LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-E030350-v5 *LIGO* February 16th 2023

[see DCC for approval record]

Configuration Control & Drawing Requirements

Calum Torrie

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

1 Scope

The purpose of this document is to provide requirements on the format, distribution, control and archiving of LIGO drawings. The scope includes all drawings initiated by the LIGO Lab regardless of application (detector, civil construction, etc.) or discipline/type (mechanical, optical, vacuum and electronics). This requirement applies to LIGO and it's upgrades.

2 Configuration Control & Archiving

The basic approach and procedure for configuration control within LIGO is defined in LIGO-E000037. The following is an interpretation and specialization of this configuration control process with regard to drawings for all LIGO designs.

2.1 Purpose

The purpose of configuration control is to:

1) maintain a documentation record of the state of the system at all times,

2) review the cost and schedule impact of proposed changes at the system level,

3) review the impact to interfaces and system-level performance and function

2.2 What is placed under control?

All documentation which is relied upon to define and build the system. This includes drawings (mechanical, vacuum, optical, electrical, layout, etc.), requirement documents, specifications, procedures, and Interface Control Documents (ICDs).

Documents that are generally not placed under configuration control include:

1) technical memorandum (e.g. used to derive requirements)

2) publications

3) design descriptions

4) presentations

However, these documents should still be submitted to the DCC.

2.3 When are documents placed under configuration control?

As soon as fabrication of full-scale prototypes are contemplated, the specifications and drawings must be placed under configuration control. Documents should be placed into configuration control once baseline ICDs and costs are established. Deviations from this are accepted in early stages of design with prior approval from the Chief Engineer.

2.4 How are documents placed under configuration control?

The Document Change Notice (DCN) places the associated document(s) into configuration control within the LIGO Document Control Center (DCC). An initial release (revision code "v1") is initiated with a signed DCN. The text of the DCN may say "initial release for prototype fabrication", or similar explanation of the reason for the release. Subsequent revisions (e.g. revision

"v2") would detail the changes on the DCN. Example DCN's can be found on the DCC using DCN as the search function. The DCN should be signed using the DCC signature function.

2.5 Who approves the DCN?

Ideally, three signatures are included: (1) the "originator", (2) the "task leader", and (3) the "group leader", or "chief engineer" (unless one or more of these positions are held by the same individual). However, only (2) and (3) are required. Depending upon the organizational structure of a particular project, additional signatures may also be added by the task leader, group leader or chief engineer. It should be noted that if the DCN has interface related information, then the Cognizant Scientist, Cognizant Engineer or Subsystem Leader for the other subsystem should also be asked to sign.

1) The originator signs (generally a cognizant engineer)
2) The Subsystem Cognizant Engineer signs or the Subsystem Cognizant Scientist signs
3) The Subsystem Leader signs or the Systems Engineer signs
4) Other Approvals, e.g. Interface Related

2.6 What is the nature and level of review associated with the DCN approval?

for the Cognizant Scientist: Signature means that they concur that the design as represented by the associated document (drawing, specification, etc.) should meet the performance and feature requirements defined for the component, assembly or system and, if it relates to an interface, does not pose a risk of failure to meet requirements of the interface, the interfacing system or the overall system.

for the Cognizant Engineer: Signature means that they have reviewed the implementation of the design as represented by the associated document (drawing, specification, etc.) and it should meet all LIGO standards (for drawings, EMI guidelines, in-vacuum practices, etc.), is a sound and reasonable engineering implementation and complies with all defined interface requirements (if applicable). If there are safety risks or implications, the Cognizant Engineer should so indicate on the DCN.

for the Subsystem Leader: Signature means that they concur that the set of documentation is appropriate and within the scope of the planned activities, or if outside of the scope or costs, the implications for a CCB review should be noted. The Leader's signature also indicates that the due process was followed in the development and review of the material in accordance with LIGO procedures, e.g. that a design review was held if/as appropriate and that all comments from such reviews were addressed or closed out.

Of course in reality it is not so black-and-white; Each individual can and should make comments on any aspect of the documentation that they feel is questionable or incomplete or wrong. The above is meant to convey the emphasis in each person's review depending upon their role in the organization. Finally a signature means (if nothing else) that the individual was informed and had the opportunity to object or provide input. All too often it is possible to skip review due to time constraints. This DCN process helps to get the attention of the key individuals. Of course for this to work the DCN should be timely (i.e. before the work has already been undertaken), otherwise the DCN signature is just a 'rubber stamp".

2.7 What is the change process?

There are two levels of Change Requests (CRs) in LIGO: engineering change requests (ECR's) and cost change, (schedule or technical risk) change requests (CR's).

1. Engineering Change Requests (ECR), are managed as per the LIGO Engineering Change Request (ECR) Process here LIGO-M1200274.
2. Changes to the LIGO Laboratory M&O budget are controlled in accordance with the Change Control process defined here LIGO-M1400104. This process is used for requesting, reviewing, and documenting changes to the approved budget and when necessary a Configuration Control Board (CCB) reviews the change request, as described in this Change Control Process Flowchart here LIGO-M1900027.

2.8 Document Control @ LIGO Lab

For historical reference on document control, since the inception of LIGO refer to E000037-00, L960641-05 and L970164-02.

Document Control within the LIGO Lab:

1) **DCC:** Refer here for help in how to use the DCC, https://dcc.ligo.org/wiki/index.php/DCC_Help

2) **Document Control Center (DCC) Release**:
All drawings must be released into configuration control (i.e. all subsequent changes are tracked and explained on a DCN) before production, or before installing into a LIGO interferometer or an observatory operations facility (e.g. LDAS installation, Mass Storage Room (MSR) rack layout, etc.) This also applies to "prototypes" if they are to be installed into the interferometer even if only for a limited test run. (The purpose is to have a controlled, stable and known configuration to associate with test results.)

3) **Change Authority**:
Only the cognizant engineer for a part or assembly has the authority to initiate changes. This is an expediency to ensure that changes from different interested individuals are coordinated. The cognizant engineer is the last engineer listed on the drawing and/or DCN for the last release. The cognizant engineer can be re-assigned by the Chief Engineer or the Technical (or Vacuum) Review Board Chairperson.

4) **Change Review and Approval**:
All released drawings require review and signatures on the Document Change Notice (DCN) before formal release; see section 2.5 above.

5) **Drawings for Bid/Quote must be Released**:
No drawing shall be released to a vendor for quote, bid or comment without first releasing the drawing with a Document Change Notice (DCN), which placed the drawing under configuration control; All subsequent changes must be documented and the drawing revision incremented with subsequent DCNs.

6) **DCC Number and Revision Code**:
A DCC archived drawing number has the following format: Dyyxxxx-r-G where yyxxxx is the DCC assigned number (yy happens to be the last two digits of the year in which the number was first requested), r is the revision code. Refer to DCC help linked above for more information.

7) **DCC Archival Documentation**:
DCC archived documentation shall include the following:
   i. The drawing in Adobe pdf format with a filename Dyyxxxx-r.pdf (see above for nomenclature).
   ii. For mechanical drawings, it is preferred that the file first be translated into SolidWorks (latest, or recent revision level) and stored in our PDM Pro (SolidWorks) vault. If the translation is problematic, then the file should be submitted in its native format.

   The following are optional:
   iii. Given that the SolidWorks CAD source file(s) associated with the pdf drawing in native file format are already stored in LIGO's PDM Pro (SolidWorks) vault, they are not required to be submitted to the DCC.
   iv. For "As-Built", or final drawings, in addition to the pdf one can add a "universal" file format for long term archival. The preferred formats are as follows: Mechanical CAD: **STEP,** Electrical CAD: **Gerber**
   v. Any ancillary files should be zipped together and submitted to the DCC in a common folder (the folder name would be "Dyyxxx-r") with the Adobe AcroBat drawing file.

8) **Procurement**
As a reference the link to procurement best practices is included here: https://caltech.sharepoint.com/sites/LIGO/businessoffice/procurement/SitePages/Best-Practices.aspx (this site and the included guidance is available under the Business Office Sharepoint page, the latter can be accessed from access.caltech).

2.9 Collaborators

1) Collaborator organizations, which have their own configuration control procedures and documentation standards, can use these procedures and standards with LIGO Laboratory approval (through the LIGO Chief Engineer). However, it is preferred that they use the configuration control procedures within the LIGO Laboratory.
2) LIGO would prefer that individuals obtain their own LIGO document numbers and that these appear on the drawings. However, if this is not possible the LIGO Document Control Center (DCC) can arrange for the LIGO document numbers to be added to the *.pdf documentation.

2.10 Contractors

1) Contractor organizations which have their own configuration control procedures and documentation standards can use these procedures and standards with LIGO Laboratory

approval (through the LIGO Contract Technical Monitor or the LIGO Chief Engineer, respectively). If possible, contractors are encouraged to put the LIGO numbers directly on the documents. The DCC can assign a block of numbers for this. If this is not possible the LIGO Document Control Center (DCC) will add LIGO document numbers to the *.pdf documentation submitted by the Contractors and Collaborators.

3 Project Reviews

For reference, document LIGO-M1500263 provides programmatic guidelines for the development phases of all proposed Detector Improvements (DI) to the LIGO detector from the requirements and conceptual design phase through fabrication. As a reminder, LIGO Guidelines for Advanced LIGO Detector Improvement (DI) Project Review(s) includes:

- Multiple reviews for large projects
- Single Expedited technical review for smaller projects including approval only by Systems
- For small, straight-forward projects an ECR approval is sufficient
- Documentation includes guidance on review content (e.g. Hazard Analyses)
- Per the Safety Plan (M950046): *"The LIGO Safety Officer, or his/her representative, will participate in all design reviews as a review committee member, if the chair of the review decides that there is a safety element to address."*

4 Drawing Requirements

4.1 Generic

The following guidelines apply to all drawings.

1) **CAD Package Versions & Upgrading**:
   All upgrades to the CAD software packages (defined below) will be coordinated by the LIGO Lab, General Computing Group (which might mean that the LSC is informed when we are upgrading and given a chance to prepare themselves, i.e. we will not necessarily stop a transition because one LSC player can't or won't perform the upgrade.) Do not automatically upgrade when a new release is made available.

2) **DCC Numbers**:
   All parts and assemblies must have drawing numbers and revisions per DCC Instructions.

3) **Checking**:
   All drawings must be checked by a colleague or peer prior to release. The purpose of the check is to ensure that, for example, (1) the drawing has been implemented with a LIGO approved CAD tools, (2) all technical details are complete, correct, and consistent, (3) the design is compatible with design and interface requirements, (4) the design is safe (including a check of supporting stress analysis if applicable), (5) the drawing conforms with drawing standards and good practices, and (6) the design complies with all relevant

LIGO standards (EMI, UHV, etc.). The checker's signature(s) or initial(s) should be placed in the drawing template.

4) **Approval**:
Approvals are only required for released drawings and are based (among other things) on a satisfactory check. Released drawings are drawings which are placed into configuration control. Approval signatures are indicated in the Document Change Notice (DCN) process (see section 2 for DCN process and approvals).

5) **Part & Serial Number Marking**:
All parts and assemblies are required to have their part number (i.e. DCC number) marked on them. Serial numbers are in general optional, but encouraged. However, serial numbers are required for all electronic modules/boards and required when the need for matching parts or tracking parts is anticipated. (See also additional comments on part and serial number marking specific to mechanical and electronics drawings in the subsections below.) For the specific nomenclature used in drawing and part numbering, see section 3.2.12.

6) **Drawing Templates**:
A set of LIGO drawing templates for SolidWorks should be included in your LIGO build of SolidWorks. These templates are on the DCC here, LIGO-F0900044.
The drawing template must (as a minimum) indicate the DCC number (Dyyxxx), the revision code, the item name, the date, the author, and the DCN number which releases the drawing (if the drawing is under configuration control, i.e. has a letter in the revision code).

7) **Drawing Trees**:
A hierarchical, indented drawing 'tree' or list, with optional html links to the drawings, shall be created and updated for each assembly and sub-assembly. A drawing tree should include the parts list. An E number shall be given to each tree and it shall be released and revised via the DCN process. Drawing trees can be made in Microsoft Word or Excel.

8) **Drawing Size, Type Size and Readability**:
The minimum font type should be no less than 10 pt. If the content can't fit, then increase the drawing size or split the drawing into multiple sheets. LIGO uses standard A, B, C, D and E drawing sizes. A and B sizes are preferred, but when necessary larger drawings should be created. When rendering into an Adobe Acrobat (*.pdf) format for electronic filing into the DCC check to make sure that the *.pdf file is the proper size (i.e. C-size for a C drawing) and that the resolution is such that the content is readable.

9) **Multiple Page Drawings**:
Multiple sheets are permitted. All sheets should have the same DCC number, and the same revision code, and a sheet (page) number. The separate sheets should never be given separate DCC numbers. If a change is made to a single sheet then the entire drawing (all sheets) are marked as revised.

10) **Fasteners**:

All fasteners shall be Imperial (SAE, ASME) i.e. no metric fasteners. The SolidWorks toolbox provided with your build should be utilized. Details on LIGO acceptable fasteners and inserts can be found here: https://awiki.ligo-wa.caltech.edu/wiki/Fasteners.

11) **Dates**:
Please use the designation 7 JUL 04, JUL 7 2004, or similar on all drawings, DCN's etc. This is intended to prevent confusion between US and European date conventions.

12) **DCN's**:
Example Document Change Notices (DCN's) can be found on the DCC by searching for DCN under title. These documents are always "E" (engineering) type documents.

13) **DCN Number on the Drawing**:
In the revision history block on the drawing template, the Document Change Notice(s) (DCN) used to release the drawing version(s) (revision(s)) must be cited. This provides a cross-reference to the DCN that explains the reason for the drawing change, the implications of the change and has the signatures authorizing release. The DCN number should appear only on the first sheet of multiple sheet drawings.

14) **Electronic Filing in the Document Control Center (DCC)**
All drawings, drawing trees, and Bill of Materials (BOM) or Parts Lists must be electronically filed into the DCC as both source files and Adobe Acrobat files. Document Change Notices (DCN) must be filed electronically into the DCC with signatures as Adobe Acrobat files.

4.2 Mechanical Drawings

The following guidelines are specific to mechanical drawings (including mechanical piece part drawings, mechanical assembly drawings, optical layouts, civil construction drawings, piping & instrumentation, etc.).

1) **Initial LIGO Mechanical CAD Packages**:
For initial LIGO drawings the preferred CAD packages were I-DEAS and AutoCad (or Mechanical Desktop).

2) **LIGO Mechanical CAD Packages**:

The CAD standard software packages for advanced LIGO design work to be SolidWorks and in 3D as preferred, with use of AutoCAD (or Mechanical Desktop) and in 2D as potentially acceptable (to be reviewed on a case by case basis by the Chief Engineer). SolidWorks is the "official" CAD tool for LIGO.

3) **Solid vs 2D**:

Solid models are the preferred method for generating drawings and will be required for all complex assemblies.

4) **Reserving a DCC Number**:

(i) The Category denotes document type, such as: **D** for drawing, **T** for technical note, **E** for Engineering specification/description, etc ...

5) **Dimensioning and tolerancing**:
Dimensioning and tolerancing per ANSI Y14.5M - 1994. Even with this standard, there are many ways to dimension and tolerance. Refer to existing drawing examples on the DCC for guidance and useful examples.

6) **Units**:
Drawings shall be dimensioned in inches, except for layouts where dual dimensions are preferred, in the following format: inches [mm].

7) **Part Variant or "Type"**:
For some parts it is convenient to define a few variants which are (generally) identical with the exception of a single (or a few) dimension(s). Generally the variants are defined by a variable dimension(s) and a table of the part "type" code and the associated dimension. The variant or "type" code should be a two digit number.

8) **Bill of Materials (BOM)**:
All mechanical assemblies shall have a bill of materials (BOM). It is preferred to include this on the first page of the assembly drawing.

9) **Name of Designer / Engineer**:
In order to aid in identification, it is recommended to indicate your name(s) on the drawing with your first initial and last name e.g. C. Torrie and not CIT.

10) **Drawing Title:**
Each drawing should have the System, Sub-System, Next Assembly and Part Name indicated. E.g. D040136-03: ADVANCED LIGO SUS ETM PEN TEST MASS MAIN BODY

11) **Part and Serial Number Marking**:
For specific callouts refer to existing drawing examples on the DCC for guidance and useful examples.

12) **Weldments**:
Typical practice is to only provide a drawing with the dimensions of the final weldment but also if deemed, by the cognizant engineer for the subsystem, to be useful for LIGO to provide piece part drawings to the manufacturer, then the following note must be placed on each piece part drawing: *"This piece is part of a weldment. Dimensions shown are approximate; weld induced shrinkage or fill, and post weld annealing and machining considerations are not included. See DXXXXXXX-vY for required dimensions of structure after welding. where DXXXXXXX-vY is the drawing of the weldment."* This note should be prominent -- not just buried in a list of notes, but large, bold text.

13) **Sheet Metal:**

Sheet metal drawings are to be dimensioned in the bent/folded state. It is not required to also provide flat sheet drawings. (However bear in mind that additional time may be required by the manufacturer to determine the proper dimensioning of features in the flat state and errors may be made which can cause additional delays before delivery; If the sheet metal part is complex, it may be in our best interest to provide the flat state drawing(s) as well.) If flat sheet drawings are not provided, the SOW/RFQ should emphasize that it is the contractor's responsibility to determine the flat state. The SOW/RFQ should note that the CAD files can be made available for the manufacturer's use. However, the drawing always takes precedence over the CAD file. Hole dimensions on sheet metal (or machined) parts should be from single/common datums, unless there is a specific, well-motivated, need to control hole-to-hole dimensions tightly. LIGO standard drawing templates are available with notes that are applicable to sheet metal parts.

4.3 Electronics Drawings

The following guidelines are specific to electronics drawings (including schematics, board layouts, power distribution, wiring/interconnect diagrams, block diagrams, etc.).

1) **Top-level System Wiring Diagram** All subsystems (or subsets of subsystems if the subsystem is huge, like ISC) are required to have a top-level wiring diagram. Names for racks and rooms at an observatory are depicted in D1002704 or D1003141. Example wiring diagrams that meet these standards are D1900511-v8, D0902810-v9, D1900161-v4. Note, there will likely need to be sub-drawings for specific portions of the wiring that require interfacing at the Systems level; we must accept that information may be redundantly represented, and work together to ensure cross-drawing consistency (this redundancy is often quite helpful, especially across the years of iterations of the drawings and the people who made them).
    a) All major components depicted (sensors, actuators, signal conditioning chassis, IO Chassis, etc) must show
        i) Brief sensor/actuator/chassis/feedthrough/cable bracket name or function (preferably matching the assembly drawing's DCC file card discussed below)
        ii) If Chassis
            (1) *assembly*-level Drawing number (see below)
            (2) Rack location
            (3) U-Height
            (4) Stubs for connecting cables, labeled with the species and type of connector
                (a) P for Pins [formerly "male"], S for Sockets [formerly "female"]), and
                (b) A clearly identifiable common acronym for the number / size / type, e.g. uD9-P for a 9-pin micro-D, or SHV-S for safe-high voltage coaxial socket.

iii) If Feedthrough, work with Systems Team (and local site vacuum reps) to establish a "Flange Layout" (e.g. D1002877) and "[in-vacuum] Cable Routing" (e.g. D1101463).
   (1) Chamber name
   (2) Chamber location
   (3) Larger-flange location
   (4) Sub-flange connection

iv) If Cable connections, cable brackets between major components must show
   (1) If, in-vacuum, work with Systems / Seismic Isolation team to update / establish an in-vacuum Cable Routing plan, e.g. D1200060
   (2) For all cables, each cable should have a unique name, preferably of the form ${SUBSYSTEM}_${ID}_${n}, where
      (a) ${SUBSYSTEM} is the three (or four) letter acronym for the subsystem,
      (b) ${ID} is some short identifier for the relevant location / signal chain
      (c) ${n} is a unique number

   e.g. SEI_ETMX_023, ISC_REFL_104, SUS_HAM2_349, TCS_ISCTEY_112

   (3) Cable / Cable Bracket drawing number
   (4) Cable length

b) Electrical grounding, Radio-frequency Interference Mitigation, and interfaces to other subsystems (DC power, Rack Layouts, CDS IO Chassis) must be planned, included and defined at this level.
   i) Design must be compliant with the LIGO EMI requirements as defined in E020350.
   ii) Where possible/appropriate, the signal chains should have a clear single point of electrical ground reference plane, a. la T1200131.
   iii) The external influence of, and internal radiation of Radio-Frequency Interference (RFI) should be mitigated. See examples of mitigation discussion in E021114 E040288, T1500444,

c) Wiring diagrams should be made in Altium, The following walks through the drawing requirements and discusses its scope, as a summary of E1700133.
   i) The ability to create a "pull sheet" of cable names, lengths, and their connections, as per G1900170
   ii) Must include a graphical representation of the Racks and ADC / DAC card placement in each IO chassis
   iii) While chassis should depict their power needs, depictions of the cable connections from chassis power port to their power supply need not be made
   iv) Wiring diagram does NOT specify a pin-to-pin map within cables, as this cable pinout and major component assembly connections are defined at a level one lower (see below).
   v) Port labels which connect signals across sheets / pages shall have Altium's Cross-references turned on, and be named with clearly-identifiable signal

description (NOT the cable name connected to it, but the signal that flows through the cable, e.g. “SRM_M2_ULLLURLR_CoilDrive”, or)

vi) Formatting
(1) Well-defined grid spacing, and prescribed error handling
(2) Sheet sizes of size C or smaller
(3) Avoid spaces in and names or labels, instead use underscores
(4) Where possible, a common, shared, library of parts that represent sensors / chassis which are used across a given subsystem (if not across multiple subsystems, if say, it’s an AA chassis)
(5) Connections to the back of the chassis shall be marked with “Electrical Type” of “Input” (and thus a small white triangle)

d) The drawing shall have a DCC number of be of “D” type.
i) The “main” entry should be a multi-page .pdf export of the drawing.
ii) In the DCC file card, all chassis assemblies used in the drawing should be linked as “related documents” such that one begins to create a drawing tree.
iii) The DCC number should be “referenced by” (aka “hooked into the tree”) higher level branches of the tree, e.g. E1100337, T1300173, E1200174
iv) The “other files” should include a zipped up Altium project package.

2) **Chassis-Level Diagram / Drawing.** All major components (chassis, sensors, actuators) are required to have a top-level assembly depicting custom boards / internal cables / components used to create the chassis. Examples of chassis assembly drawings that meet these standards are D090006-v3, D1002559-v3, D1001242-v3, D1101521-v1, D1100013-v2.
a) DC power within the chassis shall be connected following the standards outlined in T1100079. One should also read through T0810012 to ensure chassis are reliable.
b) Connector pin-outs shall follow the standards outlined in T060123.
c) All chassis must have a “D”-type DCC file card associated with drawing.
i) The “main” entry a .pdf either an Altium rendering, visual studio, graffle-style cartoon of the chassis layout,

(1) That carton / rendering should have a *top* level bill of materials for an electronics chassis — i.e. a simple list of what boards (their drawing numbers, and QTY) are being used where in the chassis (NOT a detailed BOM for all components on all boards used within the chassis as a separate .xlsx file).

(2) Consider the consumer of the chassis, who may only ever have access to the outside of the box, and want to know the signal flow between / across boards from the external input to the chassis to the external output of the chassis.

(3) The drawing should depict the labels on the front/rear panels, and those labels should be consistent (read “identical to”) the interface labels on the board connections internal to the chassis in their respective drawing.

(a) e.g. If the front panel of a generic chassis reads “CH9-12,” then the front interface card board drawing better have a

connector labeled "CH9-12" printed on it, the interface card's drawing better call it "CH9-12" on its first page, etc. all the way through the chassis. Chaos ensues when a front-panel has a label "ABCD," the interface card has "CH9-12," the drawing calls it "Ch1-Ch2_Ch3-CH4." Work hard to design the chassis as a complete self-consistent system where possible.

ii) "Other files" in the entry should include
   (1) the assembly drawing's source code (be it Altium, Omnigraffle, InkScape) should be included as an other file.

iii) In the DCC file card itself, all boards used in the chassis should be linked as "related documents" to continue the document tree.

d) All *instantiations* of each chassis must have a unique serial number (and it should be unique from any serial number of any board within the chassis) created via the e-traveler system (see instructions in E2000489).

3) **Boards / Panels / Internal Cable - Level**:
   a) All boards shall be designed in Altium
   b) Connector pin-outs shall follow the standards outlined in T060123.
   c) All boards must have their drawing number screen-printed on the PCB, and space for a serial number sticker in clearly legible locations that are visible from above once assembled within its chassis.
   d) All boards / panels / internal cables for a given chassis must have a "D" type DCC file card associated with the drawing.
      i) If a board, the "main" entry should be a several page .pdf showing multiple imaginations of the board:
         (1) first page is a block diagram of all functional portions of the board (e.g. "differential input" block, connected to "whitening," connected to "differential output"), including pin-out and type of all connectors and jumpers.
         (2) next n pages will be the detailed circuit drawings for each functional portion of the board
         (3) the last n pages should show the PCB rendering of the board, especially if multi-layered
         (4) "other files" should include
            (a) the zipped up Altium drawing package, and
            (b) a detailed list of parts, a bill of materials
      ii) If a front/rear panel, this "main" entry should have a .pdf or .png of how the front panel will appear manifested in real life.
         (1) The front and rear panel should have
            (a) large clearly legible indication of the *chassis* drawing number and function,
            (b) Clear labels of connector function that matches
               (i) The wiring diagram's library part
               (ii) The internal interface card's connector name.
            (c) smaller, off-to-the-side, indication of the panel's drawing number

(d) space to install serial number sticker.

(2) "other files" should include the front-panel express source for the drawing

iii) If an internal cable, it really only needs to detail

(1) The connector number / size / type (e.g. uD9-P for a 9-pin micro-D, or SHV-S for safe-high voltage coaxial socket)

(2) the pinout from connector to connector,

(3) shield connection(s).

4) **Part Drawing and Serial Number Marking on Racks, Chassis, Boards, etc.**:

See above discussion for each component, but in summary:

a) chassis will have their drawing number engraved on the front/rear panels of the assembly and space for a serial number sticker,

i) Metal work and front/rear panels themselves to no require serialization independent of the chassis' serial number.

b) Boards will have a drawing number screen-printed on the PCB, and space for a serial number.

c) Unless extremely custom, with multiple failure modes if misidentified, cables do not require serial numbers.