If it takes more than a couple of adjectives to describe what you want . . . .

. . . . then “winging it” may not be the right answer

System Engineering in Model Railroading:

A geek applies system engineering process to the design of an integrated deployable portable . . . . . .

. . . . . compact
flexible
DCC
Command/
Booster/
Programming
Station

15 Mar 15

Trigger Alert

This presentation is a bit geeky

No shame in leaving early

Aim

To introduce the
System Engineering Process
as an appropriate way for
Model Railroaders
to approach complex problems

a DCC Command Station is used
to illustrate the process,
but this clinic is about the process,
not a review of the design

Why on earth would one do this?

When to

- When the problem is complex, with many possible solutions
- When you are a geek who likes the engineering side of model railroading
- When you have a broken arm and cannot do anything else

Eg:

- Building a basement layout
- Modifying a fleet of cars
- Building a Free-Mo Command/ Programming station

When not to

- When the problem is simple
- When the solution is blindingly obvious

Eg:

- Purchasing rolling stock
- Laying track
- Kit-bashing a structure (usually)

System Design does not do the detail design

It just tries to get the 'big picture' architecture right

The right detail design will follow

System Engineering Process

What's wrong with what I have?
What's right?

How do I plan to use it
(Use Case)

What does it have to do
(Requirements)

To what does it connect?
(Context)

Electrical design

Physical Design

Mock-up/ Prototype risk areas

Final Build

System Design

Detail Design

Check list for the design

The design

The build

At each step, questions arise that may cause you to go back to a previous step . . . perhaps even to the beginning.

Right/ Wrong Made Easy

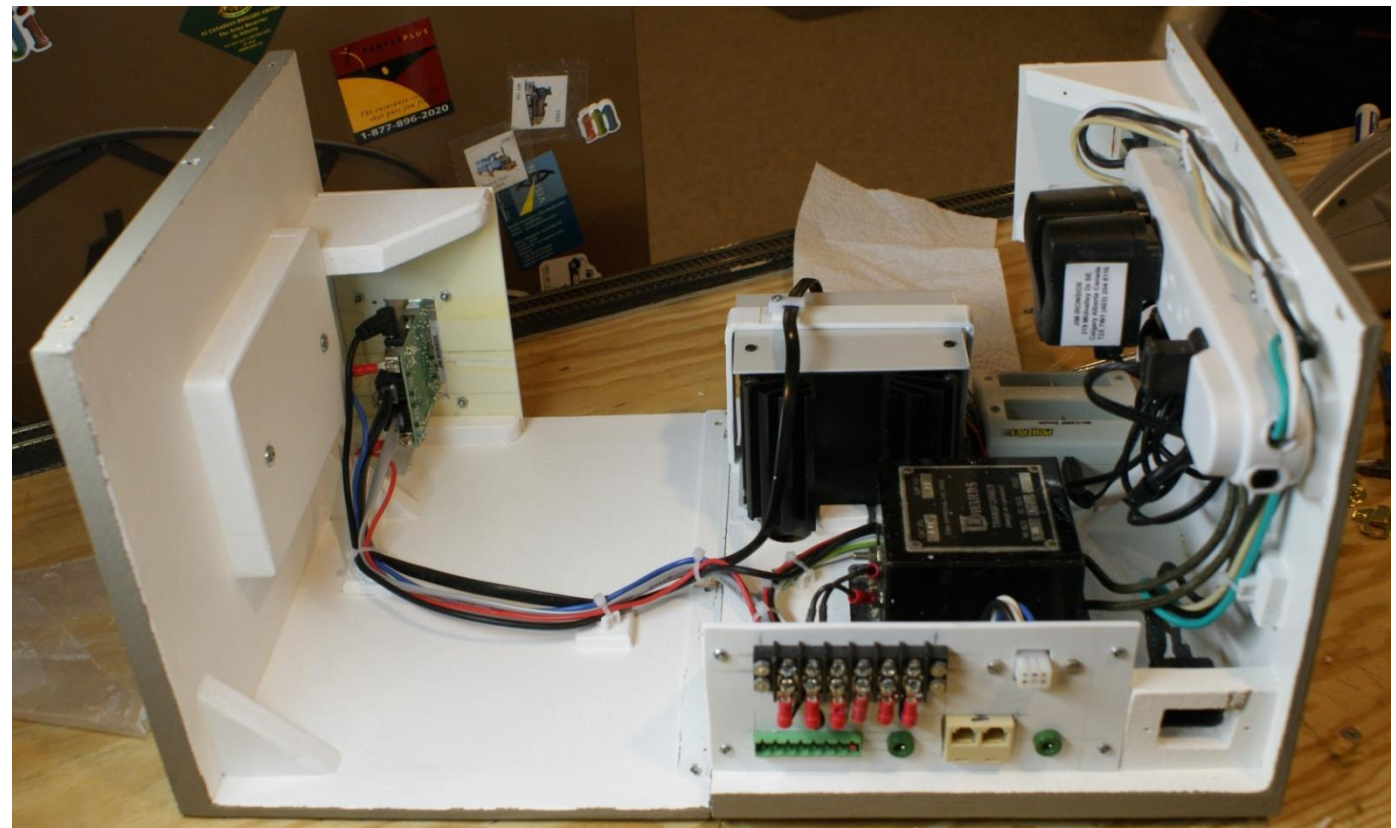
- **MAKE A LIST!!!!!**
  - Nothing focuses the mind like writing it down and trying to make it clear to yourself

What's wrong with what I have?
What's right?

Version V1

Version V0
DCS100 + UR92
Screwed to train table – not portable

Added battery charger and portability
Front, Back, and Opened views



What's wrong with what I have?
What's right?

Issues with Version 1

Uppers

- Easily transportable
- Convenient all in one DCS/ PS/ UR92/ Battery Charger
- Stacking because of recessed handle
- No dangling cords for transport
- Front and rear connections for test track
- All components accessible when case opened

What's wrong with what I have?
What's right?

Downers

- Cannot isolate the Programming and Track leads neatly (DCS100 coupling 'feature')– kluge solution in place
- Cannot isolate the UR92 neatly – must disconnect PS and LocoNet
- Marginal power supply
- No provision for PR3 or programming track
- No storage for accessories
- Maintenance access could be better – six screws
- When open, connections vulnerable, requires manipulating two moveable sections at once
- Needs circuit breaker in Track leads to protect Accessory leads for home use
- Leads too short to reach from floor to module in away use
- Needs status/ error code interpretation in visible location
- Thermal management?
- Mismatch of 7-way plug/ 8-way jack for module connection

Use Cases Made Easy

- Identify the different situations in which the item will be used
- For each, follow through the sequence of actions that will take place or capabilities that will be required
- **DO NOT LOOK INSIDE THE BOX!!!!!!**
  - [except for pre-selected components which impact use]

How do I plan to use it
(Use Case)

Command Station Use Cases V2.3

Home: I want to

- Connect to wall power with Master on/off
- Connect to Track Bus Accessory Bus, ThrottleNet, and Programming track
- Operate module from wire connected throttle or wireless through UR92 radio
- Operate module from laptop
- Program on main from laptop or throttle
- Select Programming output on unit as PR3/ Laptop or DCS.
- Select Program or Operate for module programming track on local panel
- Connect to bench programming track with Track, Programming and ThrottleNet connection. Program/ Operate on local bench track panel
- Charge throttle batteries

1

2

3

How do I plan to use it (Use Case)

Away: I want to

All

- Connect to wall power with master on/off
- Charge throttle batteries

As Command Station

- Provide BoosterNet output
- Power Track Bus or Accessory Bus
- Interface computer to setup
- Program locos on a programming track and on main

As Booster

- Interface to BoosterNet
- Power Track Bus or Accessory Bus

As Command Station or Booster:

- Act as UR92 node or disable UR92

As Programming Station

- Program with PR3 and Laptop or with DT402 and DCS
- Select Program or Operate for programming track on local panel on track

Requirements Made Easy

- Think “It shall do . . . . ” or “It shall be . . . . ” for each Use Case
- Check against the Rights and Wrongs to ensure they are covered
- Check against the Use Cases to ensure they are covered
- For “druthers” think “It should do . . . . ”. These items are sacrificial if necessary. Identify as “Desirable”
- **DO NOT OPEN THE BOX** (unless you have specific bits that you want to use, then identify them as constraints

What needs does it have to meet (Requirements)

Command/ Program Unit Requirements – V2.3

- Constraints: Must use
  - DCS100 Command Station
  - PR3 Programming interface
  - UR92 Radio interface to throttles
  - PSX-1 Circuit breaker to protect Accessory Bus

What needs does it have to meet (Requirements)

Command/ Program Unit Requirements – Home V2.3

- Drive Track and Accessory Buses
- Allow Accessory Bus to function when Track Bus is shorted (Circuit breaker on Track Bus)
- Interface to computer to program equipment including sound equipped equipment
- Interface to computer for control of trains
- Feed programming track on module
- Feed programming track on workbench
- Provide back panel connectors for semi-permanent connections and front panel connections for temporary connections
- Charge batteries
- Have master on/ off switch on front
- Minimize footprint; max 12” (30 cm) high on feet
- Easy internal access for maintenance
- Clear indications of status of controls on front panel
- Easy access to component (DCS100, UR92, PR3) controls and indicators
- Self-explanatory labels/ controls and indicators
- (Desirable) Status and controls cheatsheet on unit
- Front access only after installation in home setup

What needs does it have to meet (Requirements)

Command/ Program Unit Requirements – Additional Away V2.3

Packaging

- Not more than two units (Command/ Program Unit and separate Programming Track) , plus laptop
- (Desirable) Package programming track with Command Unit for transport
- Physically protect components in transport; not environmental protection
- Stackable
- Storage for cables and accessories for standalone use as booster; accessible away but not at home
- No dangling cords in transport
- All Ogden Road cables disconnected at rear panel left behind
- Unit (less programming track) does not need to be on table

Functional

- Connect to BoosterNet (as Command Station or Booster), DCC Common, 110VAC
- Power Track and/ or Accessory bus
- Track circuit breaker not in circuit
- Deal with Digitrax program leads ‘coupling’ issue
- Allow UR92 to be totally disabled eg power and LocoNet connection (if necessary)
- Program equipment including sound equipped equipment from Laptop
- Re-Railer on programming track
- Use own programming track or allow connection to external programming track

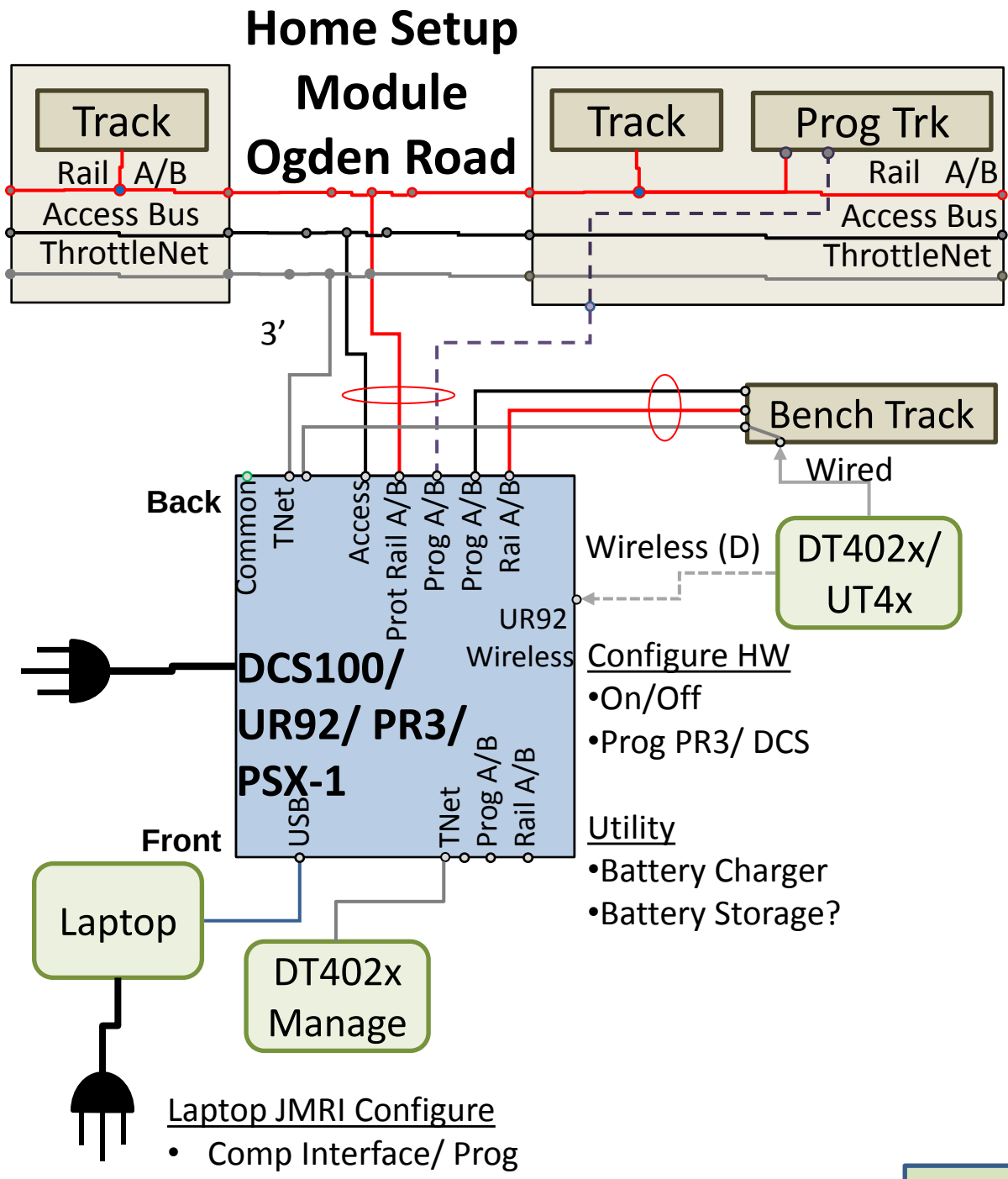
What needs does it have to meet (Requirements)

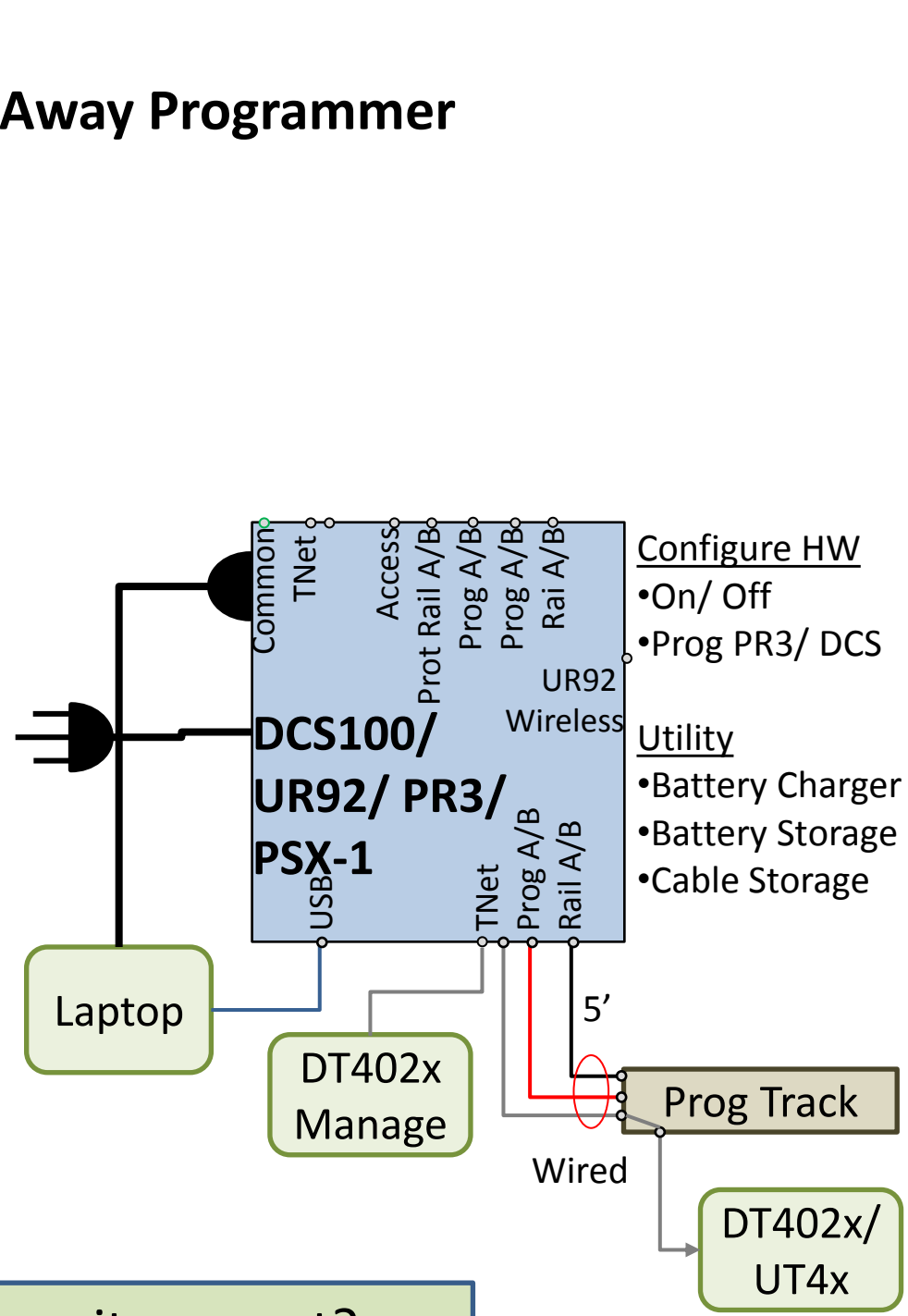
Context Made Easy

- **DO NOT OPEN THE BOX!!!!!** **Keep it black**
- Different Use Cases may have different contexts
- Identify all of the items/ interfaces to which the unit will connect
- This includes space (eg for a layout, walls and doors)

To what does it connect?
(Context)

Command Station V2.3
Use Case Context

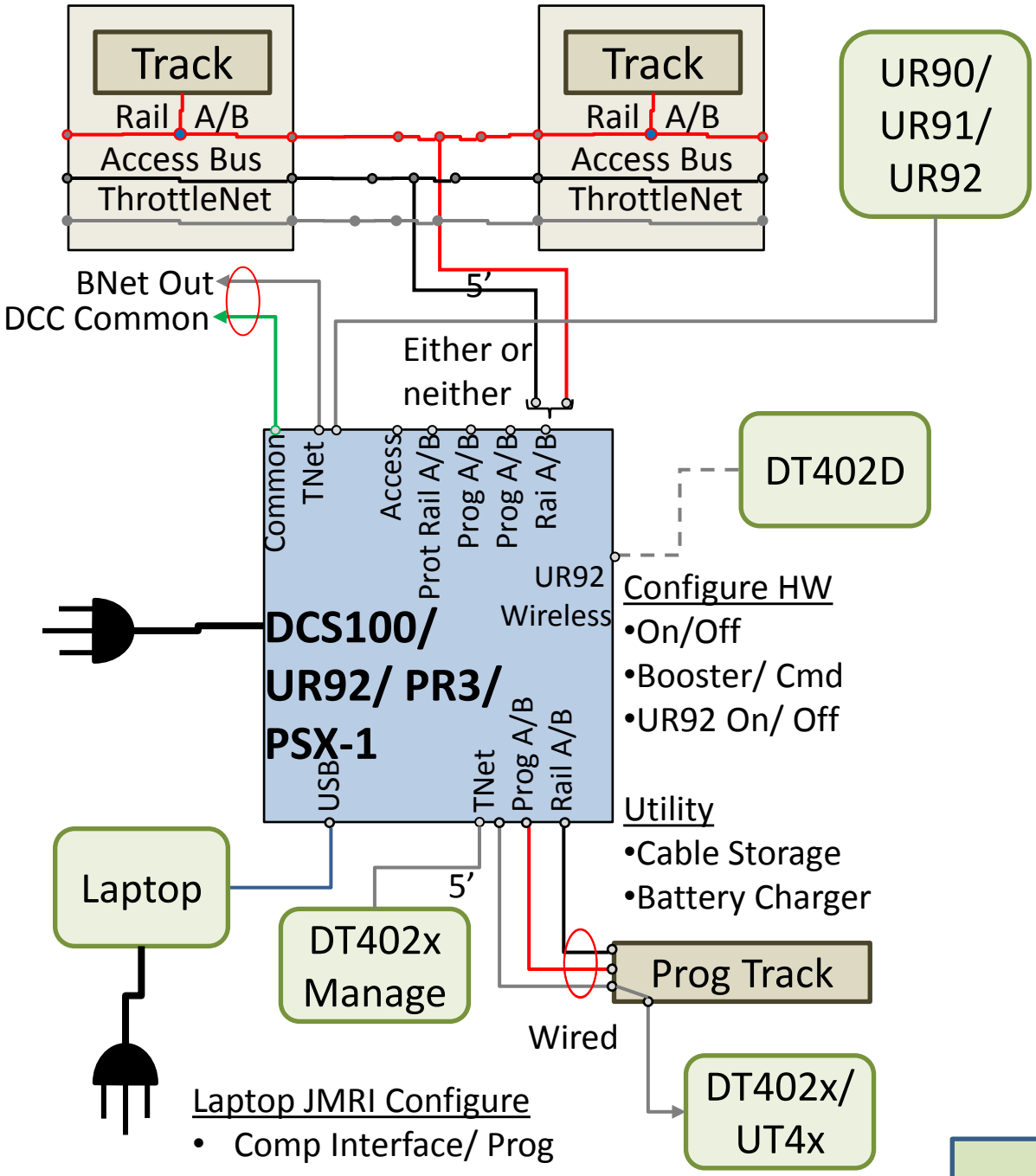




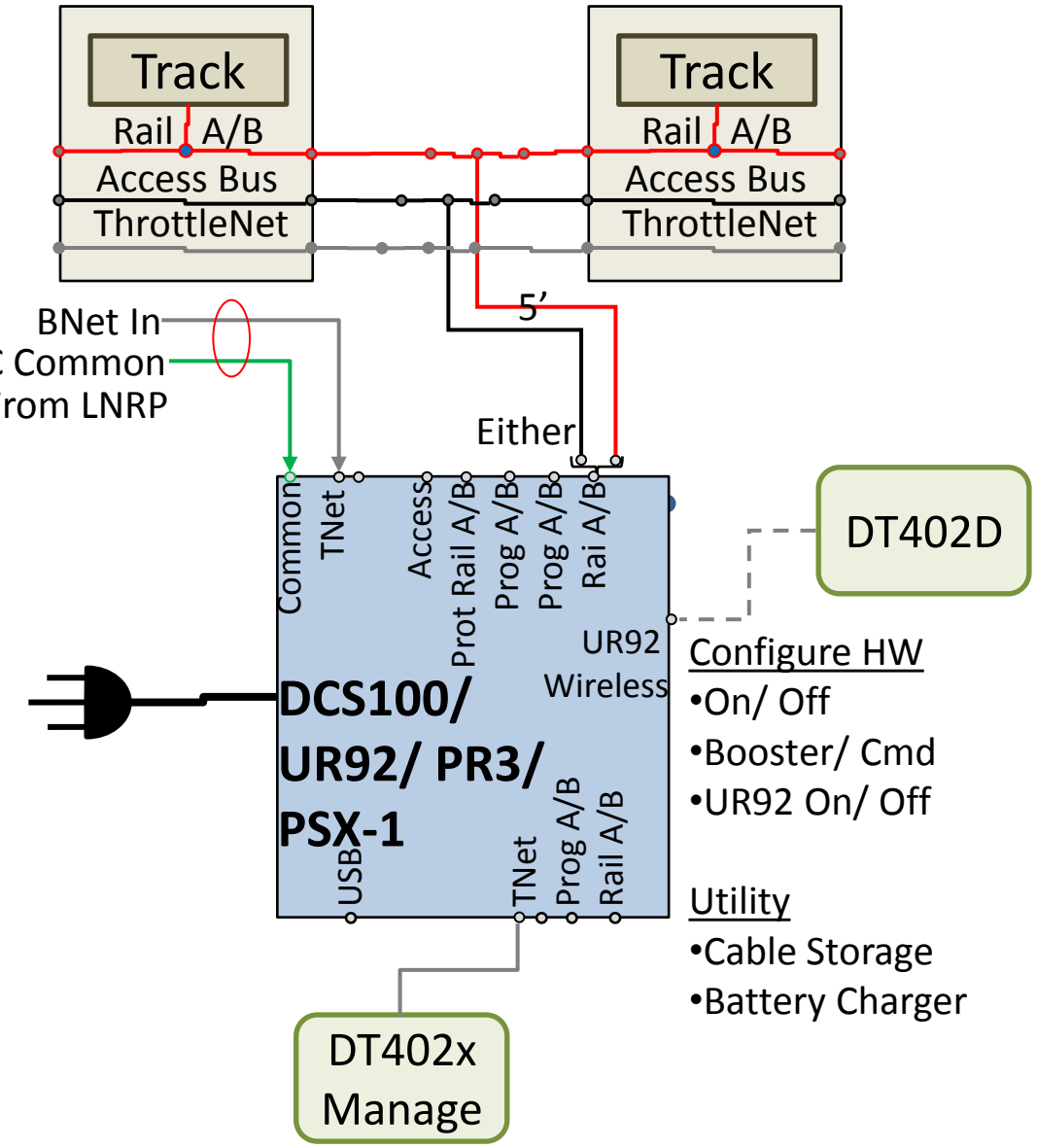
To what does it connect?
(Context)

Command Station V2.3
Use Case Context

Away Command Station



Away Booster



What does it connect to?
(Context)

Summary to Here

- We now know (sort of) what we want
  - The good and bad about what we had before
  - How it is going to be used
  - What it has to do (and be) each way it is used
  - What it has to interface with (electrical, space, etc) each way it is used

We do not yet know what is inside the box

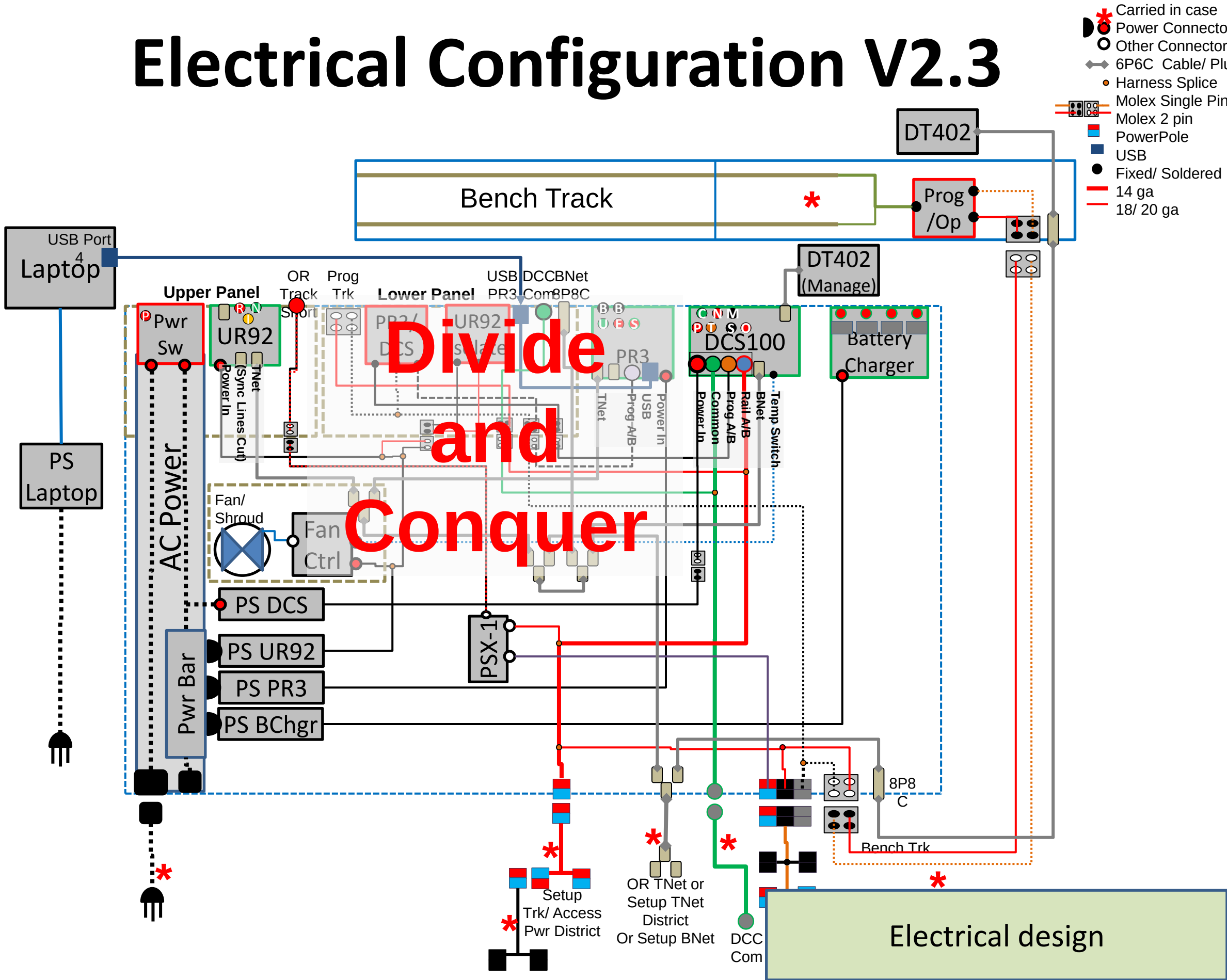
Electrical Design Made Easy

- Create PowerPoint grouped representations of common design objects
- Use PowerPoint connector lines to represent wiring
- Develop colour, attribute, and thickness code for wires/ functions
- Use standard electrical/ electronic components – preferably those available from more than one source
- **At the end, there is a very strong interaction with the physical design!!!**

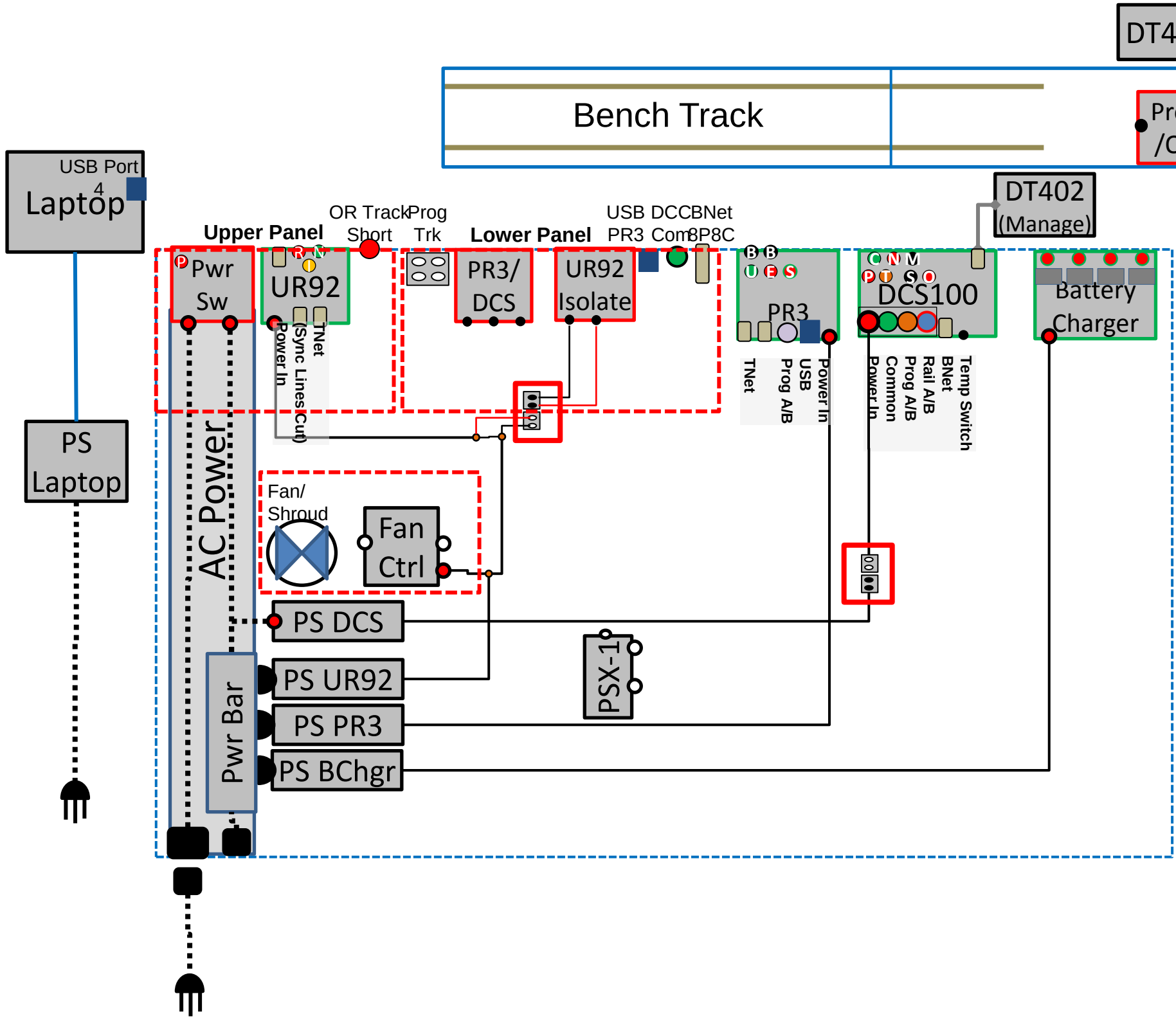
Electrical Considerations

- Components directed in design
- Component availability and price
- Multi-source components
- Form Factors
- Standardization
- Installation

Electrical Configuration V2.3

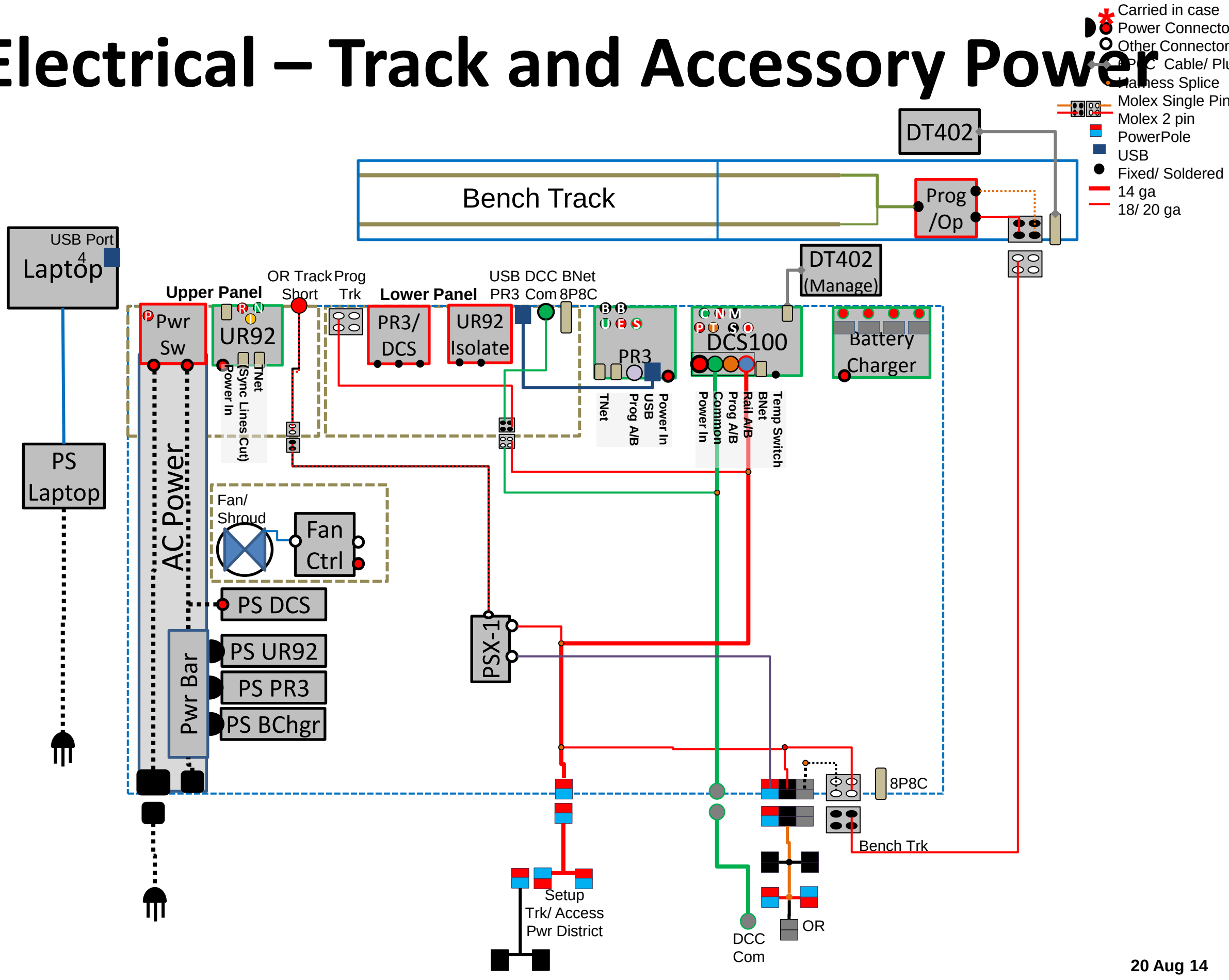


Electrical – AC/ DC Power



20 Aug 14

Electrical – Track and Accessory Power



20 Aug 14

Electrical - LocoNet

Carried in case
Power Connecto
Other Connector
6P6C Cable/ Plu
Harness Splice
Molex Single Pin
Molex 2 pin
PowerPole
USB
Fixed/ Soldered
14 ga
18/ 20 ga

DT402
Bench Track
Prog /Op
USB Port 4
Laptop
DT402 (Manage)
OR TrackProg
Short Trk
USB PR3
DCC Com
BNet 8P8C
Upper Panel
Lower Panel
Pwr Sw
UR92
PR3/ DCS
UR92 Isolate
PR3
DCS100
Battery Charger
Power In
(Sync Lines Cut)
TNet
TNet
Power In
USB
Prog A/B
Power In
Common
Prog A/B
Rail A/B
BNet
Temp Switch
PS Laptop
AC Power
Fan/ Shroud
Fan Ctrl
PS DCS
PS UR92
PS PR3
PS BChgr
Pwr Bar
PSX-1
Setup Trk/ Access Pwr District
OR TNet or Setup TNet District Or Setup BNet
DCC Com
OR
8P8C
Bench Trk

20 Aug 14

Physical Design Made Easy

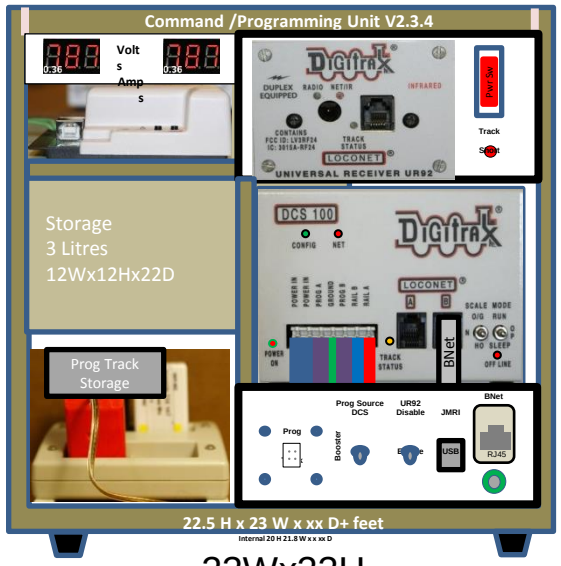
- Use your camera
- Use PowerPoint
- Get photos from Internet, eBay, etc
- Scale photos of equipment/ parts to correct size
- Use drawings of other components scaled to size
- Play with the parts
- Print out occasionally to get a feel for the state of design

Physical Considerations

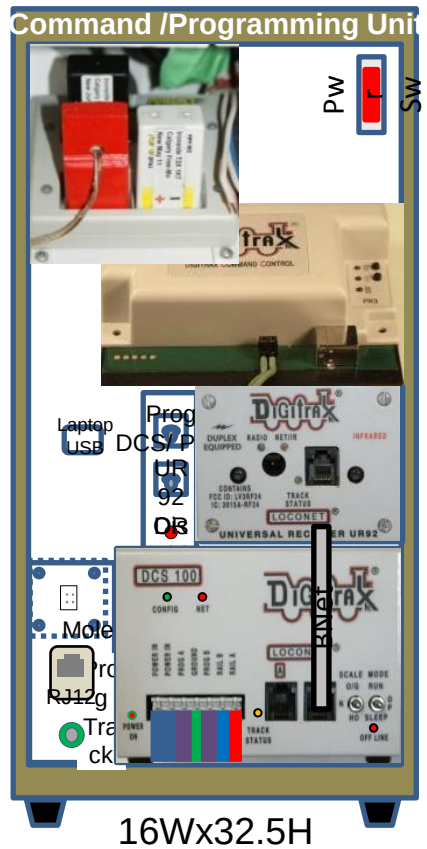
- Human Interface
  - Often (usually?) the most important factor
- Footprint
- Component placement
- Cable routing
- Heat Management
- Maintenance
- Ease of Construction
- Materials
- Finish
- Environment
- Transportability

Physical Design

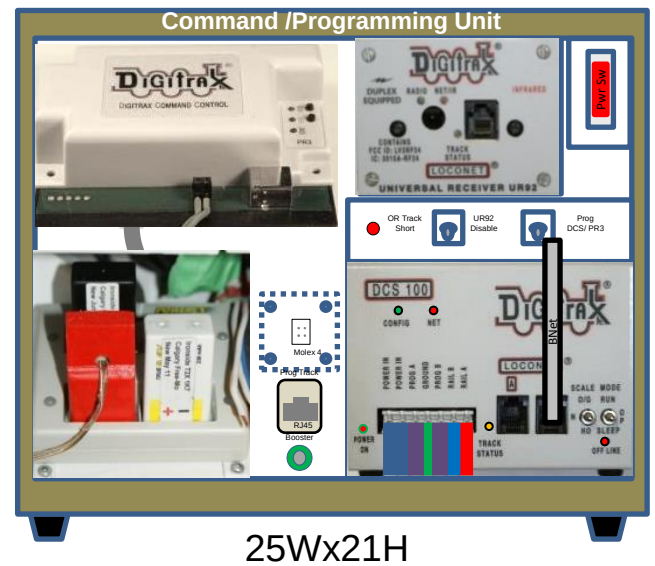
Alternate Configurations



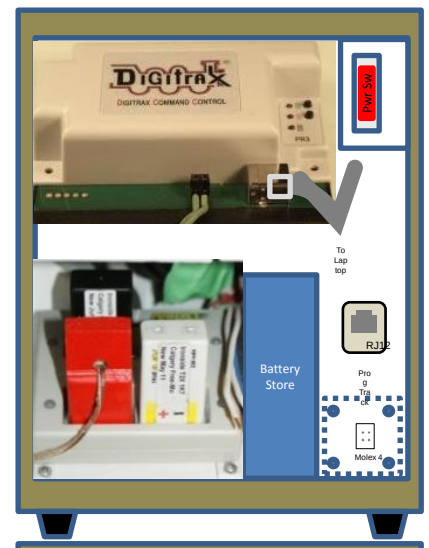
23Wx23H

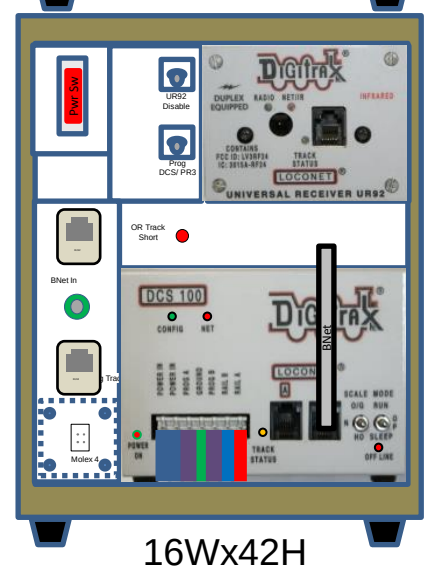


16Wx32.5H

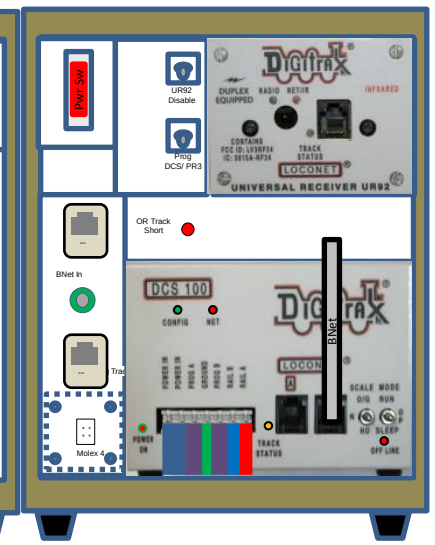


25Wx21H





16Wx42H

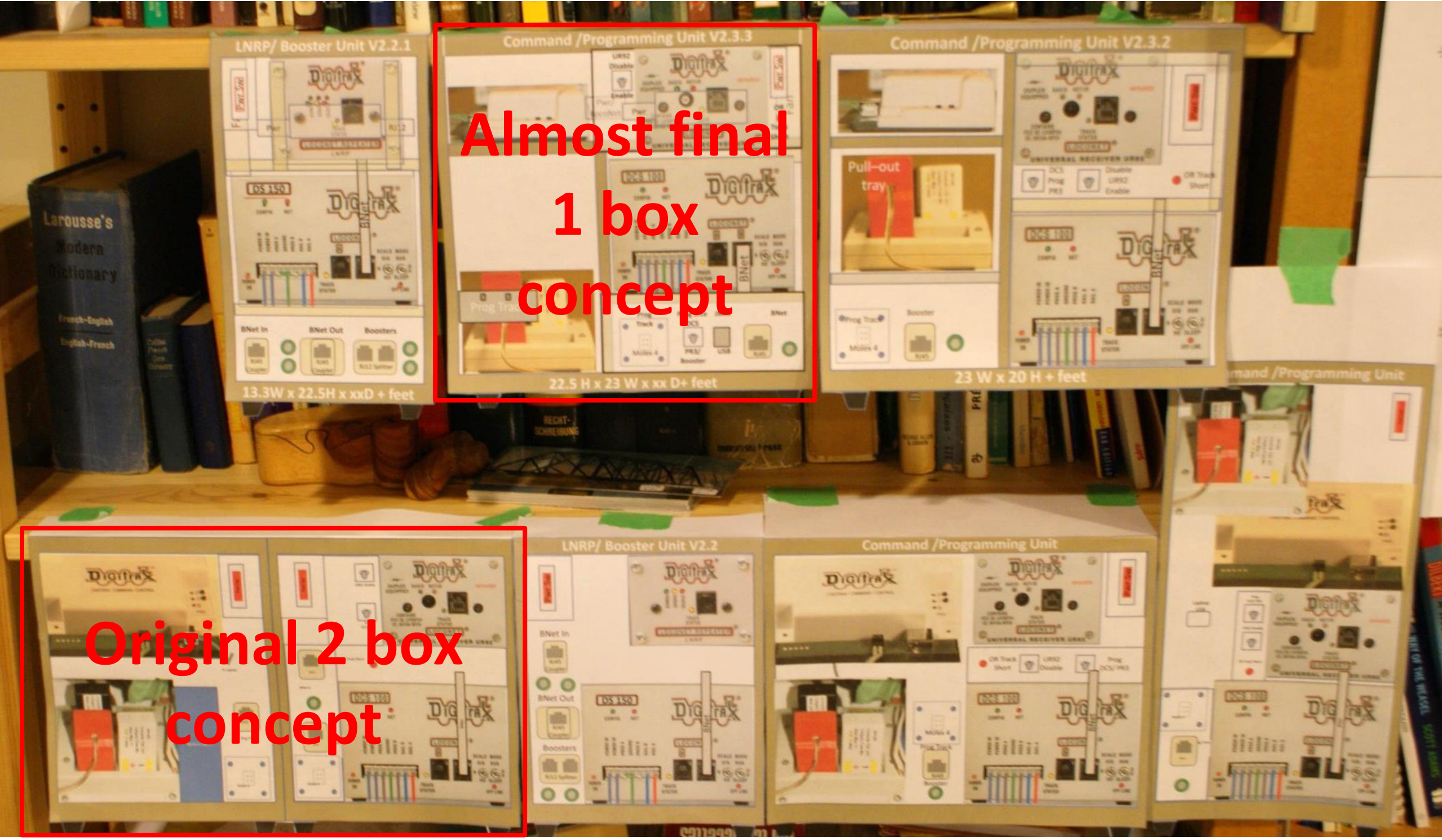


32Wx21H

Combined vs two box configuration:

- Reduced total panel footprint
  - 25Wx20H, 500 cm2 vs
  - 2x 16Wx20H, 640cm2)
- Some cabling reduction
- Decreased footprint if horizontal
  - 25 vs 32W cm, 21H cm
- Increased footprint if vertical
  - 25 vs 16W cm, 42H cm
- Less deployment flexibility
  - Booster or programming vs both
- Less installation flexibility
  - Must be 23W x 23H cm

Physical Design



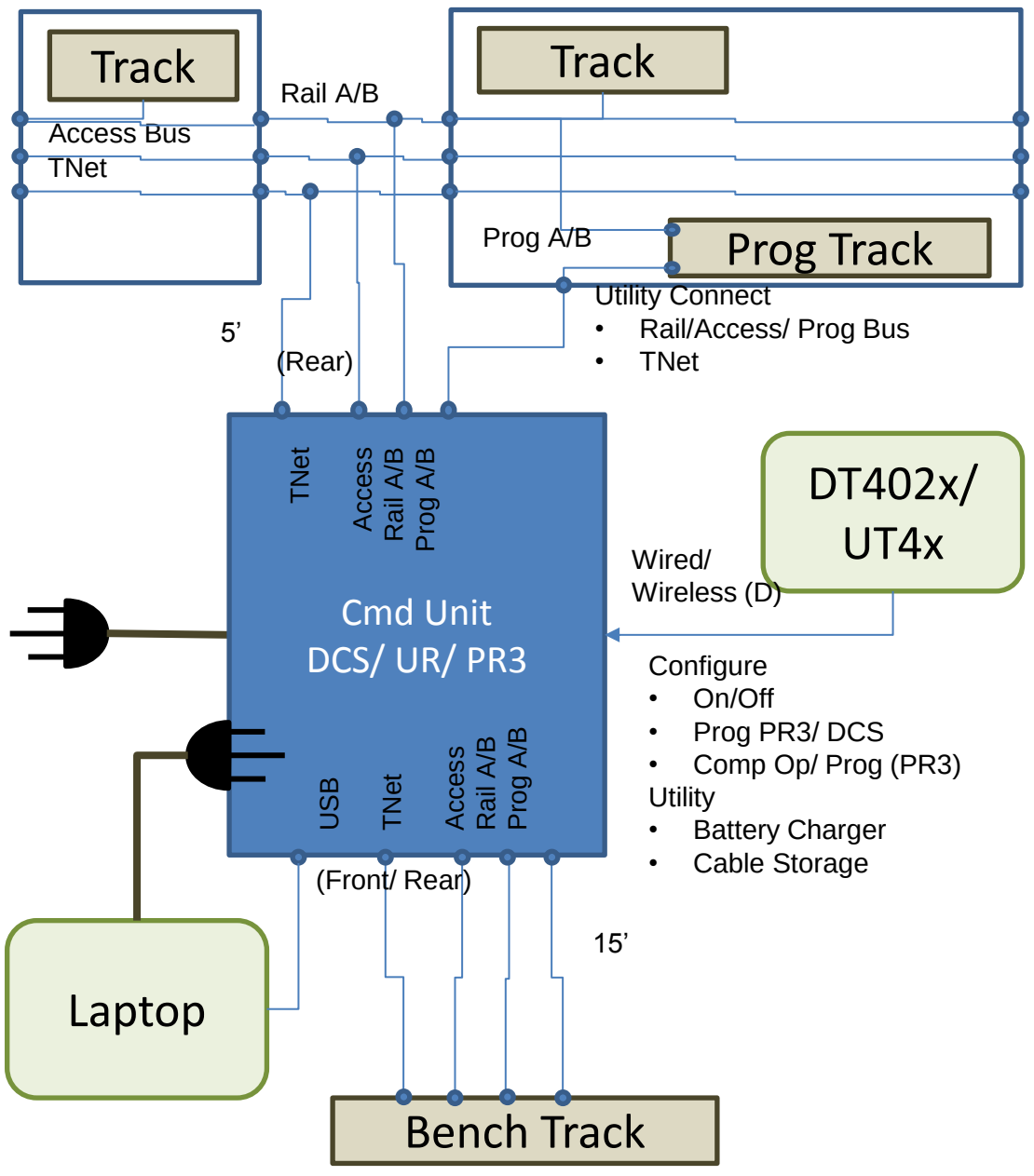
Several alternative front panel designs printed and hung.

Post side by side to get a feel for the problem and solution

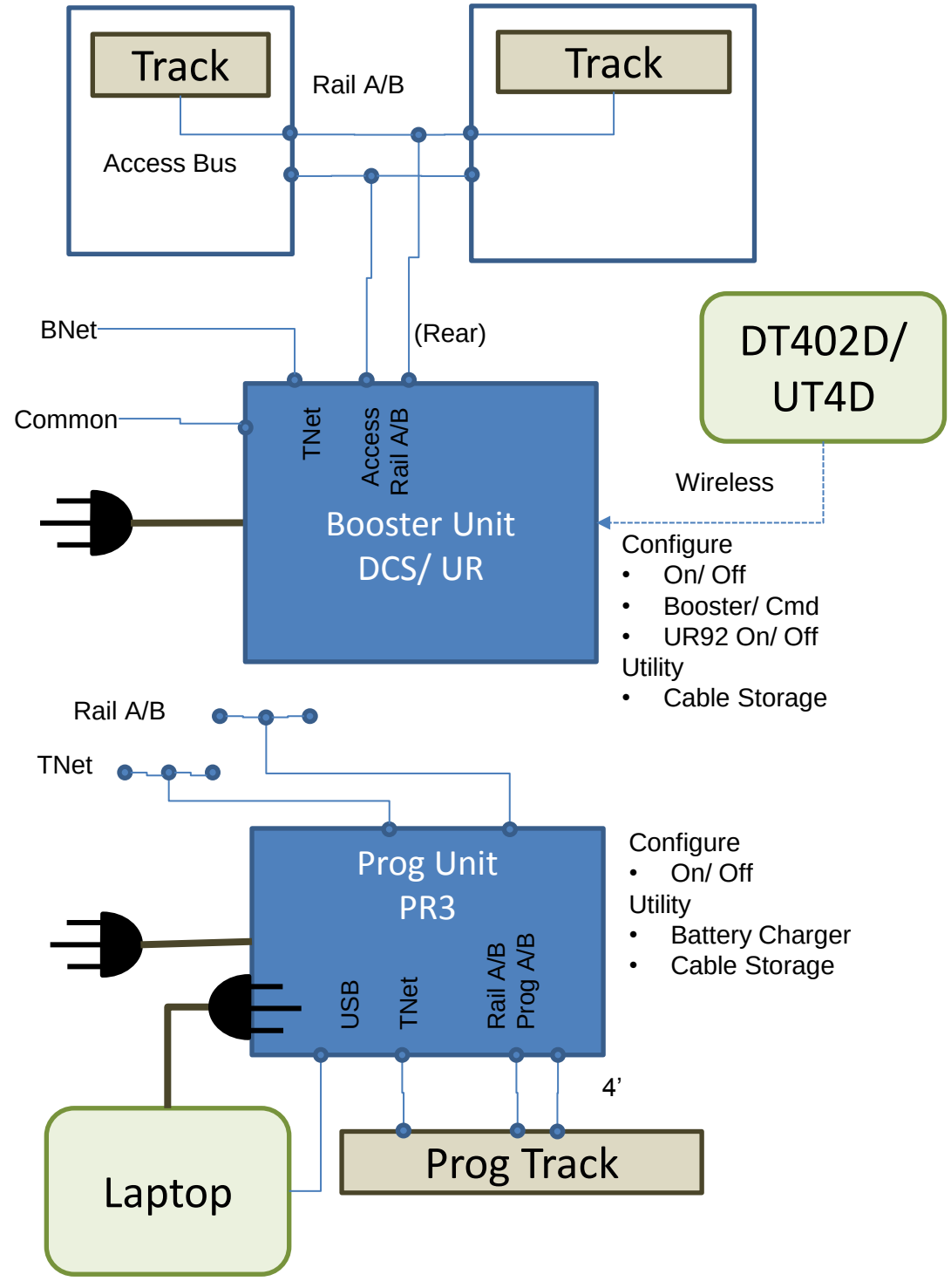
Physical Design

Original Concept – Context

Home Setup
Module Ogden Road

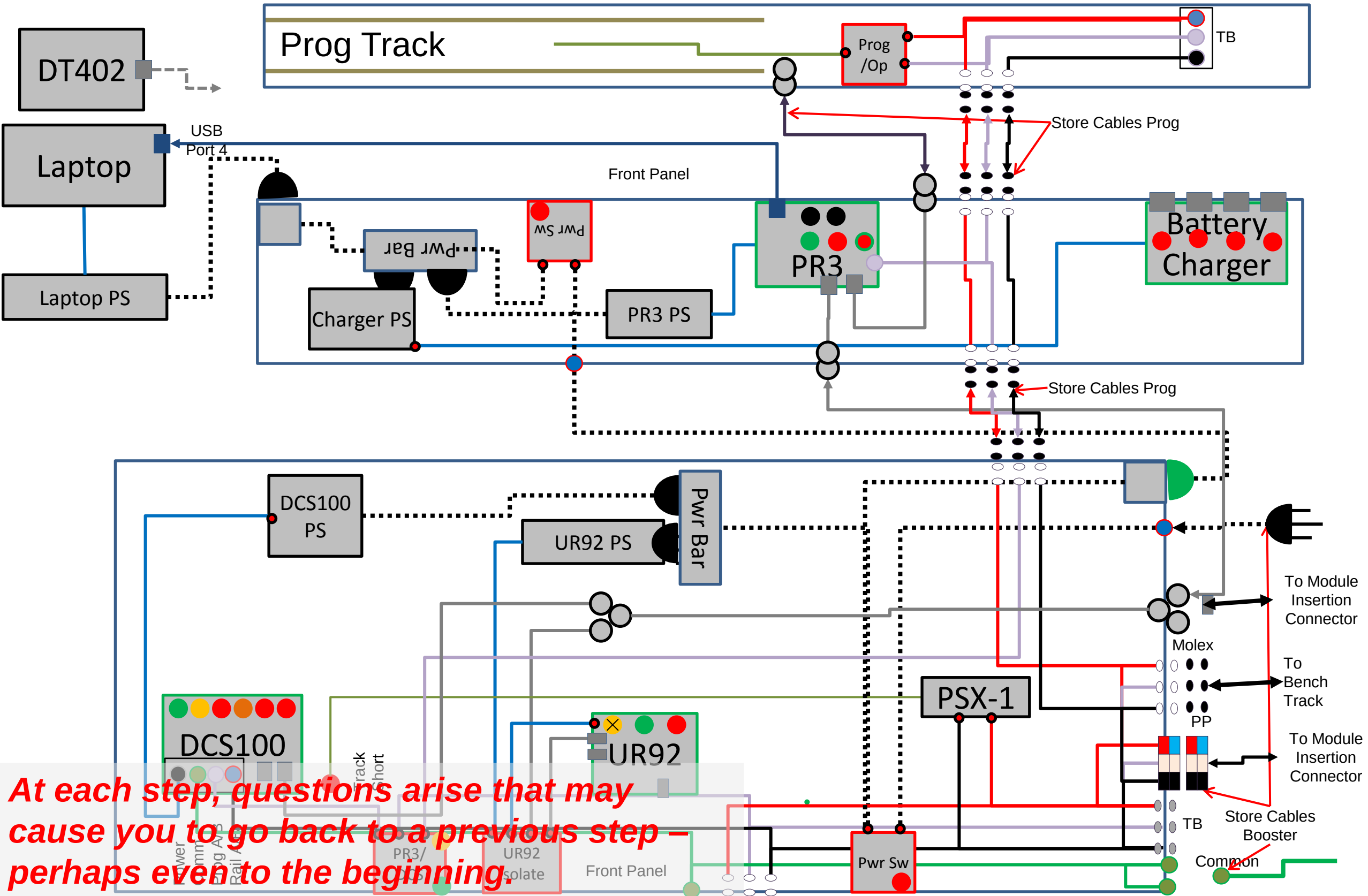


Away Setup



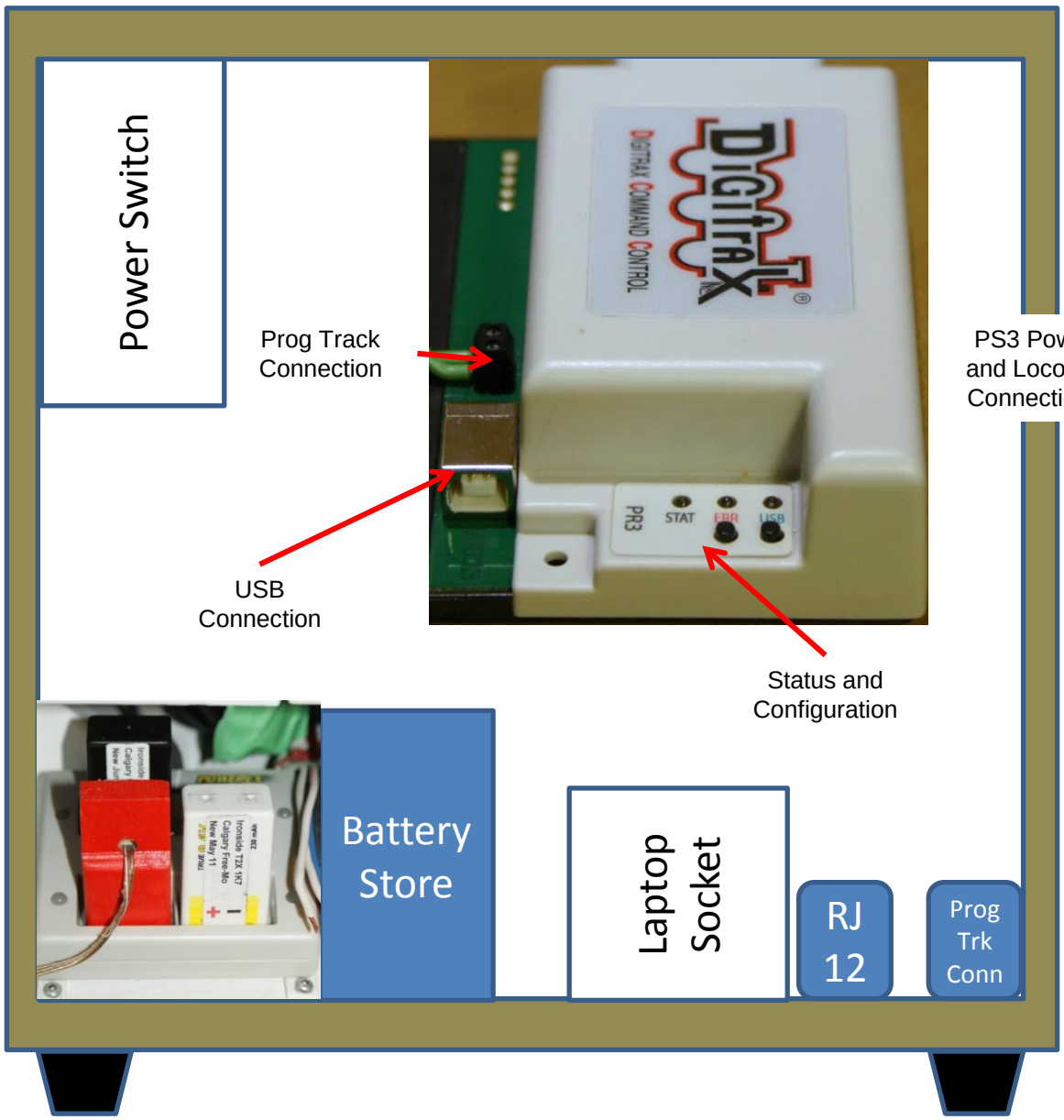
At each step, questions arise that may cause you to go back to a previous step – perhaps even to the beginning.

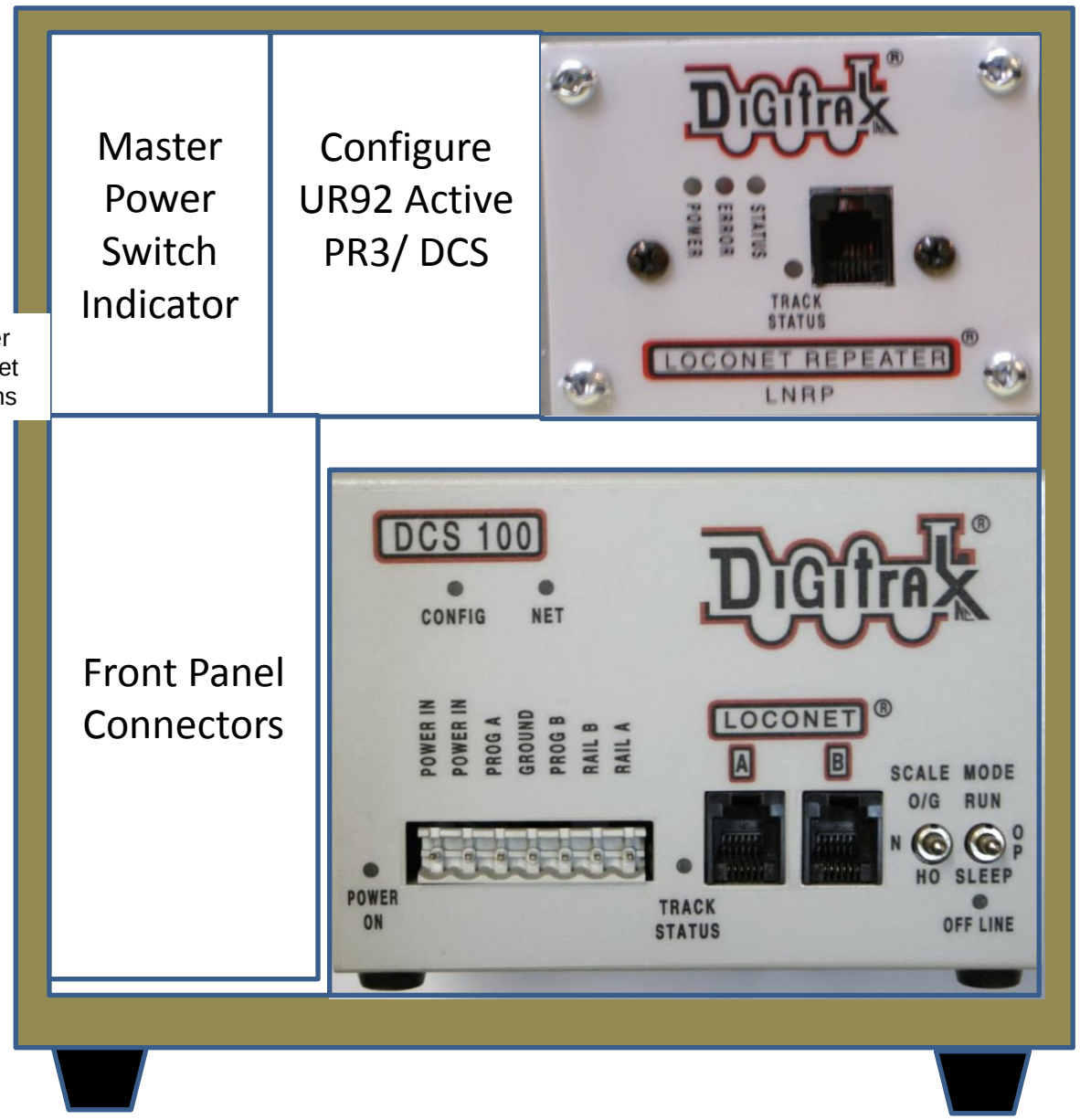
Original Concept – Electrical



At each step, questions arise that may cause you to go back to a previous step – perhaps even to the beginning.

Original Concept - Physical





At each step, questions arise that may cause you to go back to a previous step – perhaps even to the beginning.

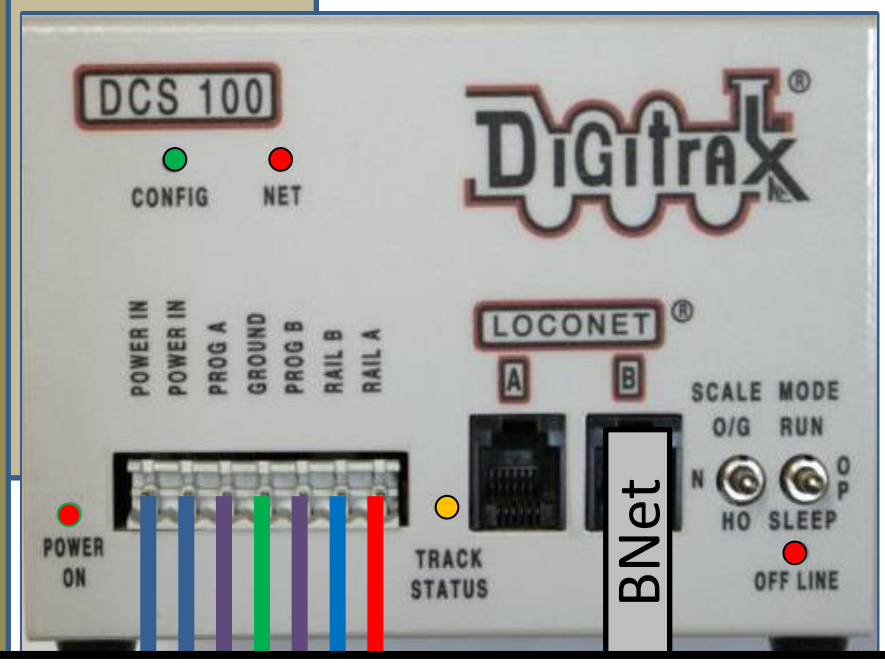
Command /Programming Unit V2.3.4

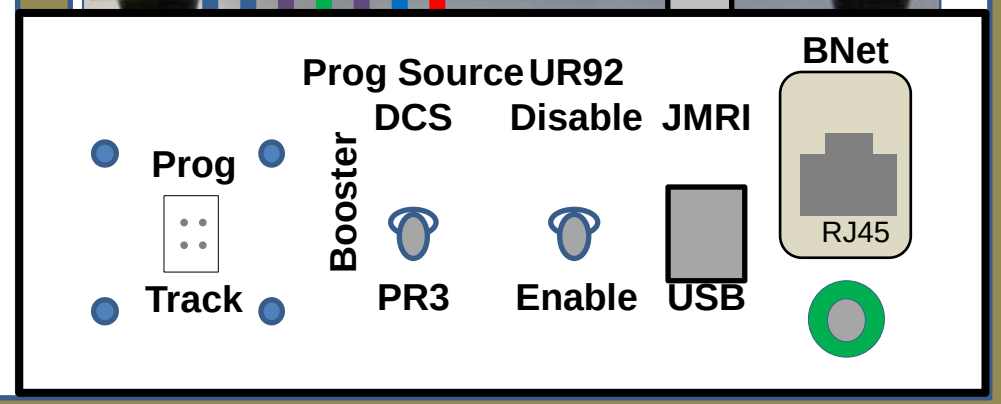
Pwr Sw

Track

Short

Storage
3 Litres
12Wx12Hx22D





22.5 H x 23 W x xx D+ fe

Internal 20 H 21.8 W x x xx D

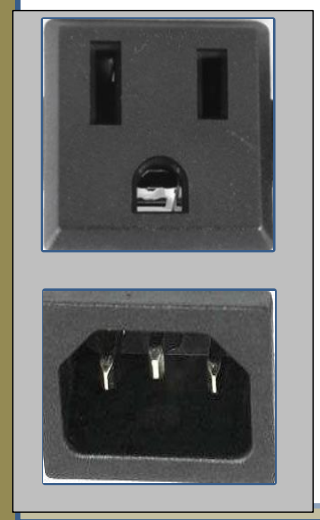
Physical Design

Command/ Programming Unit V2.3.3

Stores:

- Power Cord
- Prog track cable/ TNet
- BNet cable/ ground 24”
- Setup Track Power District cable 48”
- Setup BoosterNet cable 48”
- Accessory Bus Adapter 6”
- Batteries 4

Storage
3 Litres
12Wx12Hx22D



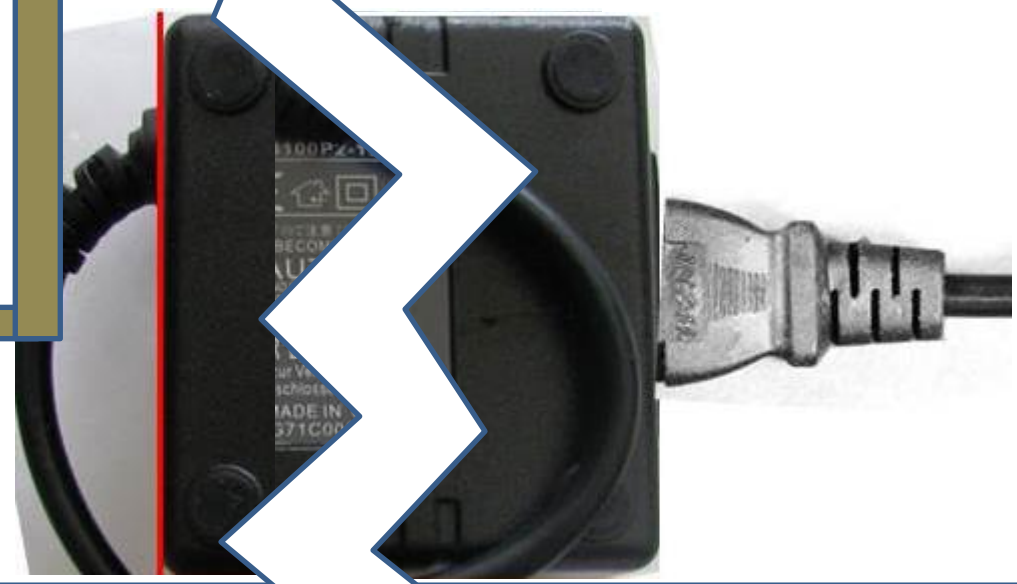
Physical Design

UR92

Fan

Storage

DCS100



Side View

Physical Design

Summary to here

- System design is done
  - We know what we want
    - Checklist for the design
  - We have a rough design
    - Electrical
    - Physical
    - Interacting

We are ready to get to the detail

Mock-ups Made Easy

- Mock-ups address risk areas and unknowns in physical design, particularly user interface, component placement, and construction ease
- Making:
  - Use PowerPoint pictures previously developed, pasted to cardboard
  - Use real components where available
  - Use corrugated cardboard for structure; base and one or two walls usually enough
  - Hot or white glue parts together
  - Early in process, do not try to be too precise

Mock-up/ Prototype risk areas

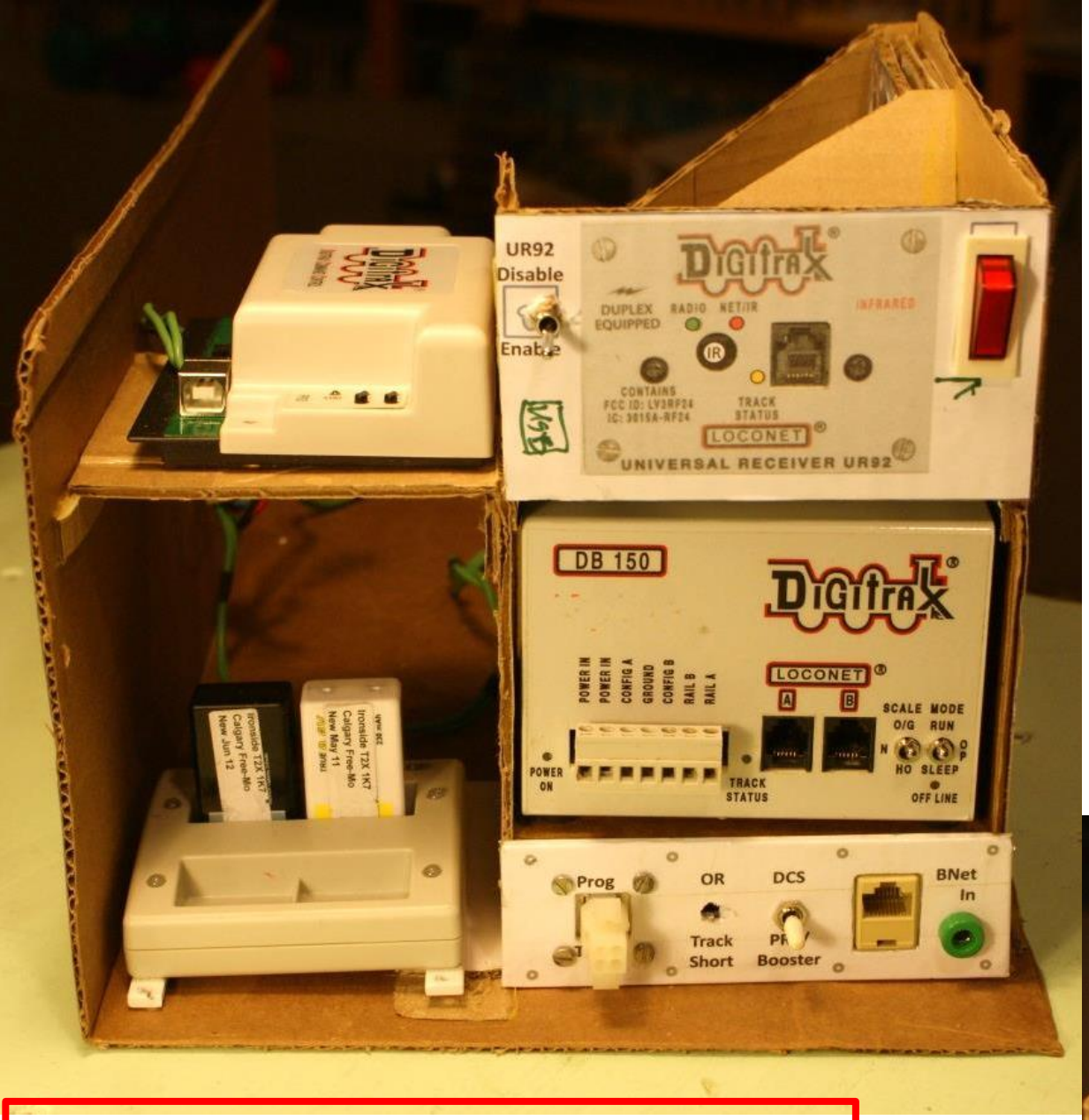
- Using
  - Visualize or mock-up external cable placement
  - 'Pretend' operate controls
  - Visualize or mock-up internal cable runs
  - Consider accessibility of parts for build/ maintenance
  - Butcher mock-up with knife and glue to make changes
- Make final mock-up more exact to ensure parts fit, preparation for real build

We are modellers, after all

Cardboard mock-up front and interior with some real components

Fan (Cardboard mock-up)

Cooling fan shroud (top not installed)

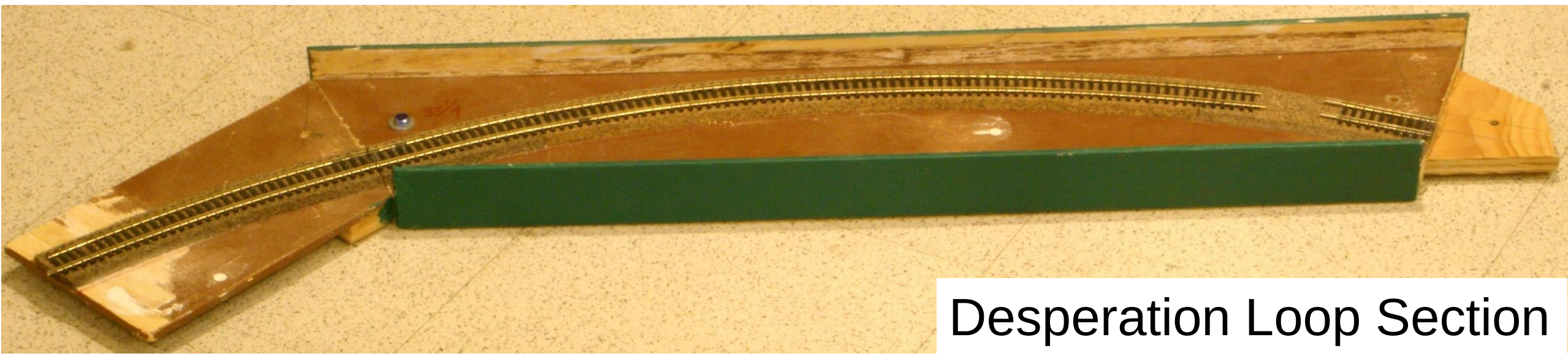


Third mock-up version.

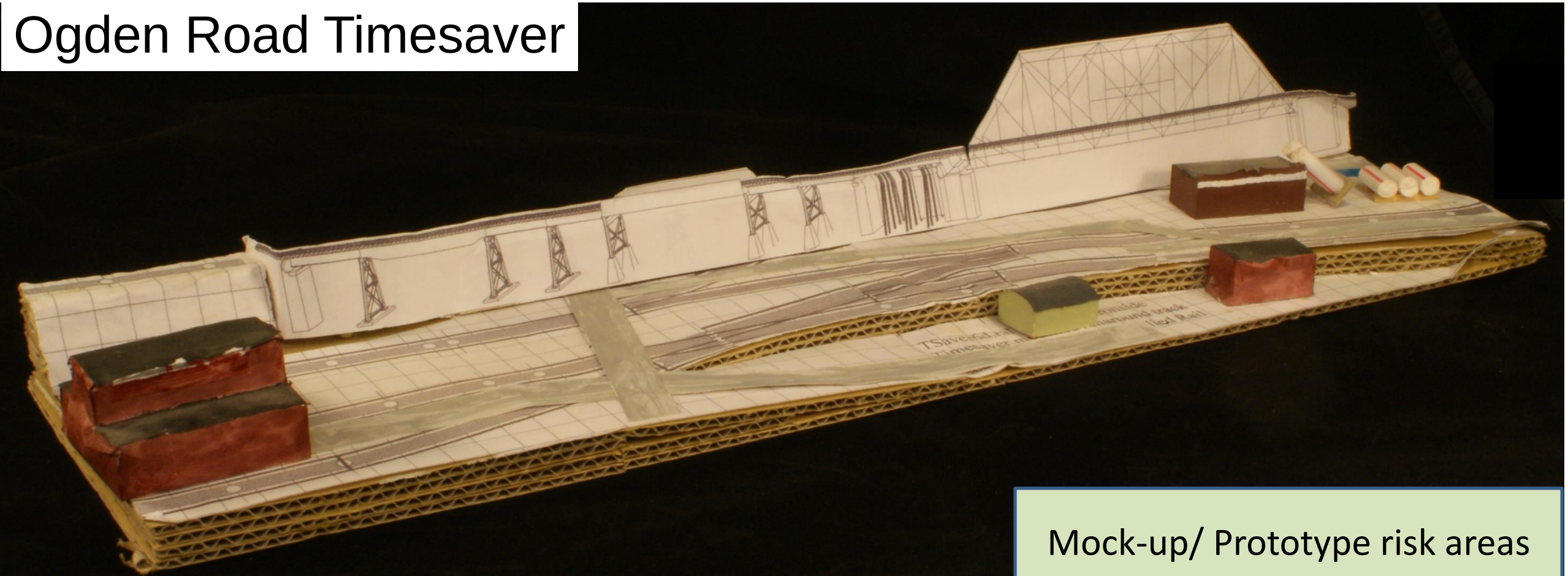
Shows arrangement of cooling fan shroud

Mock-up/ Prototype risk areas

Mock-ups/ Prototypes - Layouts



Desperation Loop Section

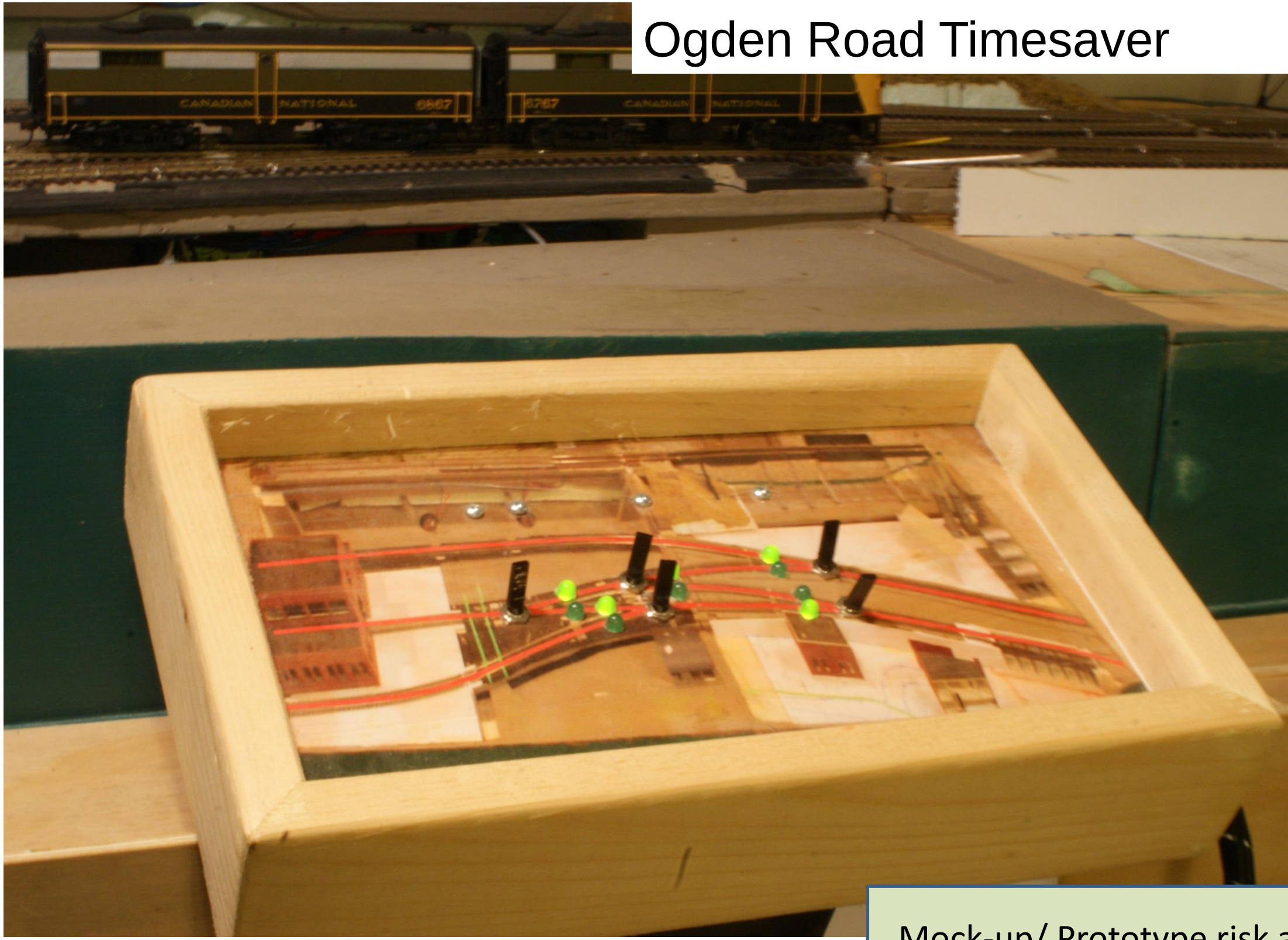


Ogden Road Timesaver

Mock-up/ Prototype risk areas

Mock-ups/ Prototypes – Control Panel

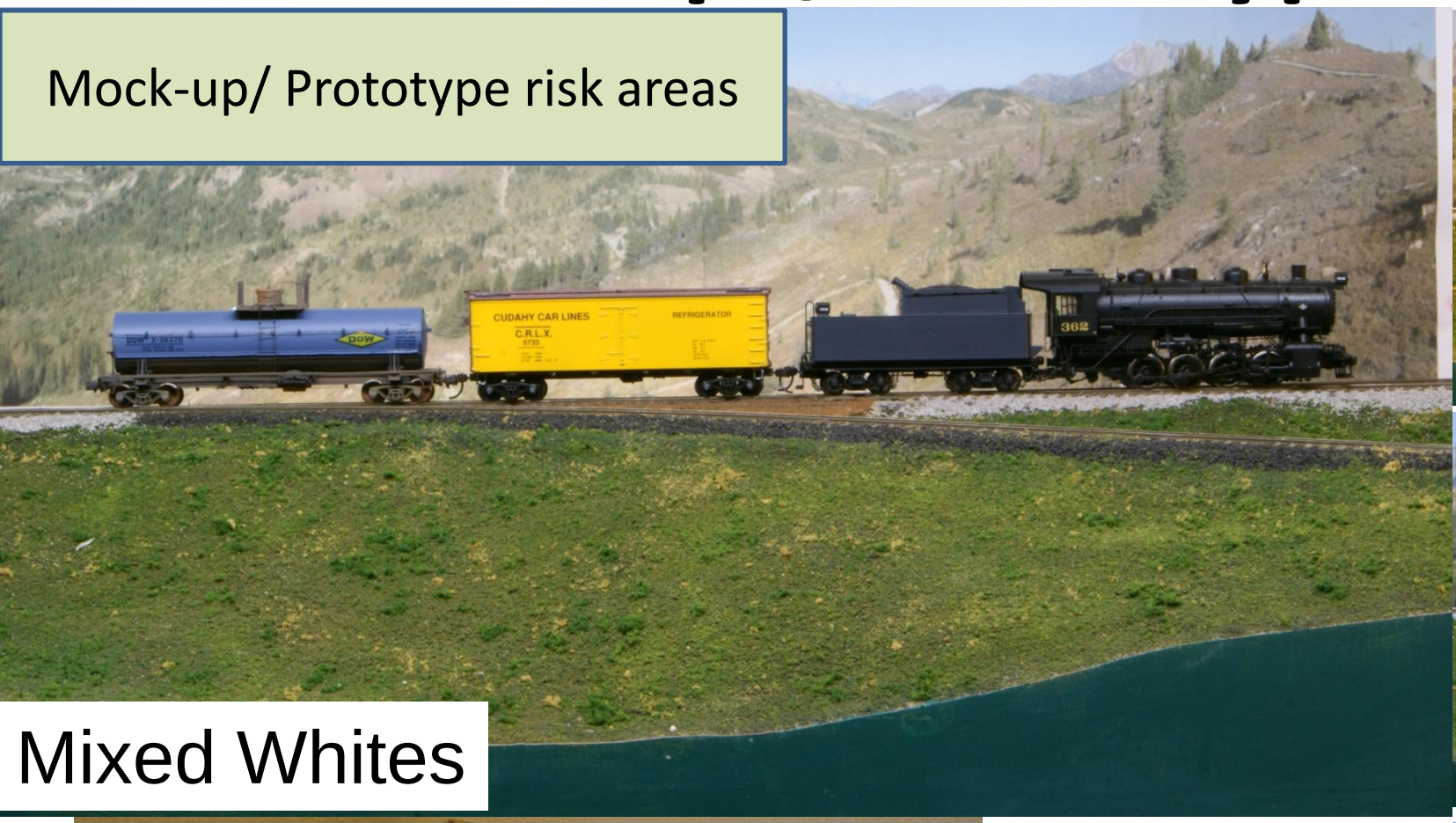
Ogden Road Timesaver



Mock-up/ Prototype risk areas

Mock-ups/ Prototypes - Lighting

Mock-up/ Prototype risk areas



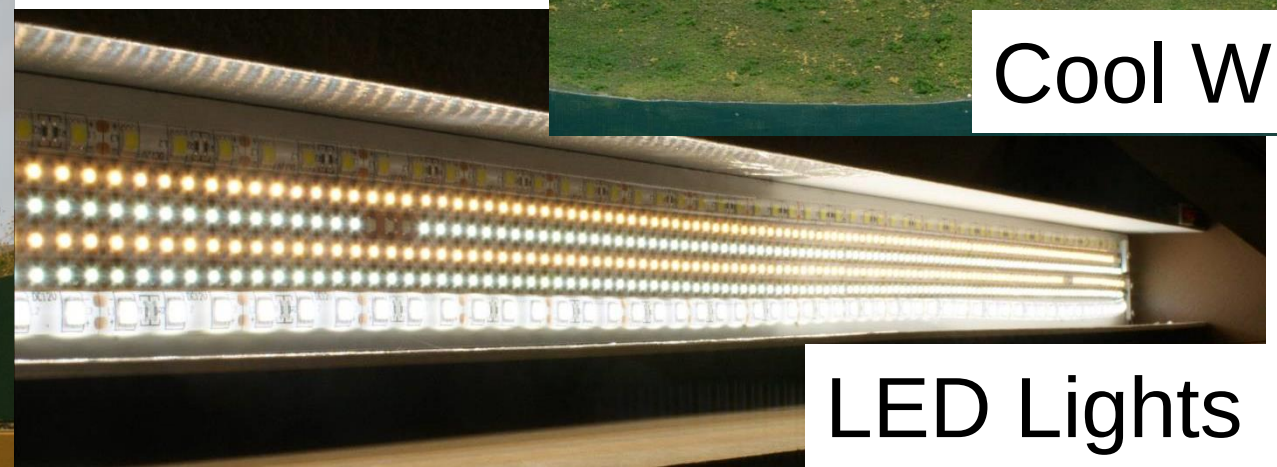
Mixed Whites

Warm White

Daylight

LED Valence

Cool White



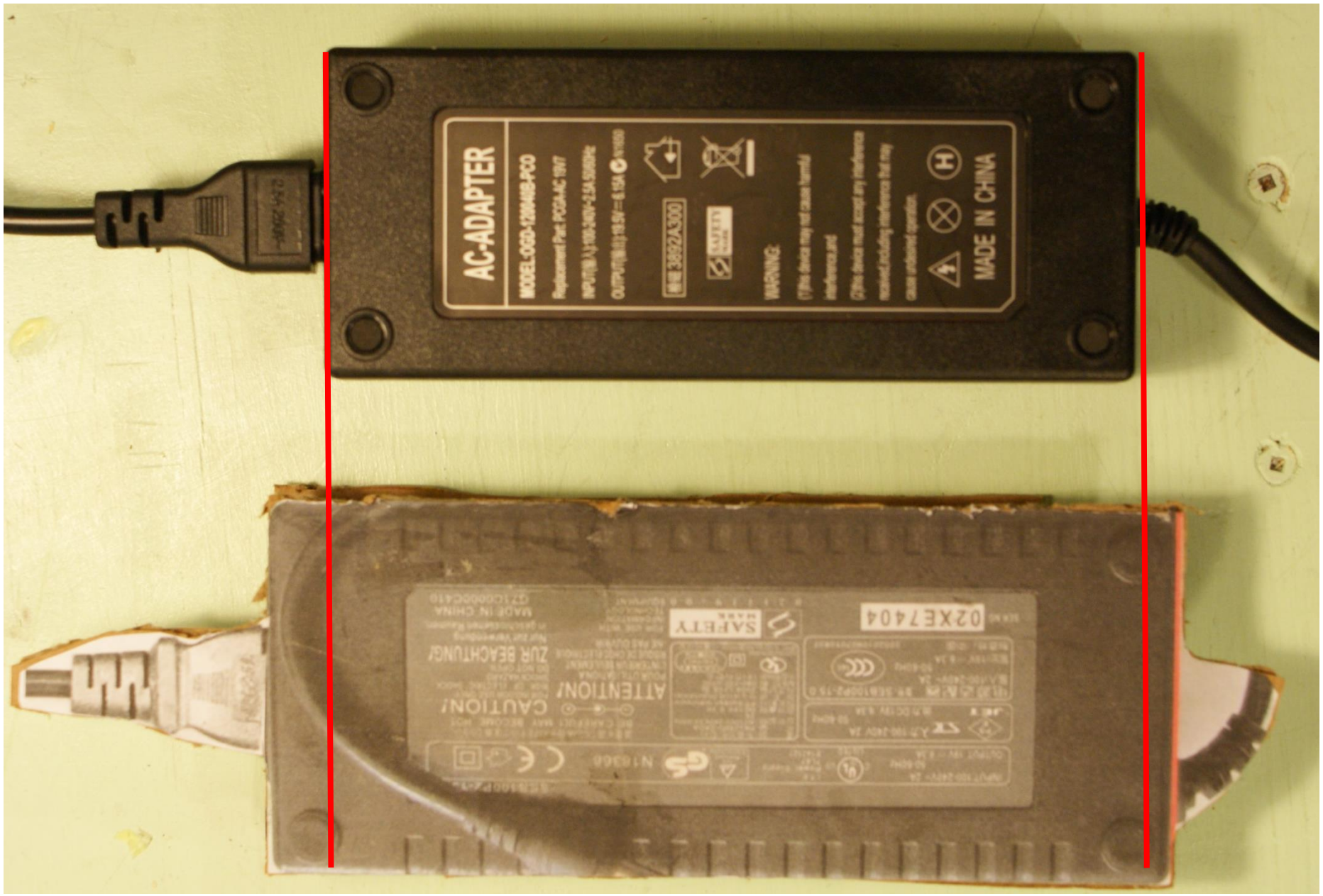
LED Lights

Final Build Made Easy

- **Use the mock-up to think through the build process!!!**
  - **Adapt parts to make them more easily fabricated**
- **Do not cut metal until you have all major parts in hand!!!**
  - **Avoid surprises from actual vs assumed part sizes**
  - **Some parts may be unavailable and need substitution**
- Think through the parts list
  - Same size parts should be cut with one equipment setting , eg table saw fence, drill setup, chopper, etc
- Look for ‘inaccessibles’ in assembly sequence
  - Holes etc inaccessible after assembly should be made before assembly
  - Assemble parts in order ensuring accessibility for clamping etc
- Ensure there is a place to adjust for tolerances as easily as possible
  - Preferably a single point which will be ‘adjust on measurement or test’
- Do not be afraid to scrap a part and make it again
  - Easier to do it early than late in the assembly process
- **Do not overthink it!!!**
  - **You will still discover and correct issues in build**
  - **There is no excuse for not getting started**

Final Build

Do not cut metal . . . . .



Real Thing

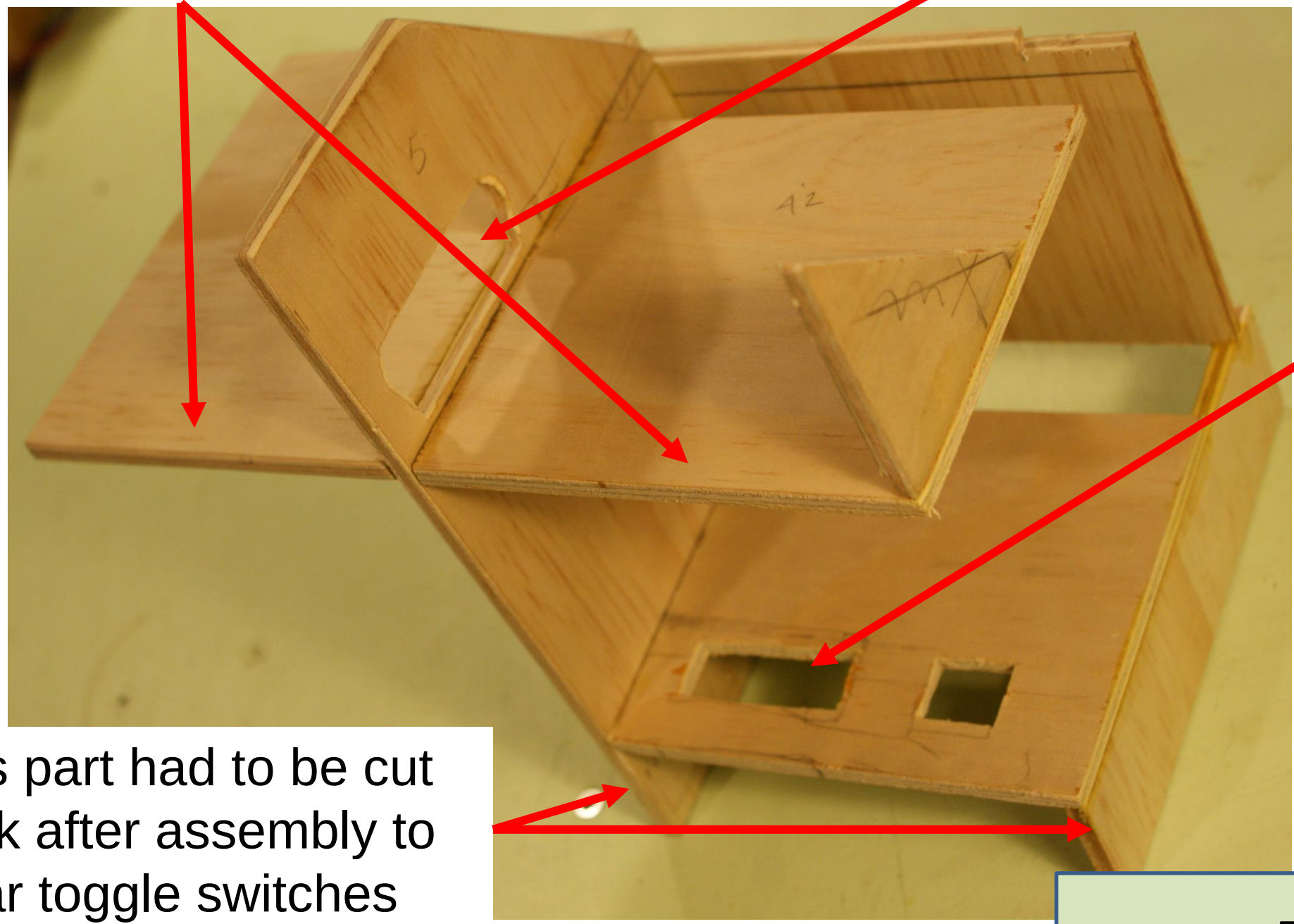
Mock-up scaled from photo – Bigger!!!!

Final Build

Learning by Doing
Shelf Sub-Assembly

A better design would have made this shelf continuous – changed during build

✓ This hole was cut before assembly



X These holes were not!!! (#$%/@#$@) Then they had to be made larger!! (#$%/@#$@#$%/@#%/)

This part had to be cut back after assembly to clear toggle switches

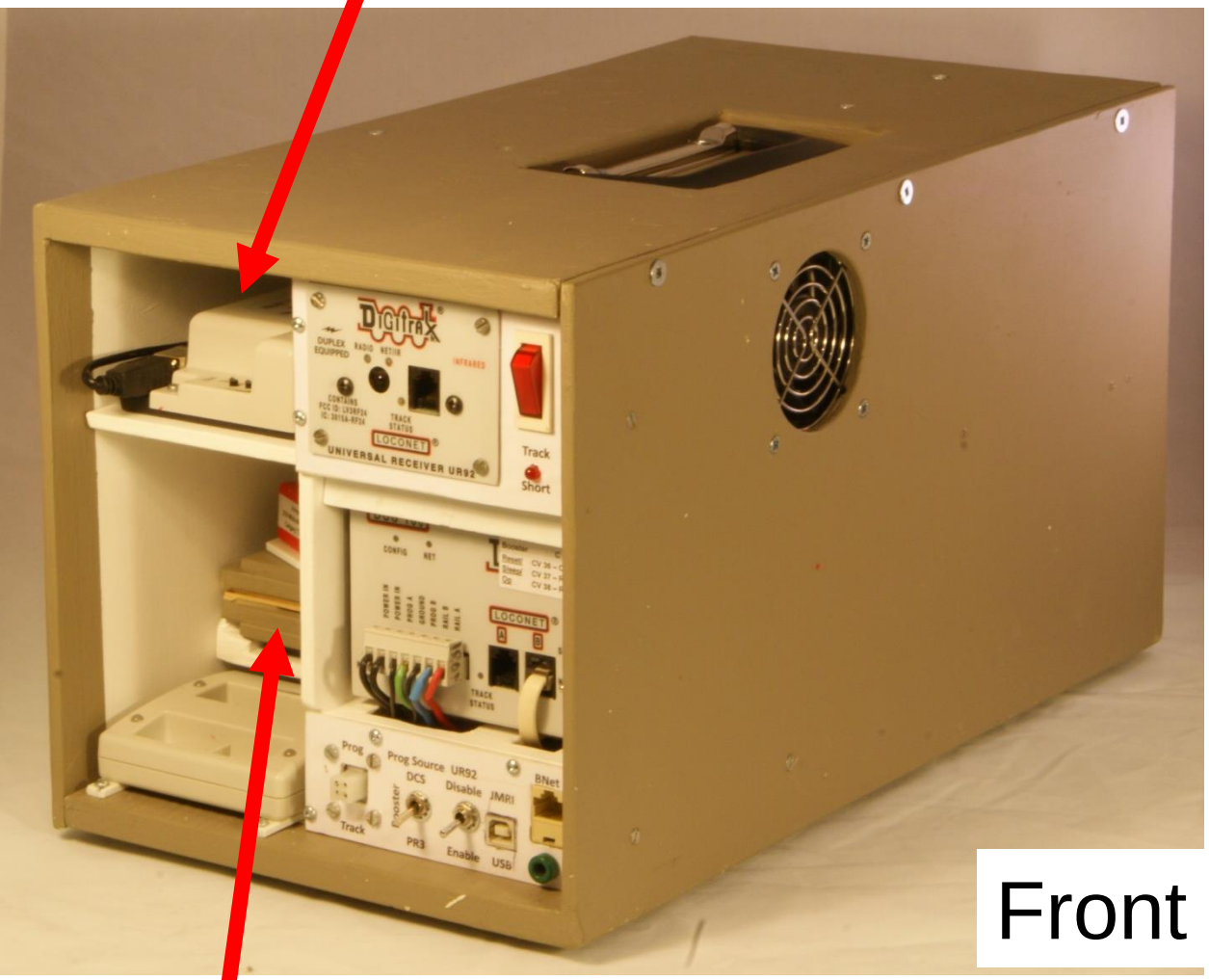
Final Build

Cabling Build Made Easy

- During Physical Design, have a rough concept before commencing build – but do not get too detailed
- Think about the major assemblies which should be dis-connectable eg control panel assemblies
- Build to the level of having all real components in place before doing detail cabling design – but be aware – components will move as design progresses
- If wiring is complex, do paper design in subsystems with boxes/ assemblies in correct physical relationships.
- Build one subsystem at a time. Test as you go, then test again. Test with a buzzer before applying power

Final Unit

Cheat sheets on shelf under



Front

Programming Track Stored

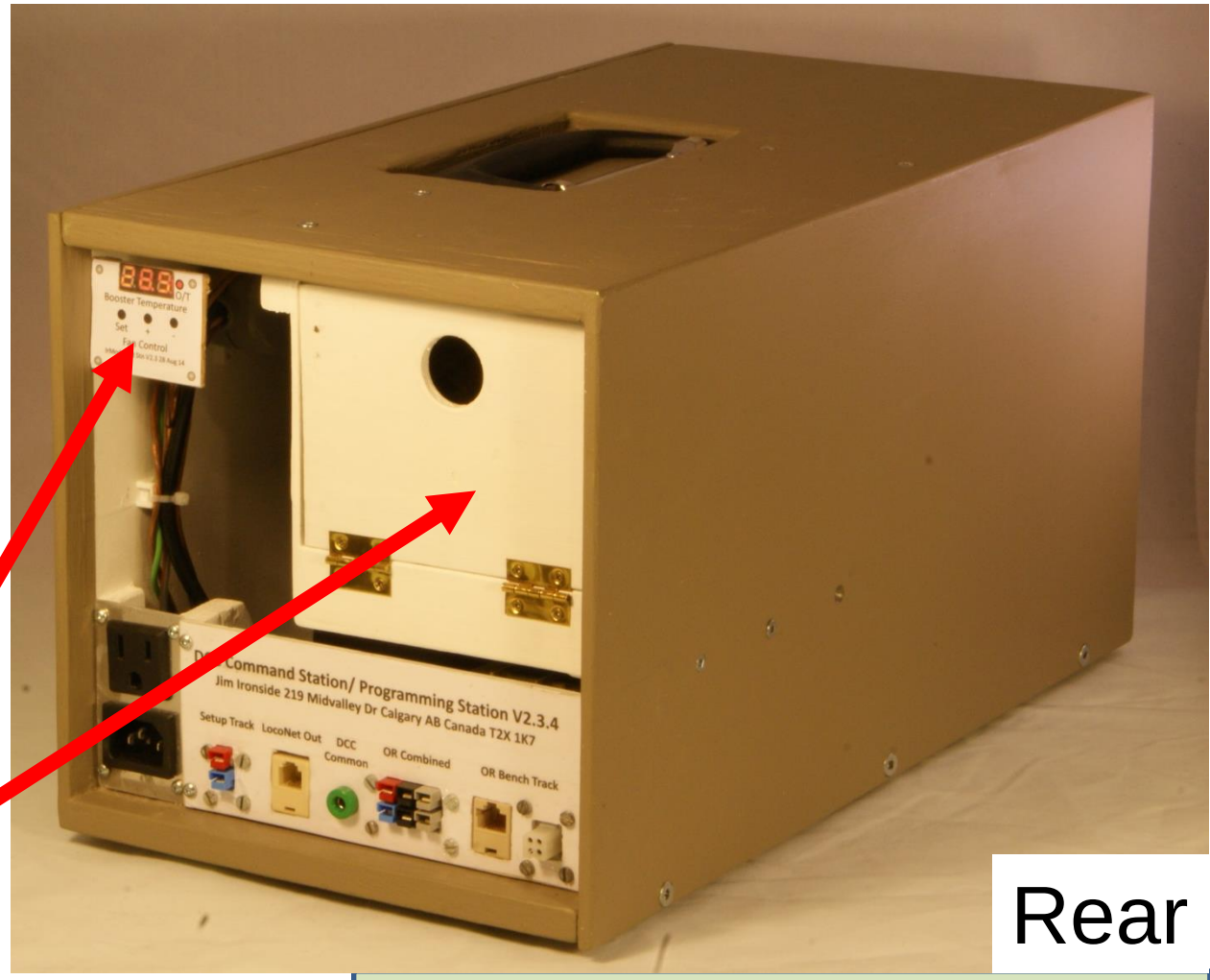
Final score:

✓ Met requirements and most ‘druthers’

X Learned a few more things that will result in V2.4

Fan Control (Still in mock-up)

Cable Storage



Rear

Final Build

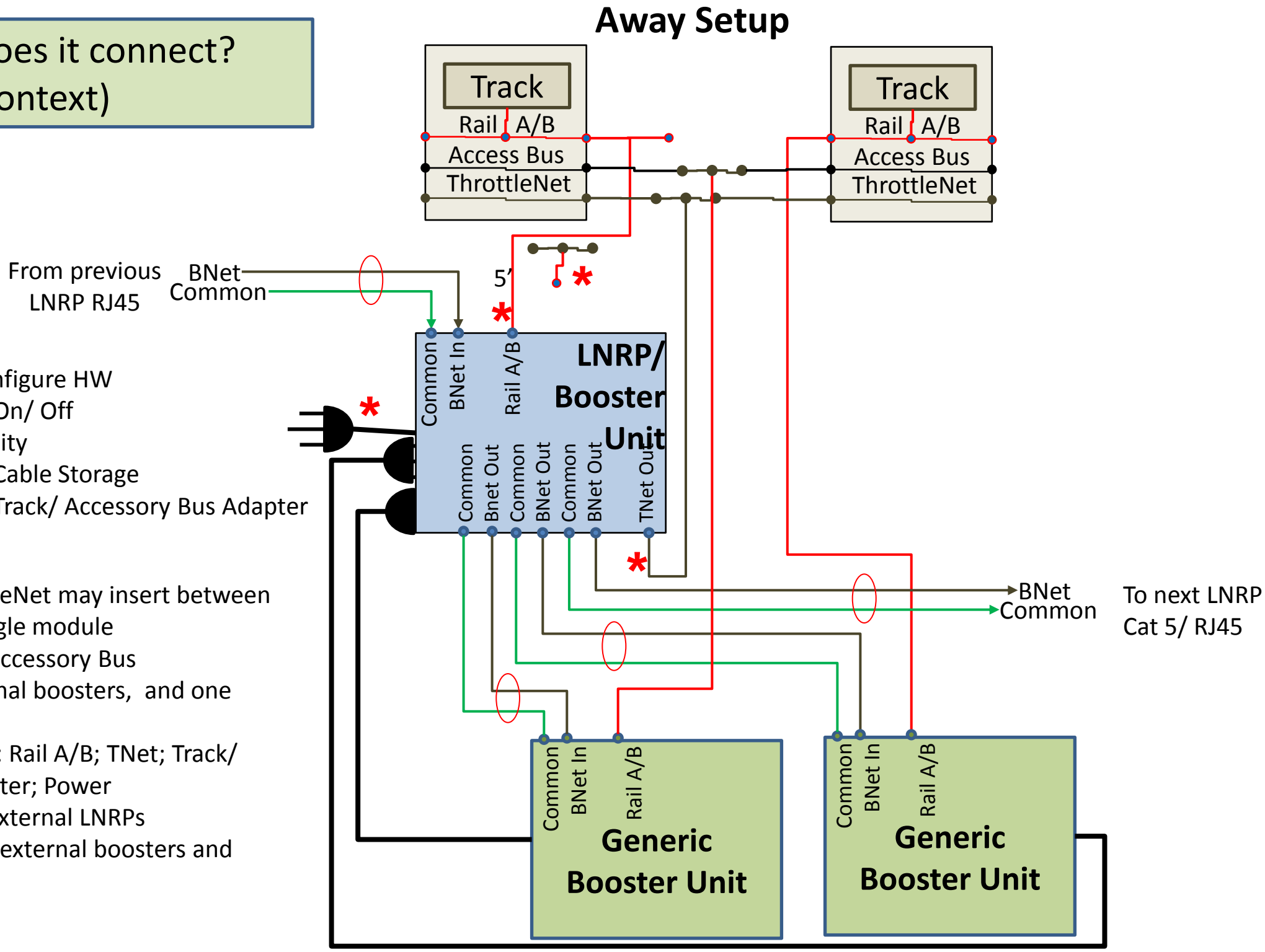
LNRP/ Booster Unit
Use Case Context

To what does it connect?
(Context)

Configure HW
- On/ Off

Utility
- Cable Storage
- Track/ Accessory Bus Adapter

Notes:
- Rail A/B and ThrottleNet may insert between modules or to a single module
- Rail A/B may feed Accessory Bus
- Supports two external boosters, and one ThrottleNet district.
- Cables to be stored: Rail A/B; TNet; Track/ Accessory Bus adapter; Power
- BNet RJ45jacks to external LNRPs
- BNet RJ12 jacks for external boosters and ThrottleNet



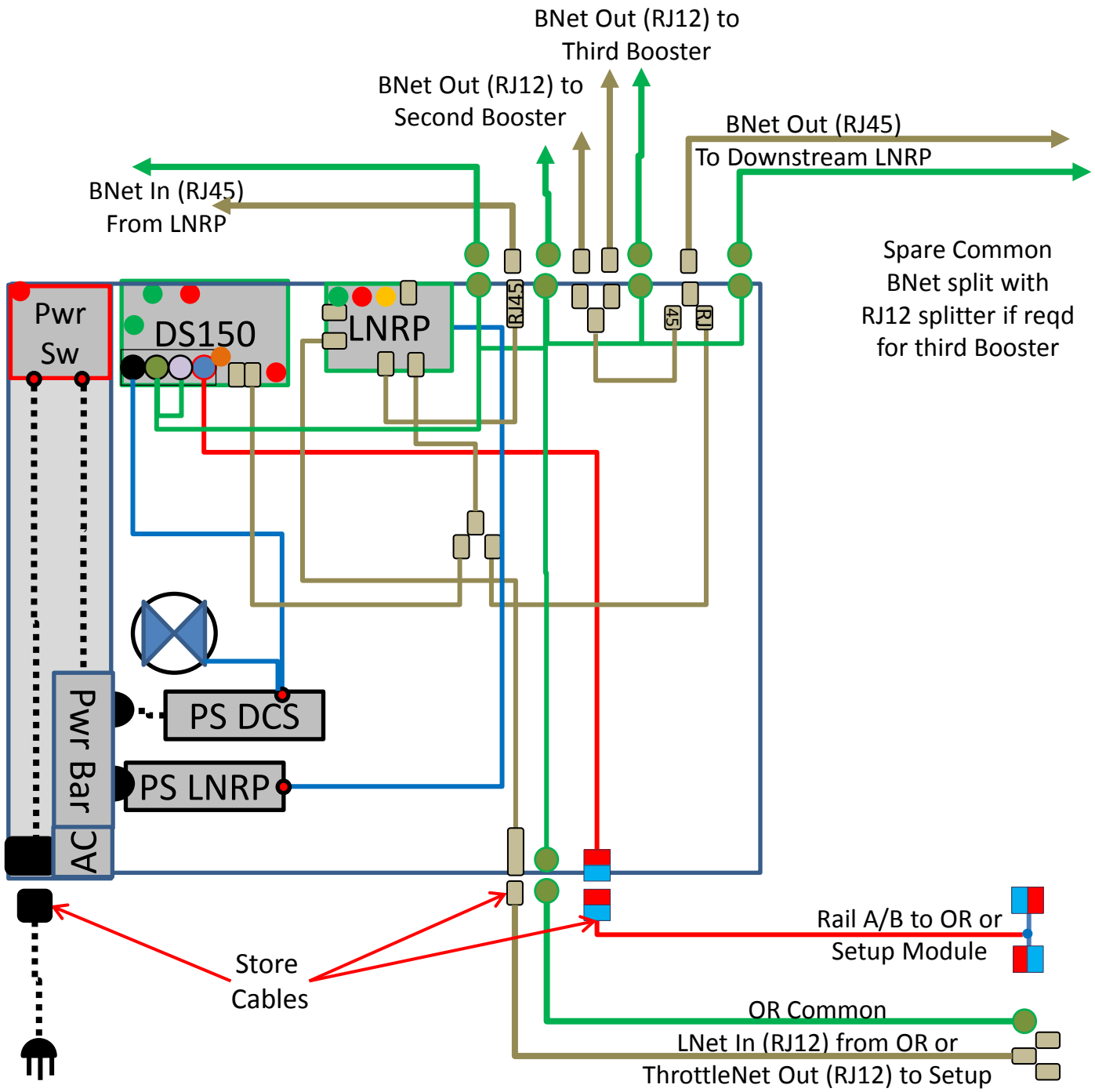
LNRP/ Booster Unit Electrical

Track
OR Prot Trk Pwr
Unprot Trk Pwr
Prog A/B DCS

LocoNet
DC Power
Prog Trk
Prog A/B PR3

USB
AC Power-
Common
Prog DCS or PR3

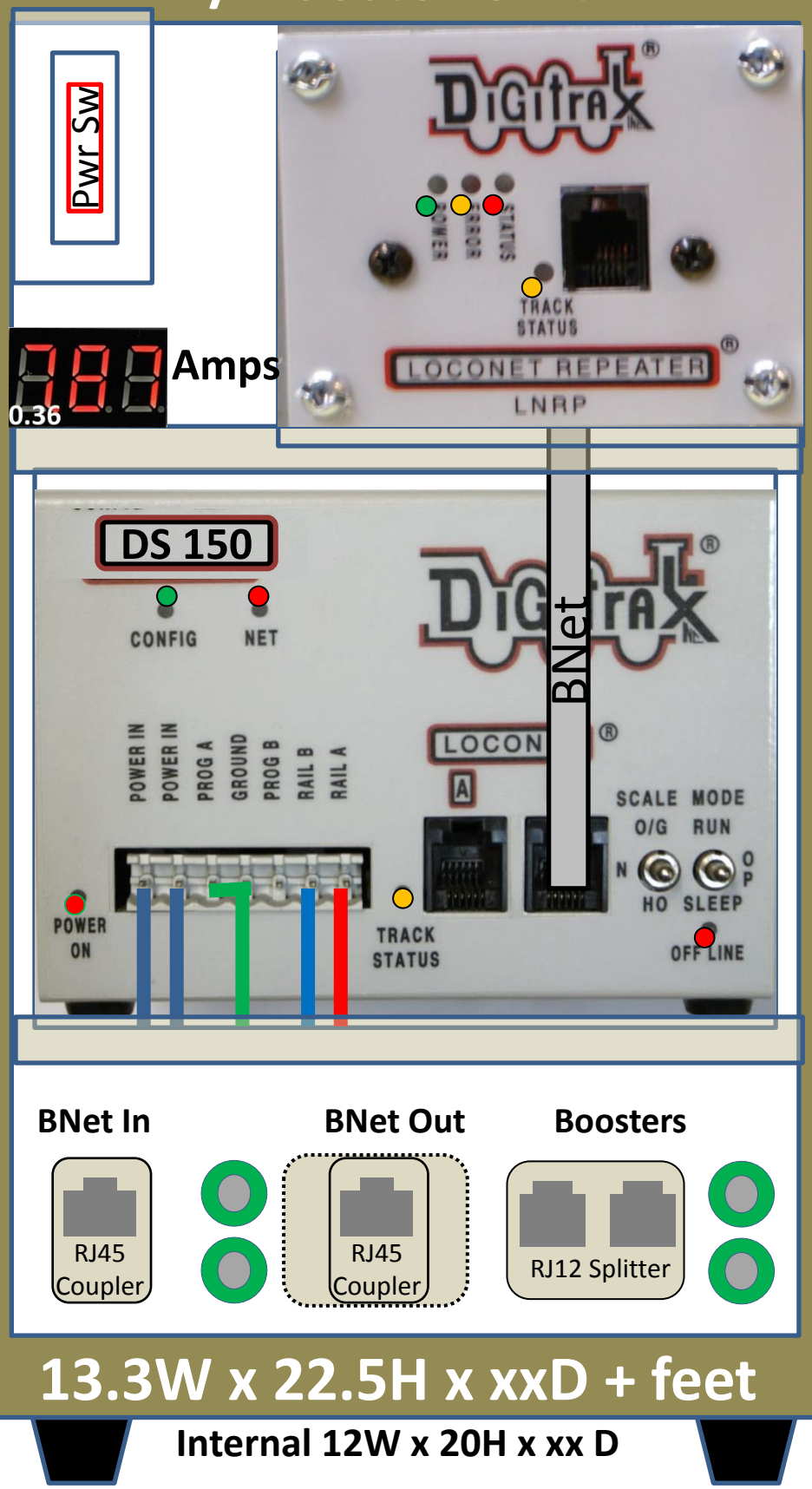
User Interface
Control
Physical Boundary



Electrical design

LNRP/ Booster Unit Physical

LNRP/ Booster Unit V2.2.1



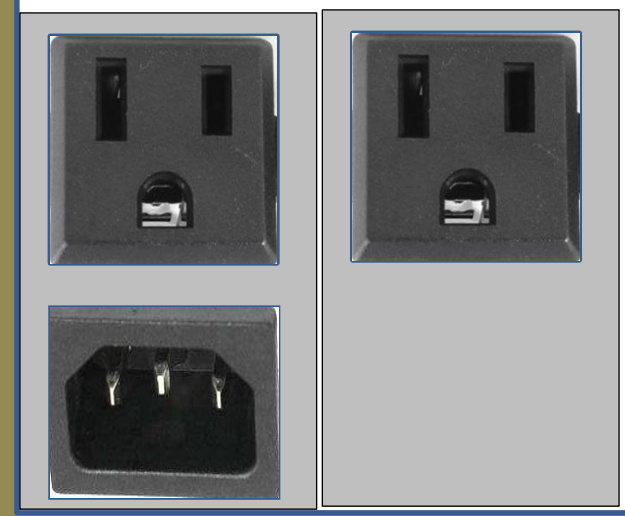
13.3W x 22.5H x xxD + feet

Internal 12W x 20H x xx D

LNRP/ Booster Unit V2.2.1

Storage
2 Litres
11W x 11H x 16D

Stores:
- Power Cord
- BNet 6p6c cable/ ground 24”
- Setup Track Power District cable 48”
- Setup LocoNet District cable 48”
- Accessory Conversion Adapter 6”



LocoNet District

RJ12

OR Com

Track Power District

Physical Design

Most Important Outcomes:

The ‘grand plan’:

Box size to hold all the kit

[Detail design inside the box was done ‘on the fly’]

Front panel design

[for best usability]

Fun

[Researching and evaluating options]

Satisfaction

[A good solution to a complex problem]

Summary

- A System Engineering Process is the ‘right thing’ for complex problems
- Gets you closer to ‘right’ the first time
- Process supports good ideas, does not replace them
- Not every problem needs a paper process – it’s the thought (process) that counts
- Documentation supports maintenance/ evolution
- **Engineering can be (at least) half the fun**
- **Don’t forget the other half!!!!!**

System Engineering Process

What's wrong with what I have?
What's right?

How do I plan to use it?
(Use Case)

What does it do?
(Requirements)

To what does it connect?
(Context)

Check list for the design

Electrical design

Physical Design

Mock-up/ Prototype risk areas

The design

Final Build

The build

If you would like a copy of this presentation – email me

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Address also in Orderboard