG channel.

3.3.3. Physiological and other continuous recordings

Auxiliary continuous recordings such as an audio or video are part of the general Brain Imaging Data Structure (BIDS) Specification (see section 8.6).

3.4. SESSION specific files

These are files unique to each session of recording. For example, across multiple experiments run in the same day for one patient. Channels are defined as the entities of the amplifier, electrodes are the single metallic contacts to the tissue.

Required Files:

1. Electrode locations table: *[_space-<label>]_electrodes.tsv
2. Electrode coordinates JSON document (*[_space-<label>]_coordsystem.json)

The optional element space-<label> should be used to distinguish the files in case electrodes are expressed in multiple coordinate systems (e.g., in pixels in a photo, and in mm relative to a CT) and/or in relation to different templates or atlases (e.g., in the "individual" coordinates, as well as after piecewise re-scaling relative to the Talairach-Tournoux atlas)

Optional Files:

A number of optional files may be included once for a given iEEG session. These are listed below and described in the following sections.

3. *_photo.jpg
4. *_scans.tsv

3.4.1 Electrode locations (*[_space-<label>]_electrodes.tsv)

Electrodes form the single contact points with the brain tissue. The electrode positions and properties are stored in a .tsv file ending in _electrodes.tsv (amplifier information is in channels.tsv). This file must contain the electrode name, the electrode coordinates in 3 columns (xyz), and the size of each electrode and some optional parameters.

The electrode locations can only be interpreted together with the `_coordsystem.json` (3.4.2) sidecar, which specifies the coordinate system relative to which the positions are to be interpreted.

- **Recommended 3D coordinate systems:**
  It is preferred that electrodes are localized in a 3D coordinate system (with respect to a pre- and/or post-operative anatomical MRI or CT scans or in a standard space as specified in BIDS Appendix VIII: preferred names of Coordinate systems, such as ACPC).
- **Allowed 2D coordinate systems:**
  If electrodes are localized in 2D space (only x and y are specified and z is n/a), then the positions in this file must correspond to the locations expressed in pixels on the photo/drawing/rendering of the electrodes on the brain. In this case, coordinates must be "(row, column)" pairs, with (0,0) corresponding to the upper left pixel and (N,0) corresponding to the lower left pixel.
- **Multiple coordinate systems:**
  If electrode positions are known in multiple coordinate systems (e.g., MRI, CT and MNI), these spaces can be distinguished by the optional [_space-<label>] and [_proc-<label>] fields.

Required fields

`name`	REQUIRED. Name of the electrode contact point.
`x`	REQUIRED. X position. The positions of the center of each electrode in xyz space. Units are in millimeters or pixels and are specified in _*space-<label>_electrode.json.
`y`	REQUIRED. Y position.
`z`	REQUIRED. Z position. If electrodes are in 2D space this should be a column of `n/a` values.
`size`	REQUIRED. Surface area of the electrode, in mm^2.

Recommended fields

`material`	RECOMMENDED. Material of the electrodes.
`manufacturer`	OPTIONAL. Recommended field to specify the manufacturer for each electrode. Can be used if electrodes were manufactured by more than one company.

`group`	OPTIONAL. Optional field to specify the group that the electrode is a part of. Note that any group specified here should match a group specified in `_channels.tsv`.
`hemisphere`	OPTIONAL. Optional field to specify the hemisphere in which the electrode is placed, one of ['L' or 'R'] (use capital).

Optional fields

`type`	OPTIONAL. Optional type of the electrode, e.g., cup, ring, clip-on, wire, needle, disk, ...
`impedance`	OPTIONAL. Impedance of the electrode in kOhm.
`dimension`	OPTIONAL. Size of the grid/strip/probe that this electrode belongs to. Must be of form [AxB] with the smallest dimension first (e.g. [1x8]).

Examples

`sub-01_space-Talairach_electrodes.tsv`:

name	x	y	z	type	size	material	manufacturer
LT01	19	-39	-16	surface	2.3	platinum	Integra
LT02	23	-40	-19	surface	2.3	platinum	Integra
H01	27	-42	-21	depth	5	platinum	AdTech

The optional space label (`[_space-<label>]_electrodes.tsv`) indicates the way in which electrode positions are interpreted, see BEP003 - Common Derivatives. Examples include:

- `_space-orig` (electrodes are in the space originally extracted from the image, such as a T1 weighted MRI, CT, XRay or 2D operative photo).
- `_space-MNI152Lin` (electrodes are coregistred and scaled to a specific MNI template)
- `_space-Talairach` (electrodes are coregistred and scaled to Talairach space)

3.4.2. Electrode coordinates JSON document (*[_space-<label>]_coordsystem.json)

This _coordsystem.json file contains the coordinate system used for the electrode coordinates. The associated image is also specified. This includes an MRI, a CT, an X-Ray, or operative photo. It may also be a geometric description of the anatomy/electrodes such as a surface description in a .gii file.

Required fields

`iEEGCoordinateSystem`	REQUIRED. Defines the coordinate system for the iEEG electrodes. For example, "ACPC". See Appendix VIII: preferred names of Coordinate systems. If "Other" (e.g., individual subject MRI),

	provide definition of the coordinate system in [iEEGCoordinateSystemDescription]. If positions correspond to pixel indices in a 2D image (of either a volume-rendering, surface-rendering, operative photo, or operative drawing), this must be "pixels". See section 3.4.1: Electrode locations for more information on electrode locations.
iEEGCoordinateUnits	REQUIRED. Units of the _electrodes.tsv, MUST be "m", "mm", "cm" or "pixels".

Recommended fields

iEEGCoordinateSystemDescription	RECOMMENDED. Freeform text description or link to document describing the iEEG coordinate system system in detail (e.g., "Coordinate system with the origin at anterior commissure (AC), negative y-axis going through the posterior commissure (PC), z-axis going to a mid-hemisperic point which lies superior to the AC-PC line, x-axis going to the right").
IntendedFor	RECOMMENDED. This can be an MRI/CT or a file containing the operative photo, x-ray or drawing with path *relative* to the project folder. If only a surface reconstruction is available, this should point to the surface reconstruction file. Note that this file should have the same coordinate system specified in iEEGCoordinateSystem. For example, **T1:** "/sub-<label>/ses-<label>/anat/sub-01_T1w.nii.gz" **Surface:** "/derivatives/surfaces/sub-<label>/ses-<label>/anat/sub-01_T1w_pial.R.surf.gii" **Operative photo:** "/sub-<label>/ses-<label>/ieeg/sub-0001_ses-01_acq-photo1_photo.jpg" **Talairach:** "/derivatives/surfaces/sub-Talairach/ses-01/anat/sub-Talairach_T1w_pial.R.surf.gii"
iEEGCoordinateProcessingDescription	RECOMMENDED. Has any projection been done on the electrode positions (e.g., "surface_projection", "none").
iEEGCoordinateProcessingReference	RECOMMENDED. A reference to a paper that defines in more detail the method used to project or localize the electrodes

Example

sub-01_coordsystem.json:


```
{
	"iEEGCoordinateSystem":"ACPC",
	"iEEGCoordinateUnits":"mm",
	"iEEGCoordinateSystemDescription":"Coordinate system with the origin at anterior commissure (AC), negative y-axis going through the posterior commissure (PC), z-axis going to a mid-hemisperic point which lies superior to the AC-PC line, x-axis going to the right",
	"iEEGCoordinateProcessingDescription":"surface_projection",
	"IntendedFor":"/sub-01/ses-01/anat/sub-01_T1w.nii.gz",
	"iEEGCoordinateProcessingReference":"Hermes et al., 2010 JNeuroMeth"
}
```


3.4.3. Photos of the electrode positions (*_photo.jpg)

These can include photos of the electrodes on the brain surface, photos of anatomical landmarks (if using fiducials), an X-ray picture, a flatbed scan of a schematic drawing made during surgery, or screenshots of a brain rendering with electrode positions. The photos may need to be cropped and/or blurred to conceal identifying features—or entirely omitted—prior to sharing, depending on obtained consent.

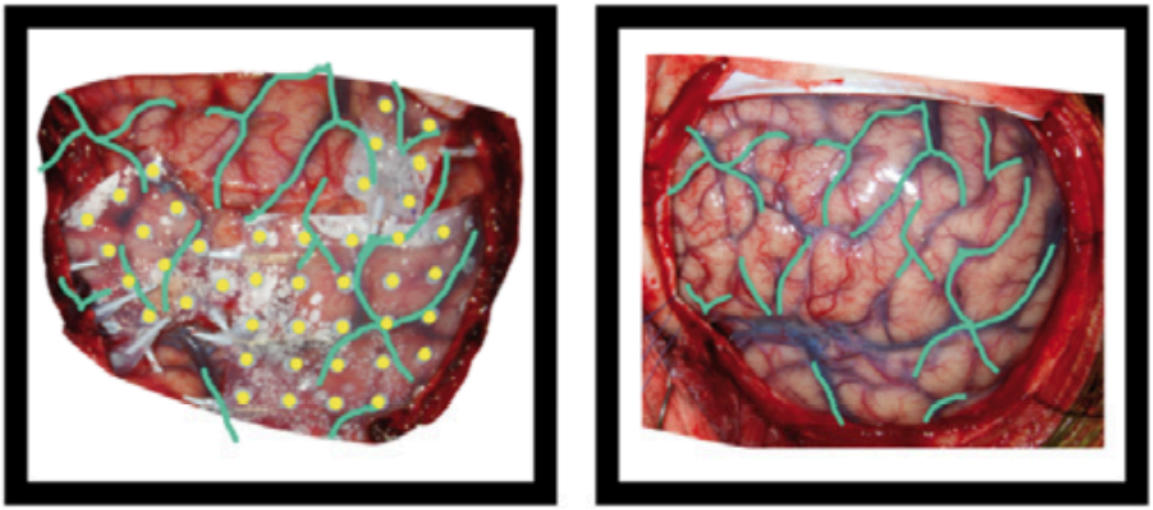
If there are photos of the electrode positions, the acquisition field should be specified with:

*_photo.jpg	in case of an operative photo
*_acq-**xray#**_photo.jpg	in case of an x-ray picture
*_acq-**drawing#**_photo.jpg	in case of a drawing or sketch of electrode placements
*_acq-**render#**_photo.jpg	in case of a rendering

The session label may be used to specify when the photo was taken.

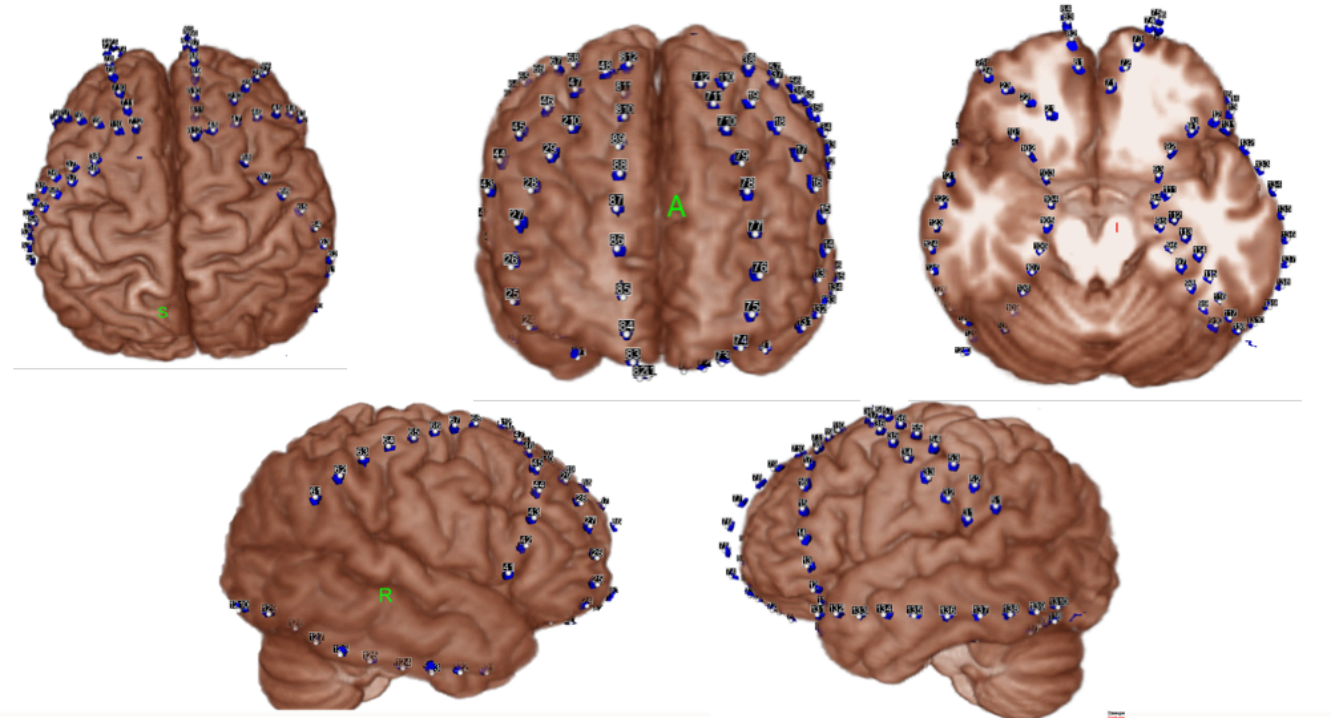
Example of the operative photo of ECoG electrodes (here an annotated example in which electrodes and vasculature are marked, taken from Hermes et al., JNeuroMeth 2010).

sub-0001_ses-01_acq-photo1_photo.jpg
sub-0001_ses-01_acq-photo2_photo.jpg



Below is an example of a volume rendering of the cortical surface with a superimposed subdural electrode implantation. This map is often provided by the EEG technician and provided to the epileptologists (e.g., see Burneo JG et al. 2014 http://dx.doi.org/10.1016/j.clineuro.2014.03.020).

`sub-0002_ses-001_acq-render_photo.jpg` (for volume rendering)



3.4.5. Multiple recordings in one session (scans.tsv)

See section "8.10 Scans key file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description.
Optional: Yes

This file is called scans, but is used to describe timing and other properties of any ieeg recording sequence or imaging acquisition sequence (each run (.nii[.gz] or ieeg) file) within one session. Each data file file should be described by at most one row. Relative paths to files should be used under a compulsory “filename” header. If acquisition time is included it should be under “acq_time” header.

Clinical EEG or iEEG recordings can be very long. If this results in multiple recordings, either because the recording software automatically breaks it up in separate files, or because some intervention was needed after which recording was resumed, the recordings should be represented as separate runs (using `_run-<number>_` in the file name). During clinical long-term monitoring of iEEG it happens that patients participate as volunteers in experiments (including tasks). Since long recordings that are split over multiple runs are represented separately in the scans.tsv file, the `acq_time` column should be used to determine whether they are part of a long continuous recording or whether there was a gap in between.

Datetime should be expressed in the following format 2009-06-15T13:45:30 (year, month, day, hour (24h), minute, second; this is equivalent to the RFC3339 “date-time” format, time zone is always assumed as local time). For anonymization purposes all dates within one subject should be shifted by a randomly chosen (but common across all runs etc.) number of days. This way relative timing would be preserved, but chances of identifying a person based on the date and time of their scan would be decreased. Dates that are shifted for anonymization purposes should be set to a year 1900 or earlier to clearly distinguish them from unmodified data. Shifting dates is recommended, but not required. Additional fields can include external behavioral measures relevant to the scan. For example vigilance questionnaire score administered after a resting state scan.

Template:

```
sub-<label>/[ses-<session_label>/]
       sub-<label>_scans.tsv
```

Example

filename	acq_time
anat/sub-control01_T1w.nii.gz	1876-06-09T00:07:10
ieeg/sub-control01_task-rest_ieeg.edf	1877-06-15T13:45:30
ieeg/sub-control01_task-motor_ieeg.edf	1889-06-15T13:55:33

3.5 SUBJECT keyfiles

3.5.1 Sessions file (*_sessions.tsv)

See section "9.1 Sessions file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description.
Optional: Yes

3.6. STUDY keyfiles

3.6.1. Participants.tsv

See section "8.11 Participant key file" of The Brain Imaging Data Structure (BIDS) Specification for a detailed description.
Optional: Yes

Template: (single session case)
`participants.tsv`
`participants.json`

Example

participant_id	age	sex	group
sub-control01	34	M	control
sub-control02	12	F	control
sub-patient01	33	F	patient

3.7 Electrical stimulation

3.7.1 Event-like electrical stimulation

In case of electrical stimulation of brain tissue by passing current through the iEEG electrodes, and the electrical stimulation has an event structure (on-off, onset, duration), the _events.tsv file can contain the electrical stimulation parameters in addition to other events. Note that these can be intermixed with other task events.
Electrical stimulation parameters can be described in columns called `electrical_stimulation_<label>`, with labels chosen by the researcher and optionally defined in more detail in an accompanying _electrodes.json file (as per the main BIDS spec).
Functions for complex stimulation patterns can, similar as when a video is presented, be stored in a folder in the

`/stimuli/` folder. For example: /stimuli/electrical_stimulation_functions/my_curve.tsv

Example

`sub-01_events.tsv`:

onset	duration	trial_type	electrical_stimulation_type	electrical_stimulation_site	electrical_stimulation_current
1.2	0.001	electrical_stimulation	biphasic	LT01-LT02	0.005
1.3	0.001	electrical_stimulation	biphasic	LT01-LT02	0.005
2.2	0.001	electrical_stimulation	biphasic	LT02-LT03	0.005
4.2	1	electrical_stimulation	complex	LT02-LT03	n/a
15.2	3	auditory_stimulus	n/a	n/a	n/a

4. Appendix I: Example iEEG cases

This section contains examples that demonstrate the structure of files for BIDS-iEEG.
Examples are included that use several different methods to electrode coordinates:

- From pre- and/or post-operative anatomical MRI or CT scans.
- From a photo taken during surgery, or a drawing made during surgery (scanned to an image afterward).
- Localizing in Talairach space using X-ray images.

4.1. Visual dataset:

This dataset is an example of a .mat file containing a single data matrix. All metadata and header file information is contained in the .json and .tsv files. The electrode locations are in millimeter and match the surface rendering of the associated gifti (.gii) file. A link to this dataset can be found here: https://github.com/bids-standard/bids-examples/tree/bep010_ieeg/ieeg_visual

```
ieeg_visual/
├── dataset_description.json
├── derivatives
│   └── surfaces
│       └── sub-01
│           └── ses-01
```

```
│               └── anat
│                   └── sub-01_ses-01_T1w_pial.R.surf.gii
├── participants.tsv
├── stimuli
│   ├── stim_100.png
        ...
│   └── stim_9.png
└── sub-01
    └── ses-01
        ├── anat
        │   ├── sub-01_ses-01_T1w.json
        │   └── sub-01_ses-01_T1w.nii.gz
        └── ieeg
            ├── sub-01_ses-01_coordsystem.json
            ├── sub-01_ses-01_electrodes.tsv
            ├── sub-01_ses-01_task-visual_run-01_channels.tsv
            ├── sub-01_ses-01_task-visual_run-01_events.tsv
            ├── sub-01_ses-01_task-visual_run-01_ieeg.gdf
            └── sub-01_ses-01_task-visual_run-01_ieeg.json
```

4.2. Auditory dataset:

This dataset was collected during a passive listening task in which subjects listened to filtered and unfiltered versions of natural speech. In this case, there is no surface reconstruction of the patient's cortex, only an operative photo with 2-D electrode locations in a corresponding TSV file. A link to the dataset can be found here: https://github.com/bids/bids-examples/tree/bep010_ieeg/ieeg_filtered_speech

```
ieeg_filtered_speech/
├── dataset_description.json
├── participants.tsv
├── stimuli
│   └── cm4_audio.wav
├── sub-cm4
│   ├── anat
│   │   └── sub-cm4_photo.jpg
│   └── ieeg
│       ├── sub-cm4_ieeg.json
│       ├── sub-cm4_space-2DImage_coordsystem.json
│       ├── sub-cm4_task-FilteredSpeech_channels.tsv
│       ├── sub-cm4_task-FilteredSpeech_electrodes.tsv
│       ├── sub-cm4_task-FilteredSpeech_events.tsv
│       └── sub-cm4_task-FilteredSpeech_ieeg.fif
```

4.3. Hand and tongue movement dataset

This link has an example dataset (with an empty datamatrix to reduce space):
https://github.com/bids-standard/bids-examples/tree/bep010_ieeg/ieeg_motorMiller2007

If a surgical photo or drawing is used, 2-D electrode positions should be specified in pixels, where the upper left corner is (0,0), the first dimension moves across rows, and the second dimension moves across columns. If an X-Ray is used, it is possible to e.g., use the "Matlab LOC package" to coregister the X-Ray with the Talairach-Tournoux atlas Miller et al., 2007, Journal of Neuroscience Methods doi:10.1016/j.jneumeth.2007.01.019) and to determine the electrodes in TT coordinates. If the "Matlab LOC package" is not used, it is also possible to specify the position of the electrodes in pixels on the X-ray, just like for photos or for drawings that have digitally scanned. If a pre- and/or post-operative anatomical MRI or CT is available, the position of the electrodes can be specified in the coordinate system that is specified by that 3-D anatomical data.

5.1. Appendix II: Preferred names of Coordinate systems

See the main BIDS specification document appendix on preferred names of coordinate systems for information on coordinate system naming. The language in that section will be copied here just before finalizing the BIDS-iEEG specification.

6.1. Appendix III: Contributions

Legend (source: https://github.com/kentcdodds/all-contributors)

Emoji	Represents
💬	Answering Questions (on the mailing list, NeuroStars, GitHub, or in person)
🐛	Bug reports
📝	Blogposts
💻	Code
📖	Documentation and specification
🎨	Design
💡	Examples

📋	Event Organizers
💵	Financial Support
🔍	Funding/Grant Finders
🤔	Ideas & Planning
🚇	Infrastructure (Hosting, Build-Tools, etc)
🔌	Plugin/utility libraries
👀	Reviewed Pull Requests
🔧	Tools
🌍	Translation
⚠️	Tests
✅	Tutorials
📢	Talks
📹	Videos

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Olivier David🤔
Manuel Mercier🤔
Iris Groen📖💬💡⚠️🐛
Giovanni Piantoni 💬💡

...

7.1. Appendix III: Simultaneous recordings of different data types

Definitions:
Synchronous = specifies that two or more data types include an explicit link between data points.
Simultaneous = specifies that the recording was done at approximately the same time with an implicit link between data points.

Simultaneously recorded data in the same subject can be considered in the following example cases:

		System	
		Same	Different

Format	Same	MEG with some ExG channels	realtime integration of different data streams: LSL, XDF, EDF
	Different	MRI + integrated physio ECoG + integrated video	typical cognitive setup using TTLs: fMRI, EEG, behavior, eye tracker

Simultaneously recorded data (of either the same type or different types) in multiple subjects, such as hyperscanning, is not considered here.

ExG = [EMG, EOG, ECG, etc].

8. Change-log

Here is a list of dates and changes made to the specs:

Extra notes not to be included in the spec

This is a place for extra information that is useful for the design of the specification extension.

Some information about MEF3

From Brian Lundstrom:

- MEF has two-layer HIPAA-compliant encryption, essentially meaning clinical data and EEG data can each be encrypted separately, which facilitates sharing
- Time indexing for each data point: a big challenge for us has been managing short gaps in the data, either by corruption or intention. Error-checking is very difficult with EDF and it is very difficult to accurately convey data with corruption without time-indexed data points

- Efficiency: time indexing also means that viewing days or weeks of data can be done very efficiently. We routinely view data over more than a week and appreciate the ability to skip around nearly instantaneously since the whole dataset need not be loaded into memory

- Compression: typically we've found file sizes of MEF to be less than half of EDF. MEF also offers lossy compression options, although we've typically used lossless.

- The 32-bit dynamic range of MEF is a bit more than other options and may be especially helpful with DC and long-term recordings that may more fully utilize the full dynamic range of current amps, which are

greater than 16-bit.

MEF has been accepted by dicom and will be incorporated in some fashion. To us, it seems that having a robust, widely accepted format would be great! If anyone is interested in participating in the dicom workgroup, let us know (Matt Stead specifically).