Practical Application of Human Factors in Flight Hardware Design

Presented by:

Sean Schimelpfening
ISS Flight Crew Integration Team
Habitability and Human Factors Branch (SF3)
NASA Johnson Space Center, Houston Texas

Agenda

- Purpose
- What is the ISS Human Factors Implementation Team (HFIT)
- HFIT Process and Services
- Why use HFIT?
- Kickoff / Early Design Stages
- PDR and HFIT Involvement
- Examples of HFIT's positive impact on design
- Final HFIT Evaluation and Hardware Turnover
- Summary

Purpose

- The following presentation and corresponding hardware demonstration were developed as training for U.S. ISS Payload Developers (PDs), to instruct them how to design hardware to meet ISS Payload Human Factors requirements and guidelines, and to brief them about the services the ISS **Human Factors Implementation Team (HFIT)** offers to them.

- Applying Human Factors requirements and guidelines to flight hardware design is not as simple as one would think. This presentation and hands-on demonstration have proven valuable to get hardware developers to think about designing crew interfaces that are safe and easy to operate.

ISS Human Factors Implementation Team (HFIT)

- The ISS **Human Factors Implementation Team (HFIT)** is an optional service (est. 2003) that provides Payload hardware developers guidance in designing flight hardware crew interfaces that meet the Human Factors requirements and guidelines (SSP 57000 Section 3.12 for ISS Payloads).

- The 2016 ISS Payloads RISE (Revolutionize ISS for Science and Exploration) effort to streamline requirements and processes established the following criteria for **requirements** vs. **guidelines**. The numbers in parentheses are the current numbers of Human Factors requirements and guidelines for ISS Payloads.

  - The **requirements** are meant to prevent crew injury and avoid damage to neighboring hardware (36 total).

  - The **guidelines** are meant to facilitate mission success (57 total). Violation of guidelines only hurts the individual Payload. Compliance with guidelines is not required for verification approval.

Human Factors Implementation Team Services

- **Two Different Routes to take with Human Factors for ISS Payload Hardware:**

  - **HFIT Services**
    - Evaluate hardware against all applicable Human Factors requirements
    - Coordinate label strategy and order labels for hardware
      - PD will not need to interact with elabel tool (1,000s of labels)
    - Provide recommendations for meeting applicable requirements
    - Provide Certificate of Compliance (CoC) for hardware

  - **Human Factors SME (Subject Matter Expert) Services**
    - Service used for answering basic questions regarding hardware
    - Developer is responsible for:
      - Meeting all Human Factors requirements and supplying your own CoC
      - Label strategy, ordering of labels, and processing your own exemptions

The HFIT Process

- **HFIT process:**
  - **Assign HFIT rep** at Payload Kickoff
  - **Determine Applicable Human Factors Requirements** (at/near System Requirements Review)
  - **Perform Initial HFIT Evaluation** (at or soon after PDR):
    - Assess prototype or mockup hardware for crew interfaces and labeling against applicable Human Factors requirements.
    - Identify issues early when it is more cost effective to influence design.
    - Provide recommendations on how the payload can comply with requirements.
  - Between evaluations: **Support the Payload Developer** as needed
    - Negotiate solutions to requirements-design conflicts.
  - **Perform Final HFIT evaluation** (after CDR or when flight hardware available).
    - Verify flight hardware meets requirements.
    - HFIT and Flight Operations Crew Rep approve pre-coordinated, non-compliances.
    - HFIT provides Certification of Compliance (CoC) after all issues closed.

Why use HFIT?

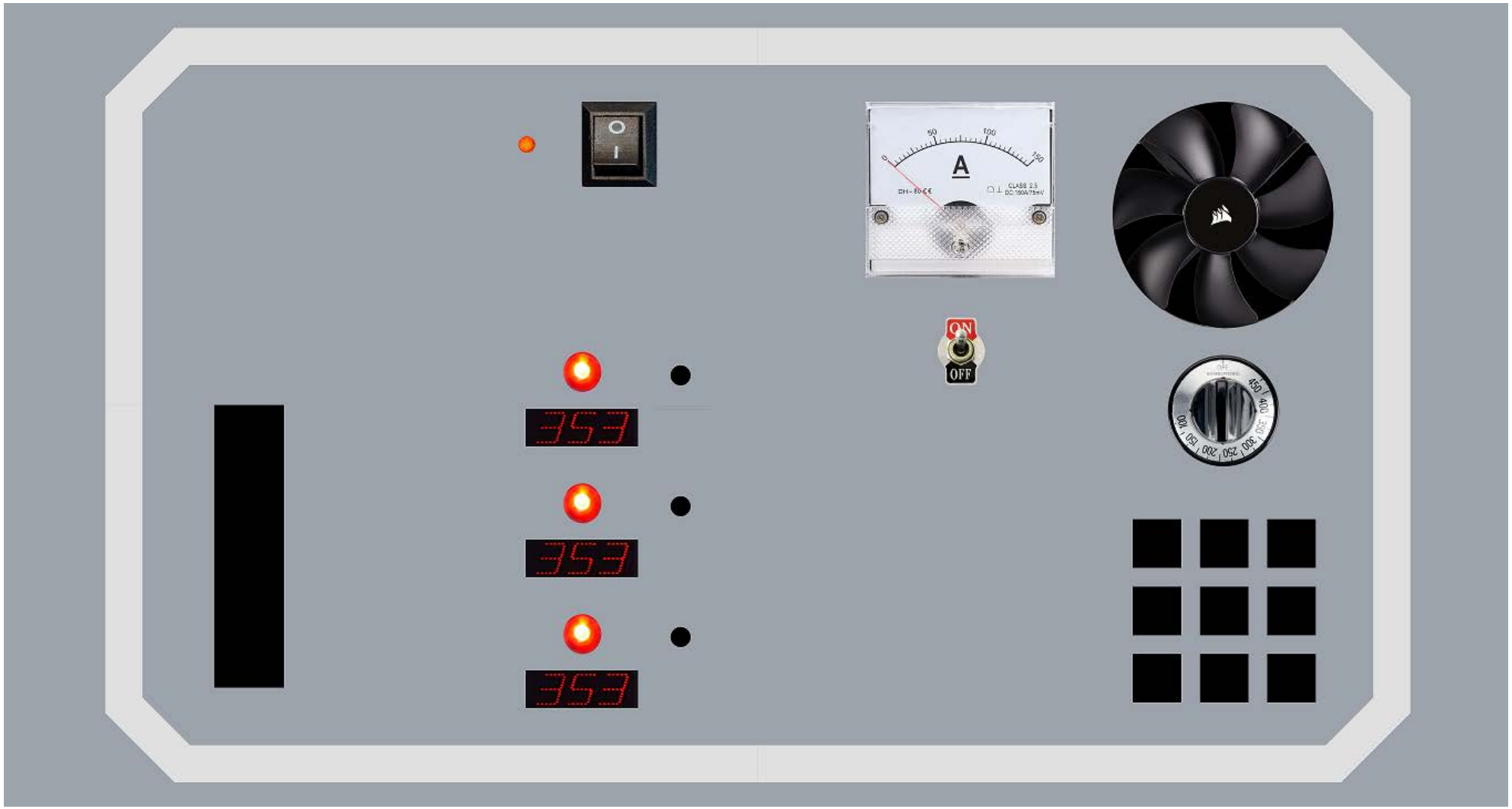
- Avoid disagreements on the applicable Human Factors Requirements.
- Identify issues early when it is cost effective to influence design. This saves PD money by avoiding late design changes.
- HFIT provides recommendations for payloads to meet requirements.
- HFIT verifies flight hardware meets Human Factors requirements and handles verification documentation for the PD so they don't have to.
- HFIT and Flight Operations Crew (FOD) Rep approval of non-safety related non-compliances avoids need for costly waiver requests.
- But most of all, HFIT involvement leads to better Human-Factored hardware that is safe for the crew to efficiently operate, maximizing science return, allowing the PD to achieve mission success.

Kickoff / Introduction to Hardware

Usually a CAD model drawing, or a low-fi piece of hardware are enough for HFIT to perform the initial review of hardware, and determine Applicable and Not Applicable requirements.

The earlier HFIT is involved, the cheaper, and easier, it is to correct possible violations.

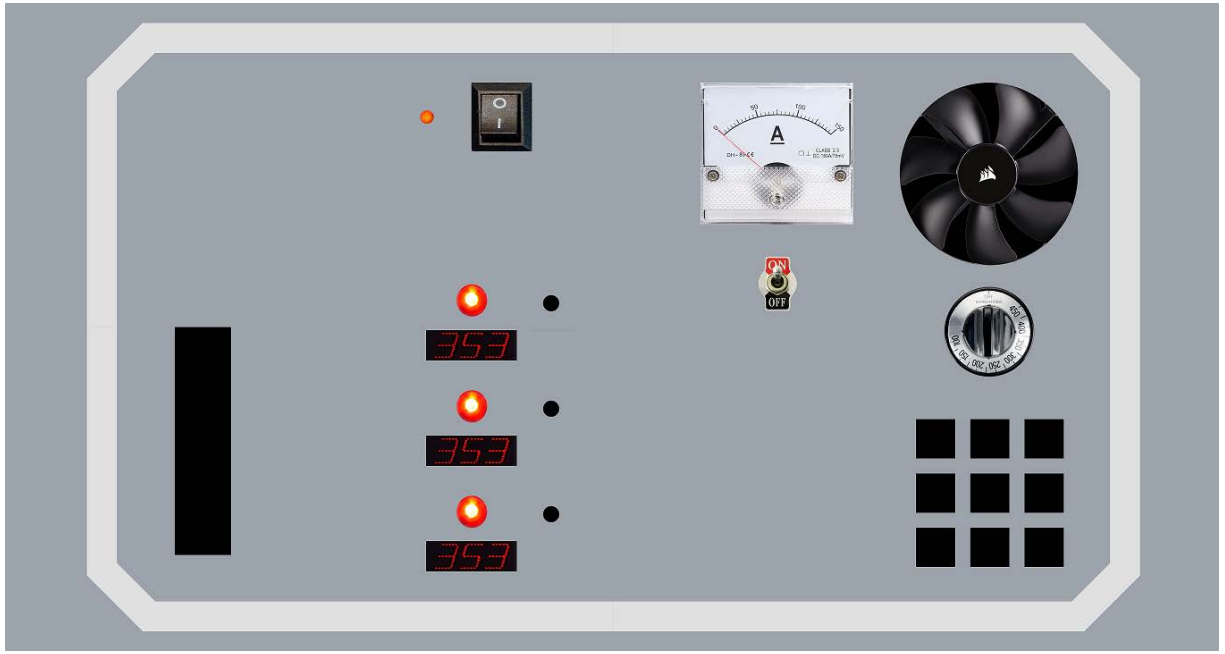
Example early CAD design of ISS Payload flight hardware



Initial HFIT Evaluation (at or soon after PDR)

HFIT Representative inspects the hardware along with the assigned FOD Crew rep and other parties as needed (e.g. Ops Lead, Payload Integration Manager). HFIT exercises all the human interfaces the crew will be expected to operate, while going line by line through all applicable requirements and guidelines to determine compliance.

- If **actual hardware is available**, HFIT physically inspects it to evaluate spacing, connectors, labeling, and potential crew injury points.
- If **no hardware is available**, the HFIT Rep can use Engineering drawings and other renderings to determine potential problem areas.
- Within one week (typical) of HFIT's evaluation, HFIT provides a draft Certification of Compliance (CoC) report that records the current state of the hardware's requirements and guidelines compliance. HFIT documents actions and recommendations to bring the hardware into compliance. As stated previously, compliance with guidelines is not required for verification approval, however, HFIT provides recommendations to meet guidelines as well as requirements because we want the Payload to be successful.

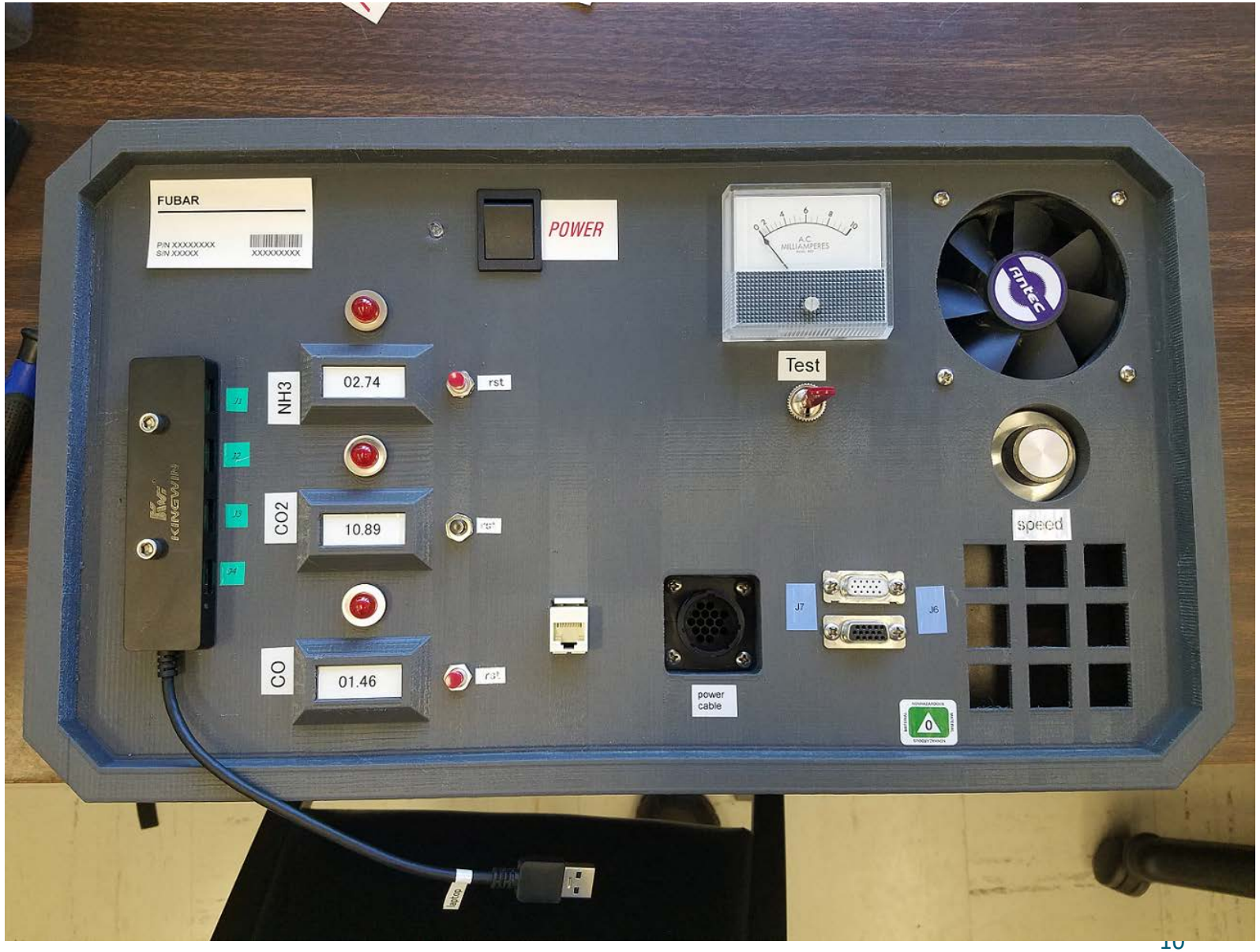


Faux Payload - Air Quality Control Hardware

Payload is called the Flight Unit Bad Air Reader. This is a faux payload HFIT developed to demonstrate Human Factors design principles to ISS Payload Developers.

<u>The Premise:</u>
Uses new filter technology to develop better filters for future, long duration spaceflight. Runs different gases through filters and alerts crew to rising levels of certain gases inside payload.

Once a certain level is reached, the crew can change out the filter elements inside the payload, reset the display, and continue with other research until needed again.

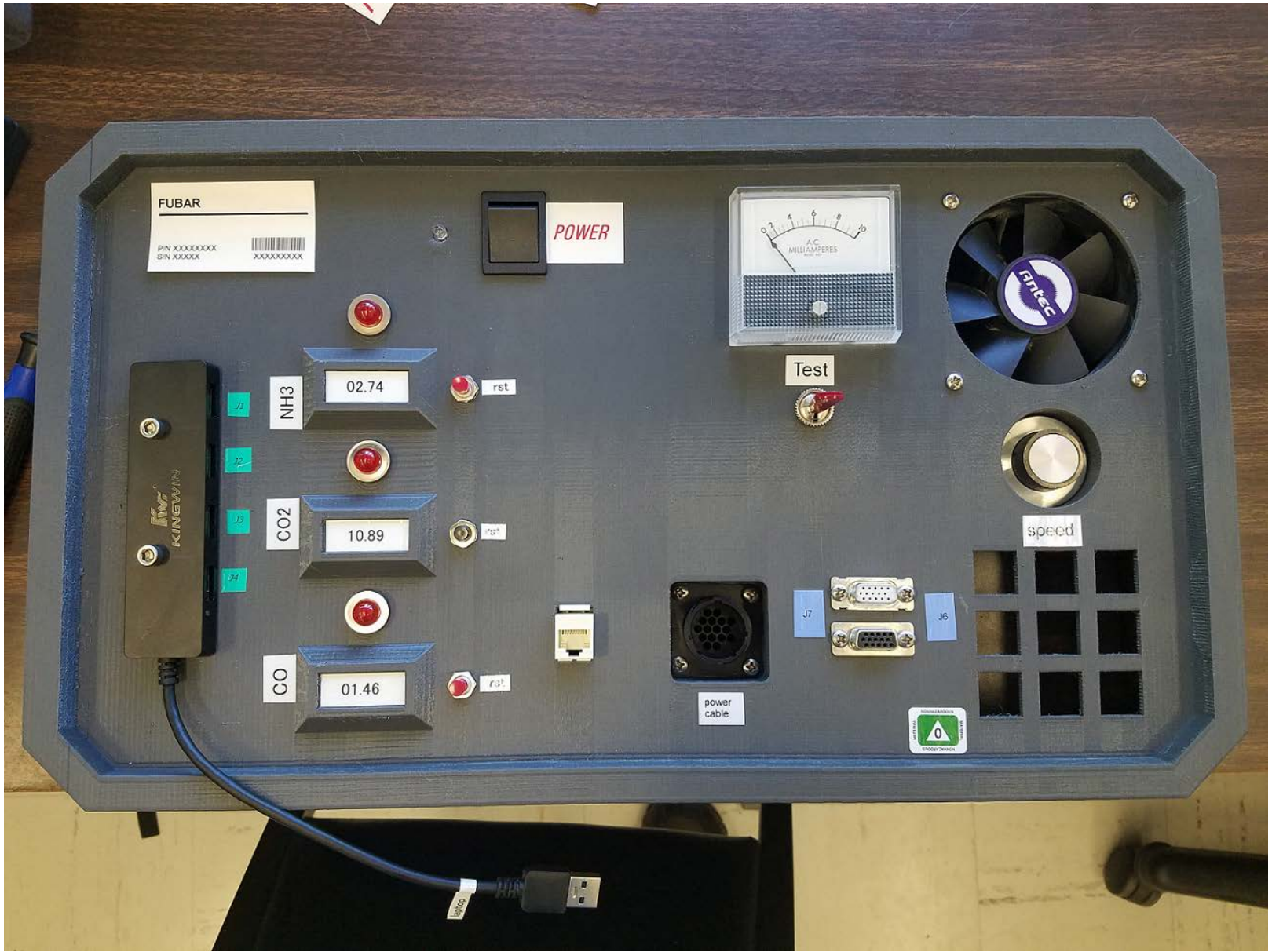


Design Review Phase of Hardware

<u>Initial HFIT Evaluation Stage.</u>
Payload Developer (PD) has built a prototype piece of hardware, and is ready for the Initial HFIT Evaluation.

Let's take a few minutes to discuss the hardware and see what potential issues, violations we can find.

No cables installed. The next slide will show all cables attached to the hardware.

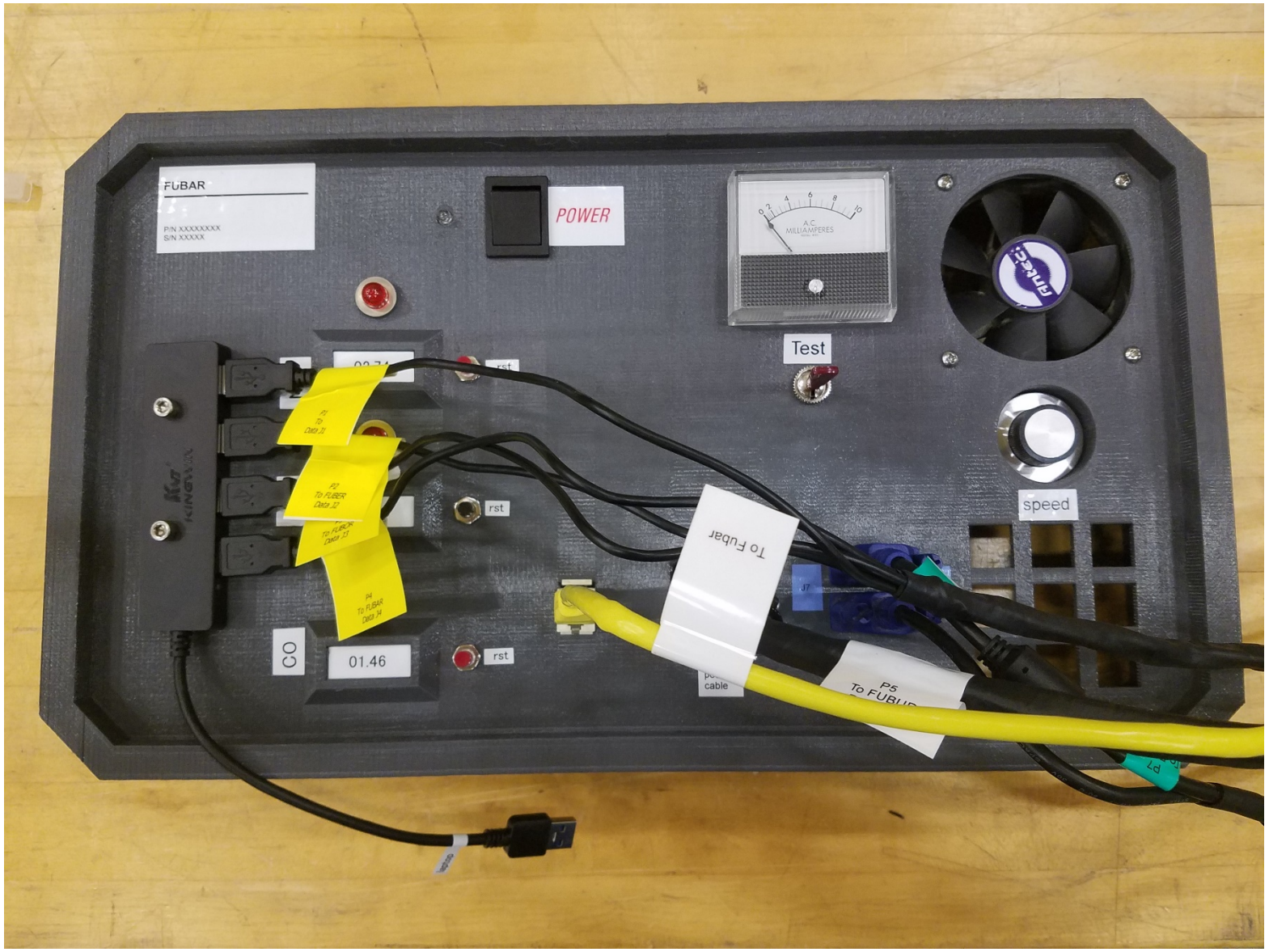


Design Review Phase of Hardware

Initial HFIT Evaluation Stage. Payload Developer (PD) has built a prototype piece of hardware, and is ready for the Initial HFIT Evaluation.

Let's take a few minutes to discuss the hardware and see what potential issues, violations we can find.

Cables installed.

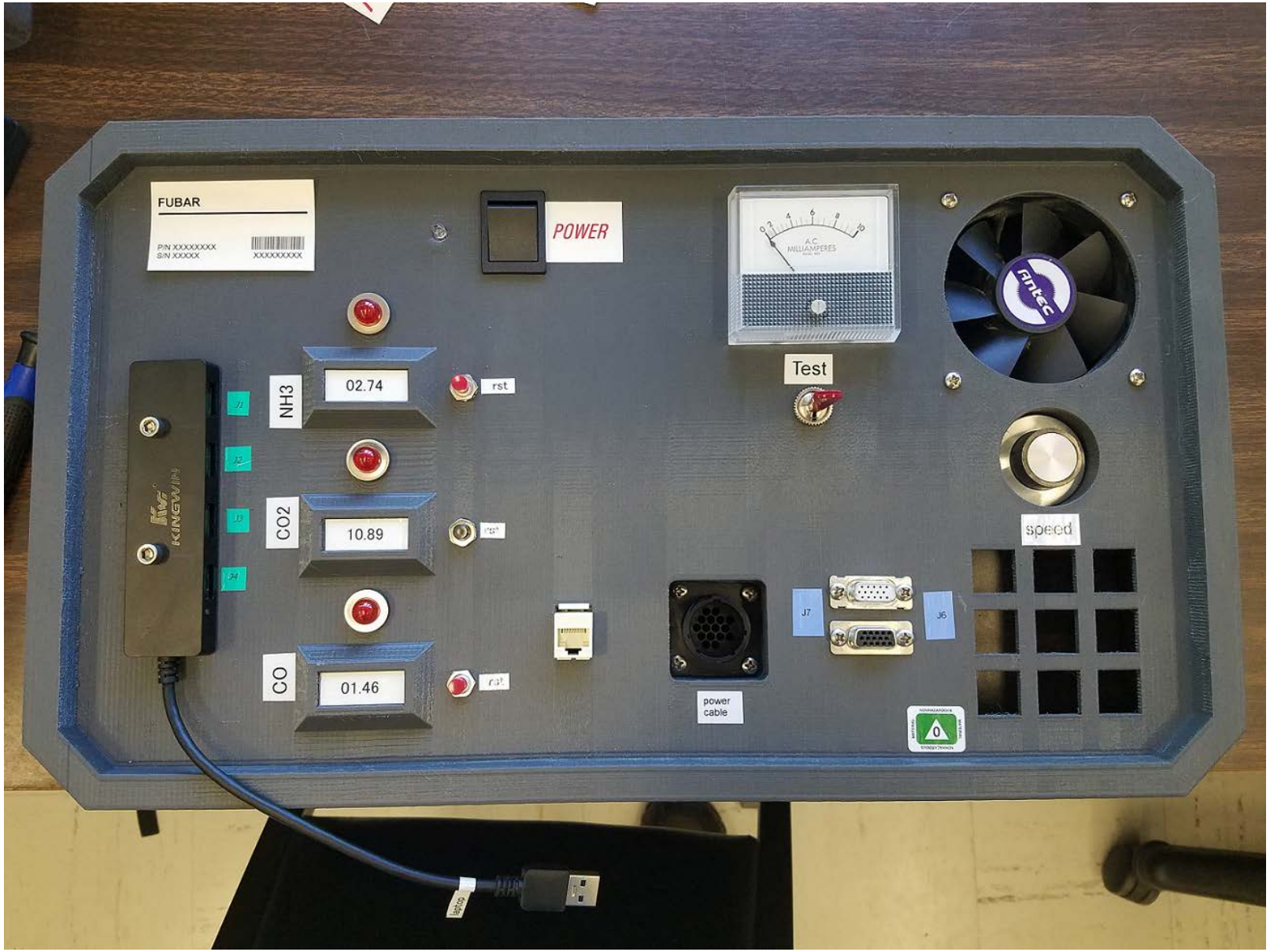


Strength Requirements and other Forces

- Grip Strength
- Linear Forces
- Torques
- Push-Pull Forces

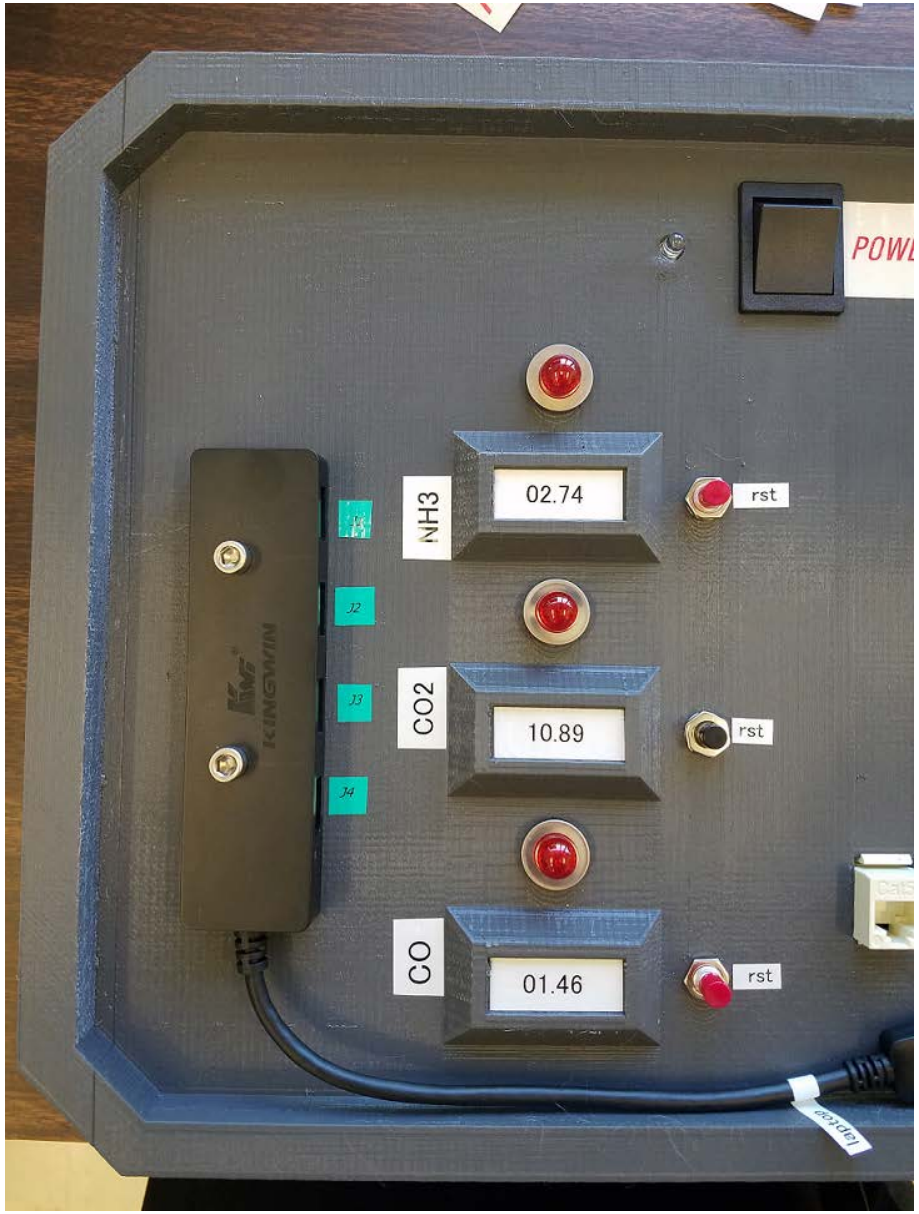
Reach, Clearance, Anthropometry, and other factors

- Clearance
- Accessibility
- Full Size Range Accommodation
- Closures or Covers



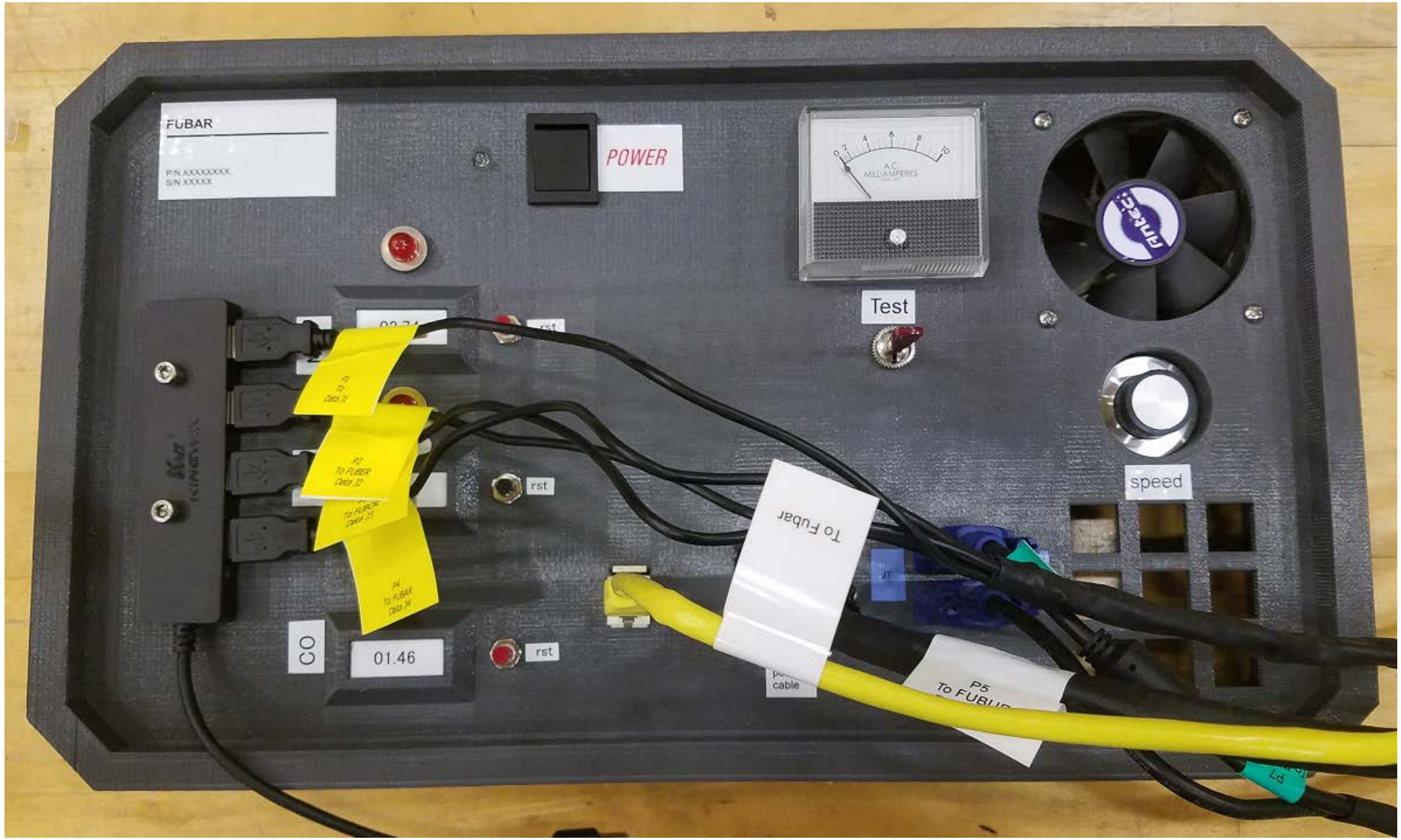
Lighting Design, Status Indicator Lights

- **Specularity**
- **LED color selection**
  - This payload used an Orange/Amber LED to indicate that it is operating nominally. There was a prior payload that used this same lighting design, and the ISS crew thought enough about this example to call it out specifically in an ISS crew debrief as being a problem for them on-orbit.
    - For ISS payloads, green is to convey hardware/software operating properly (nominally) with no faults. Orange is reserved for “payload alerts”, when a payload is not functioning properly.
  - This payload used red LED to indicate a filter was at max fill and needed to be changed.
    - Red and yellow are reserved for ISS System-level cautions and warnings, and are not to be used on payloads.
    - Flashing lights are to be avoided.



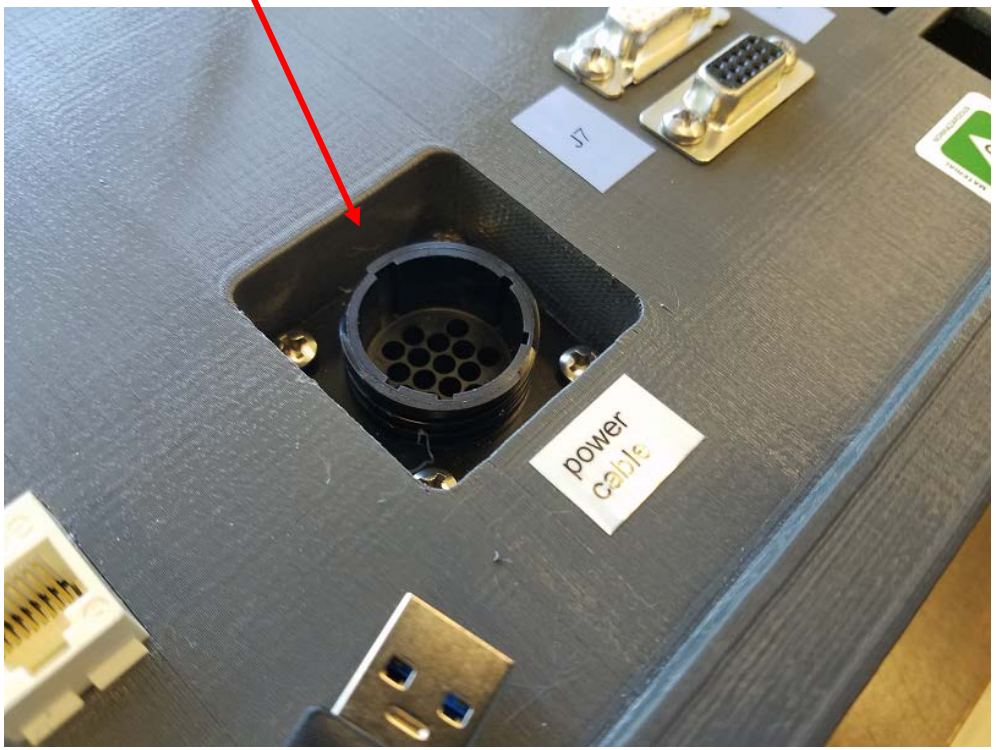
Structural / Mechanical Interfaces

- Equipment mounting
- Drawers and hinged panels
- Alignment
- Slide-out stops
- Push-pull force
- Access
- Self-supporting covers

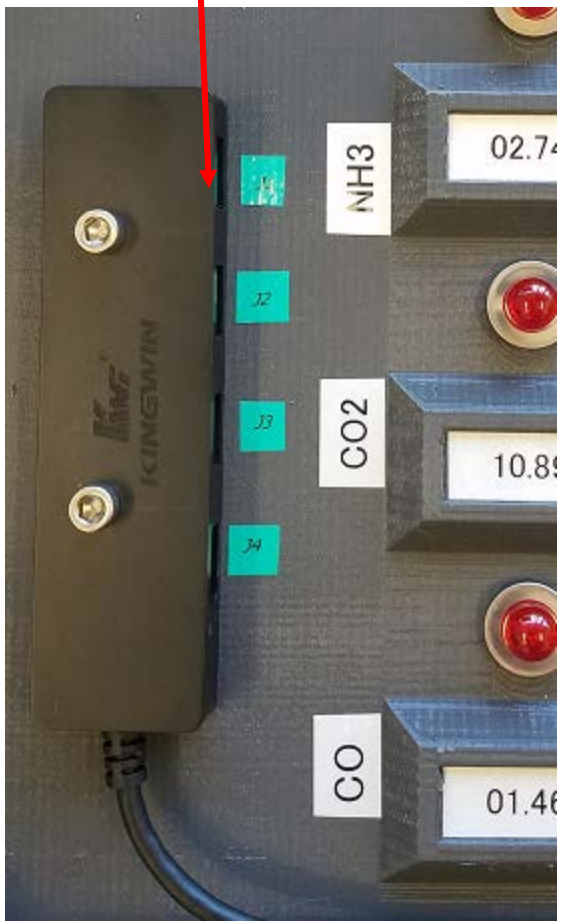


Structural / Mechanical Interfaces

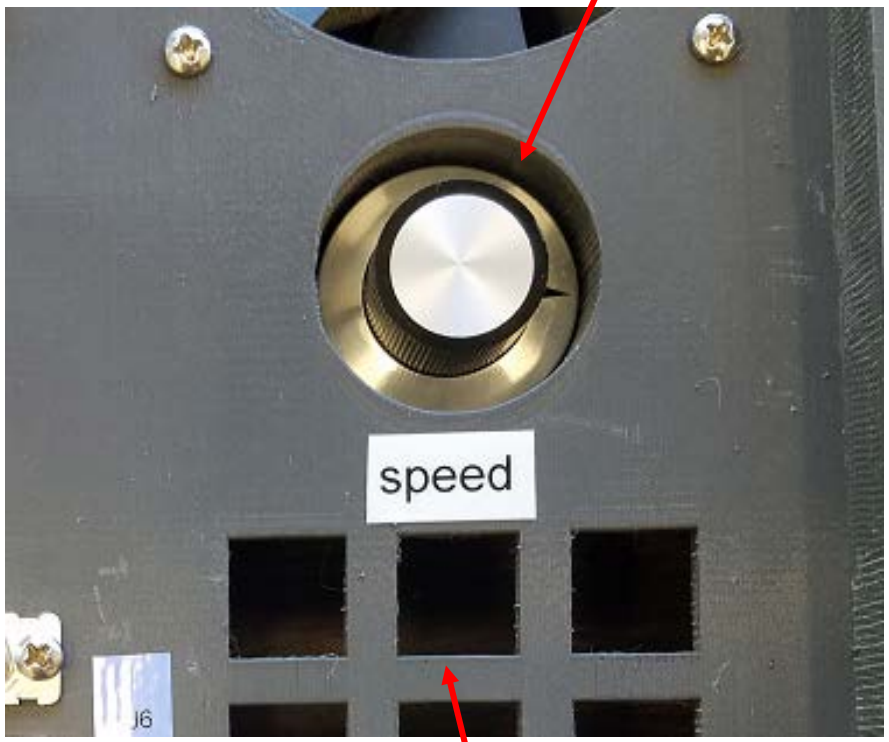
Unnecessarily recessed connector



Sideways installed connectors complicate installation



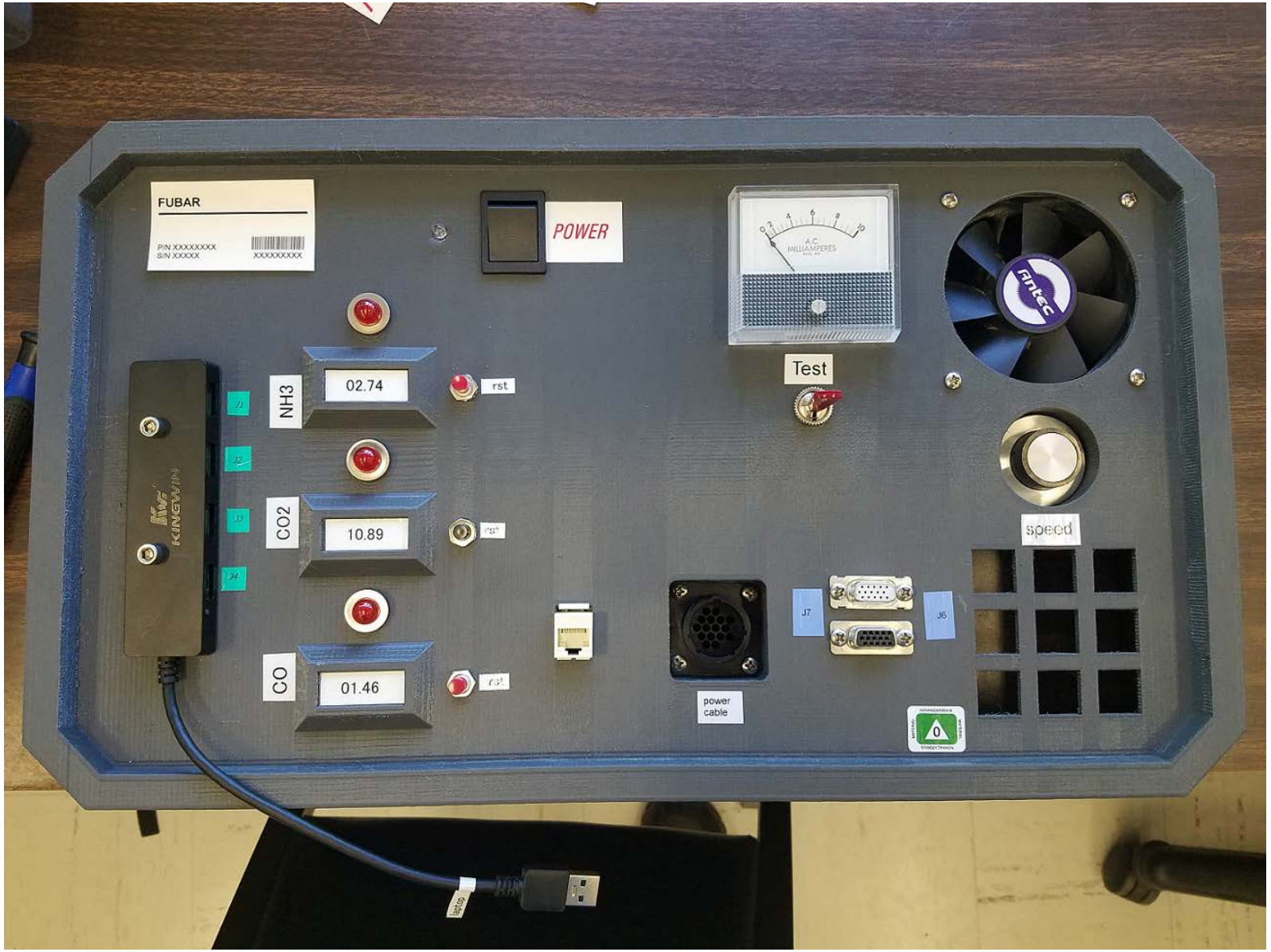
Unnecessarily recessed dial



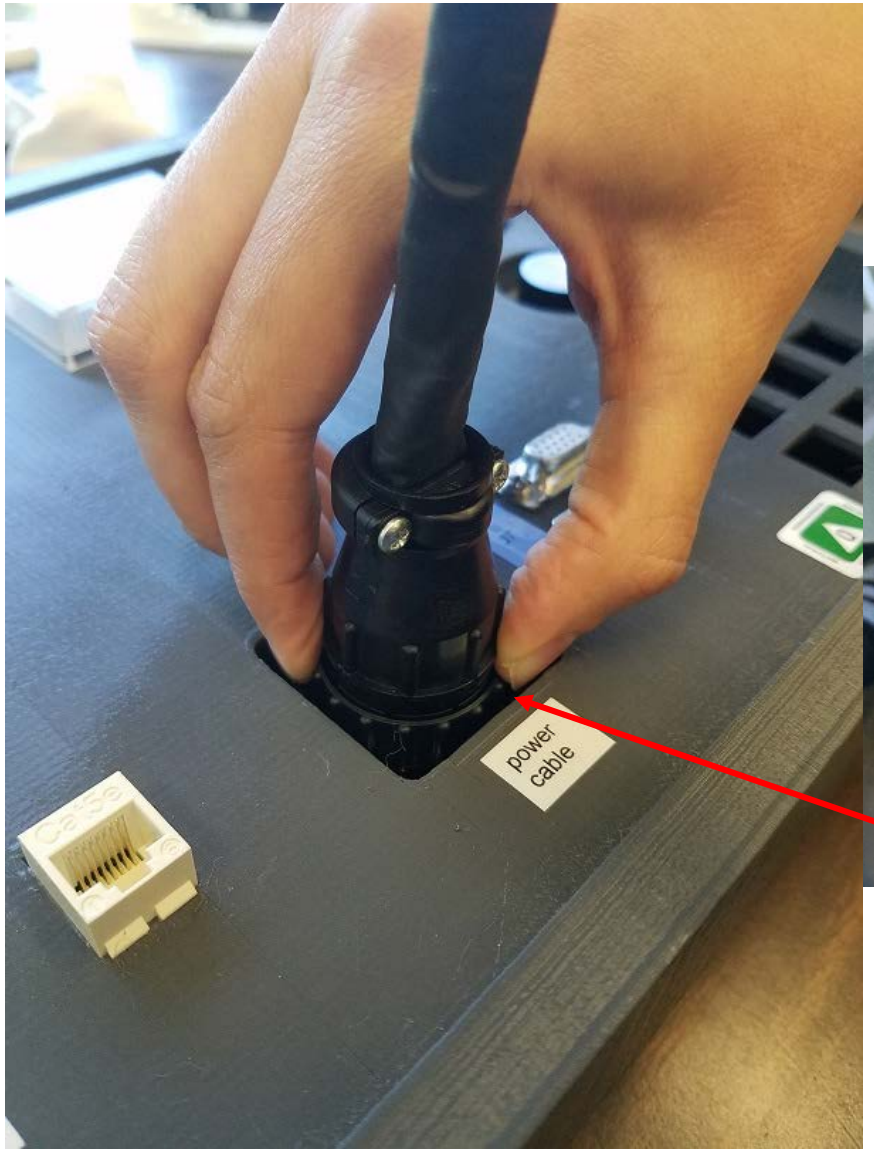
Holes in size range fingers can be entrapped

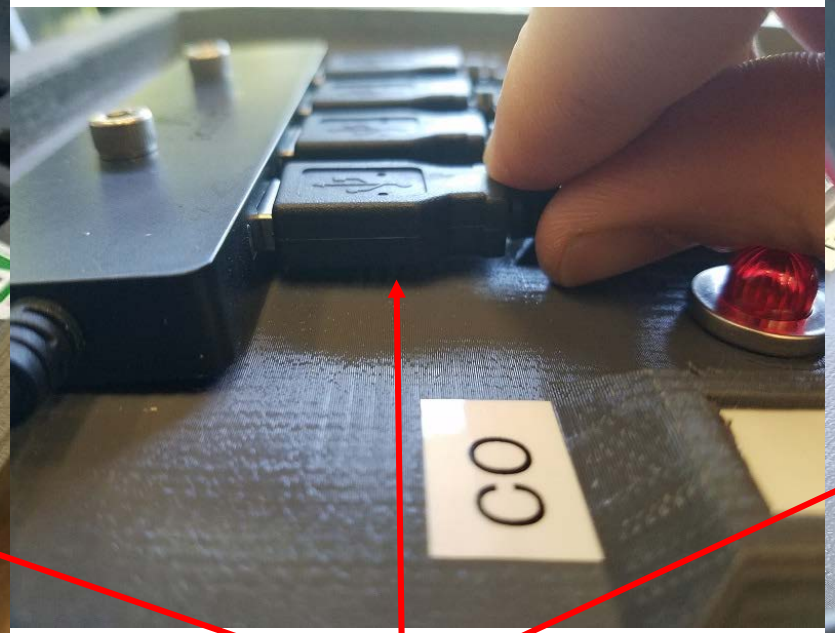
Connectors

- One-handed operation
- Accessibility
- Ease of disconnect
- Connector arrangement
- Connector protection
- Connector shape
- Alignment marks / Guide pins
- Orientation
- Hose/Cable restraints

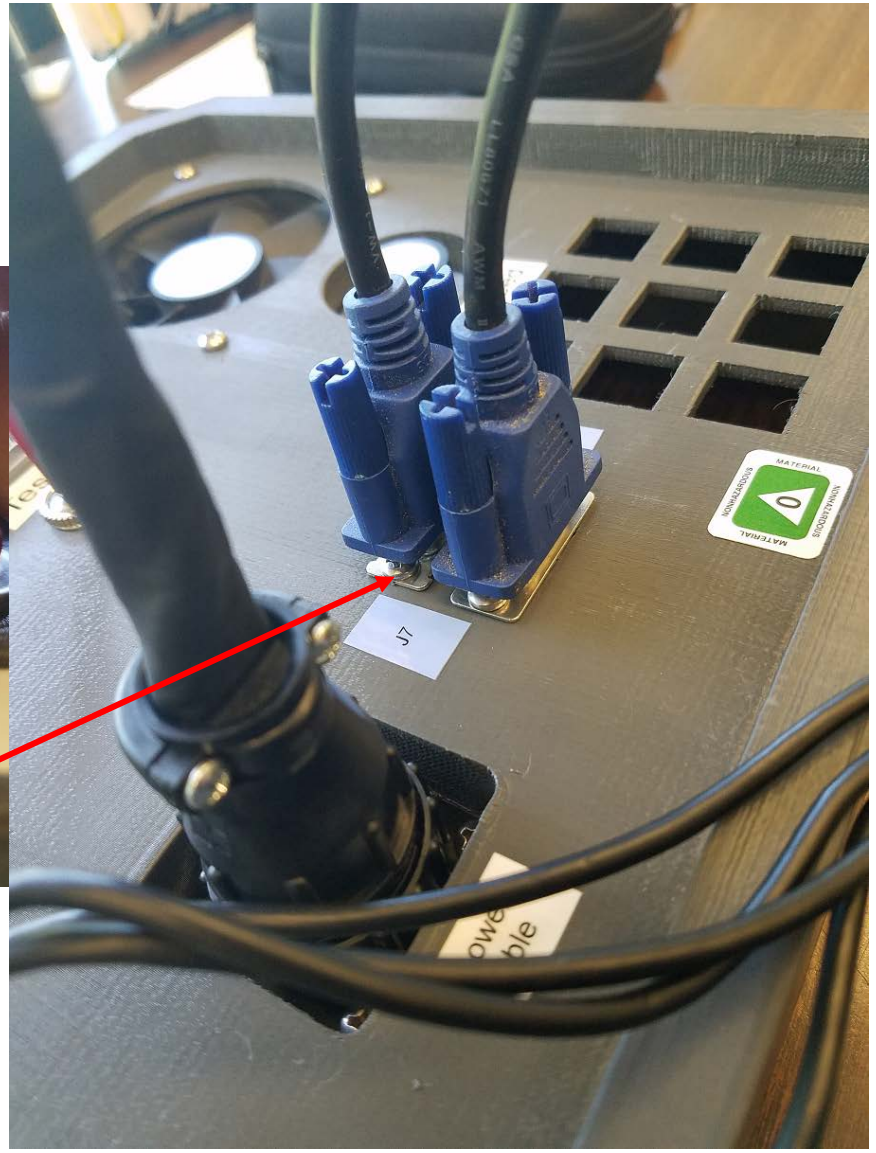


Connectors, con’t



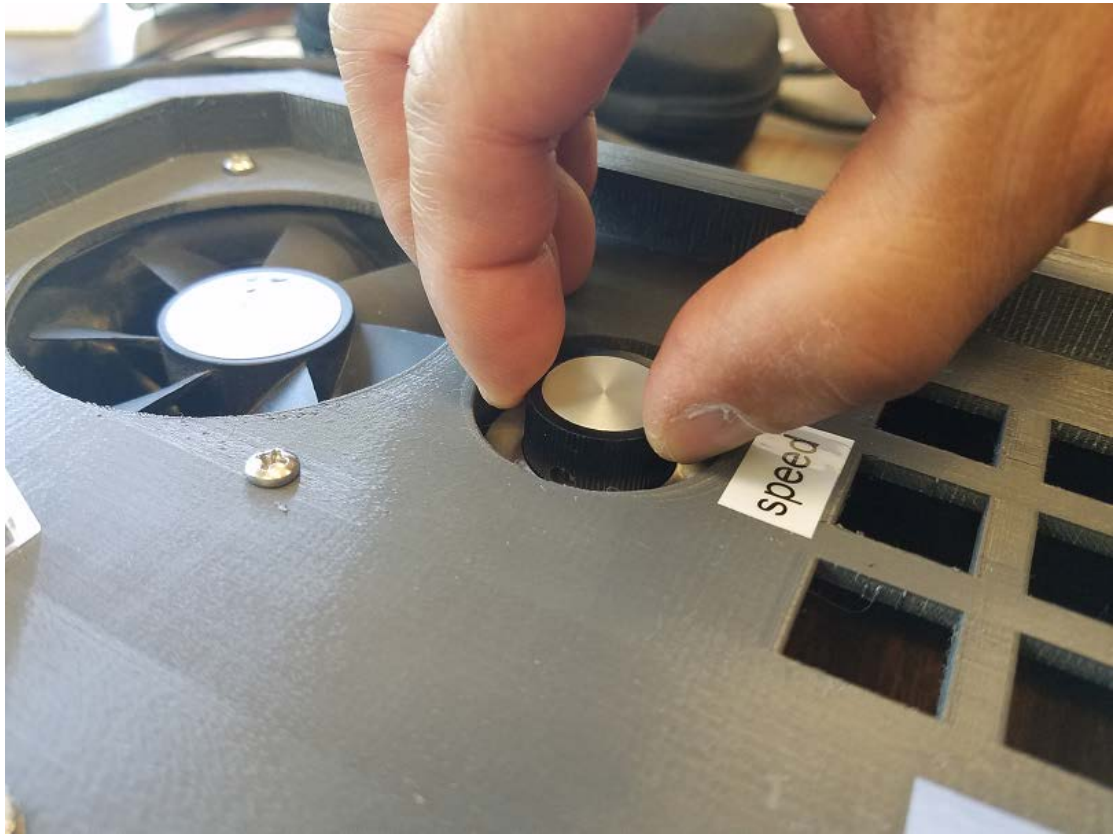


Difficult to install



Controls and Displays

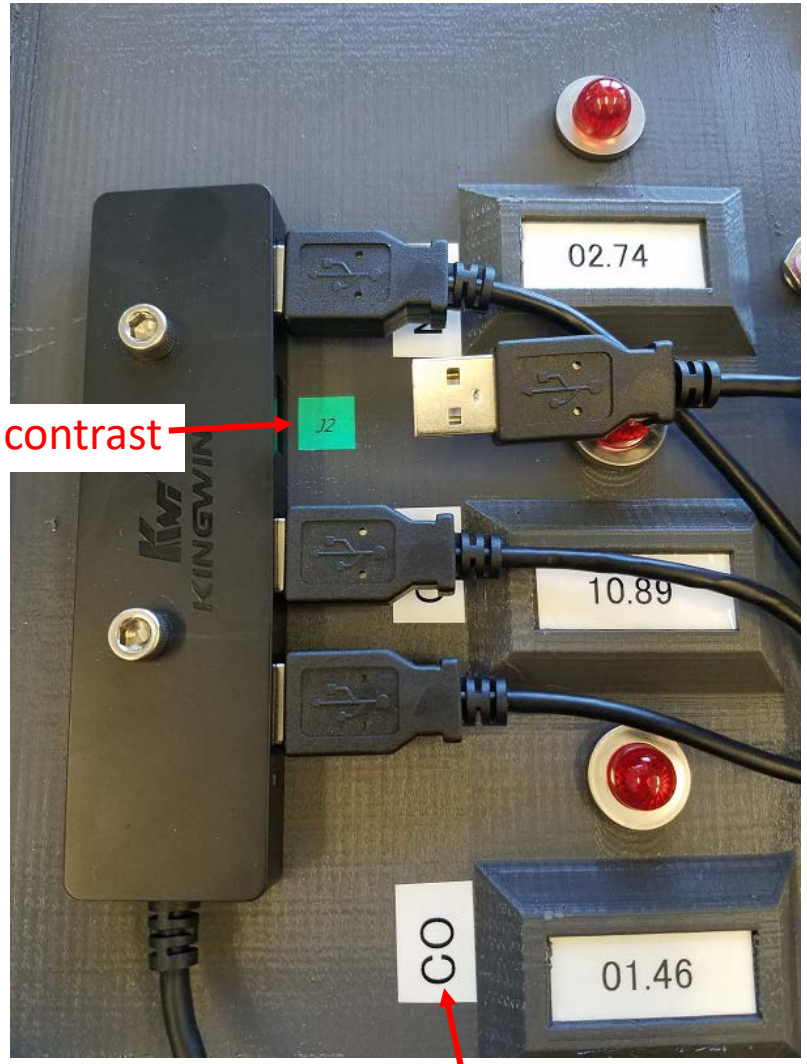
- Spacing, Obstructions, finger access, etc
- Barrier / Switch Guards missing



Labeling Issues

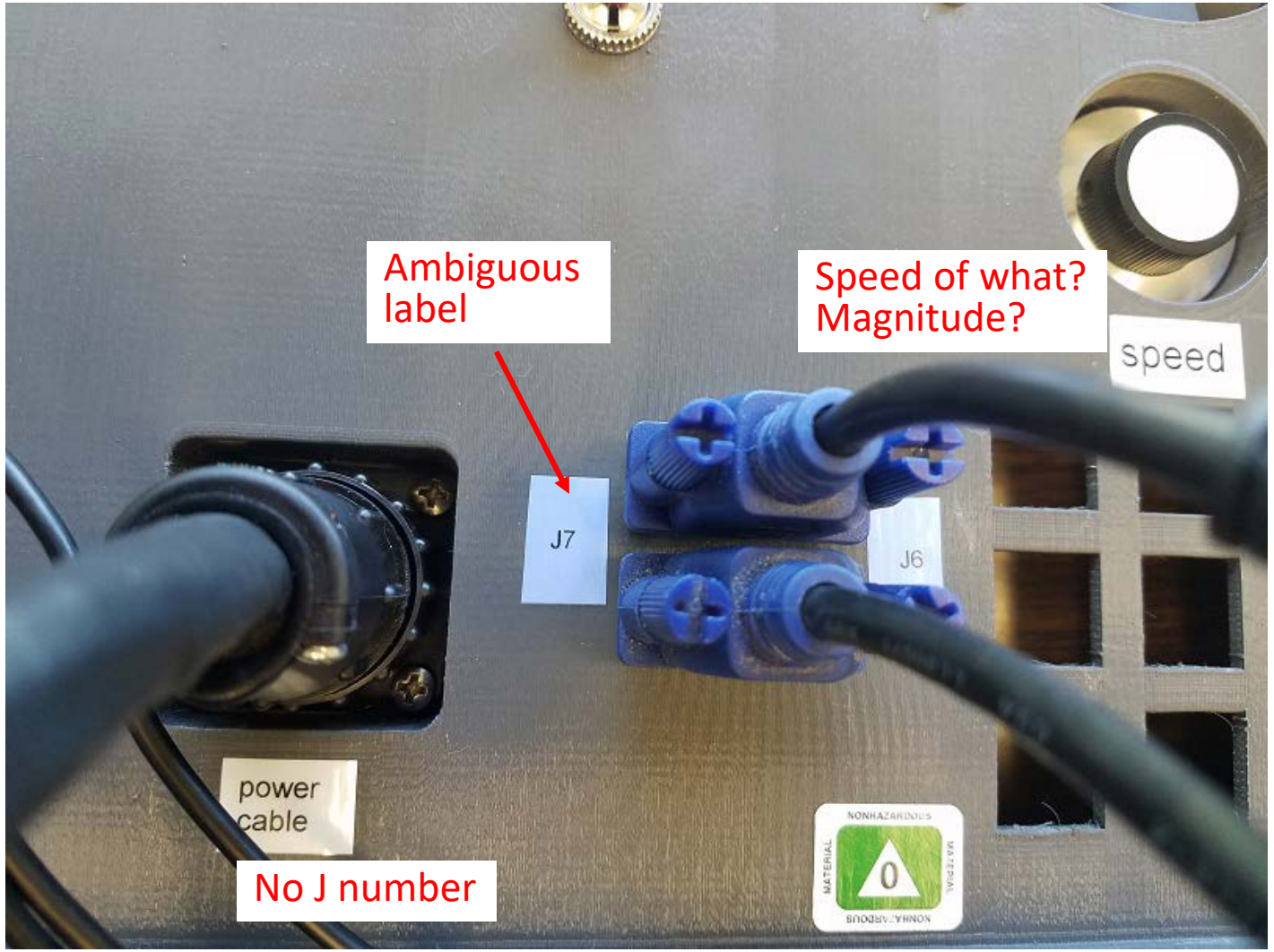
- White space
- Covering plugs/ports
- Covering displays
- Incorrect wording
- Incorrect placement
- Missing barcode
- Incorrect color use
- Generic descriptions
- Missing Identifiers

Labeling

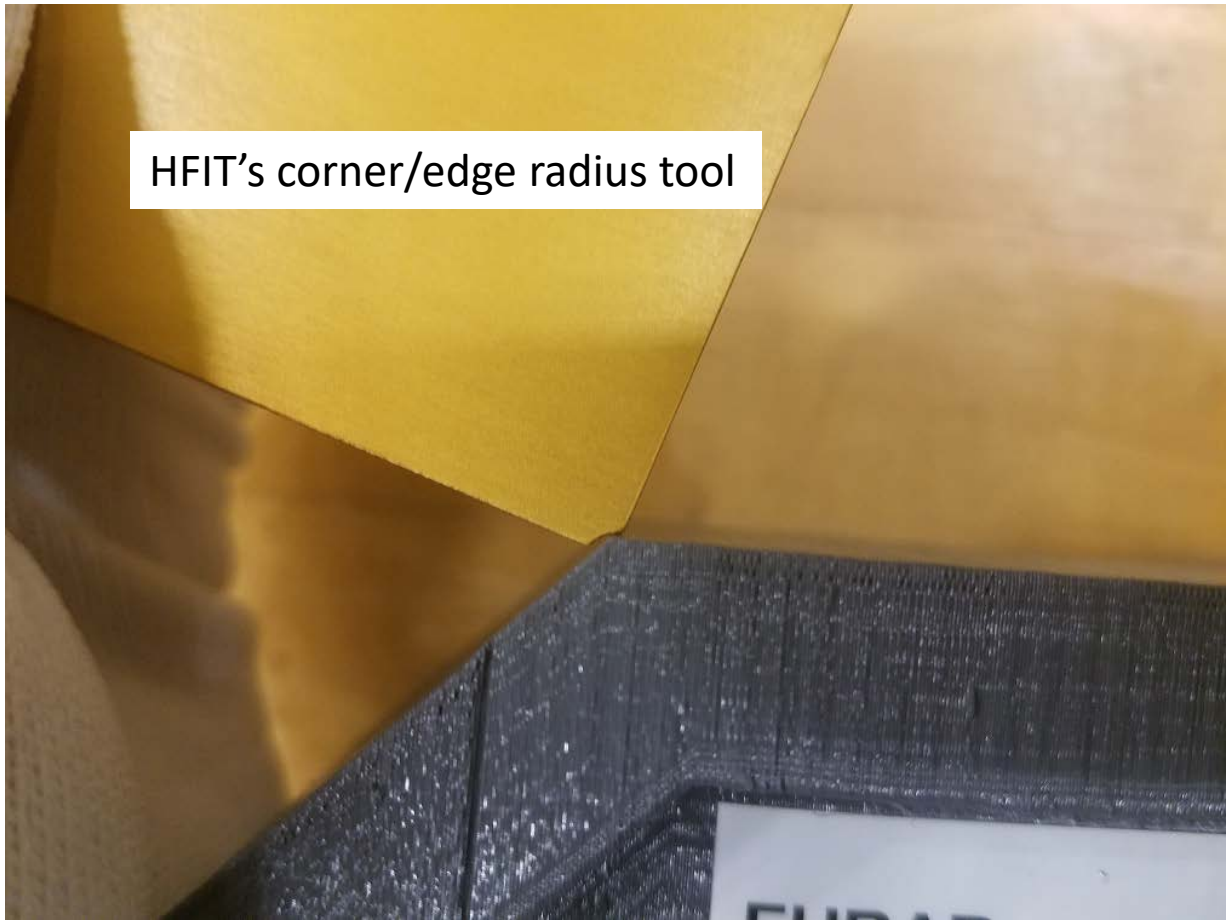


Poor contrast

Cryptic labeling: used symbols instead of spelled out names



Sharp Edges and Burrs

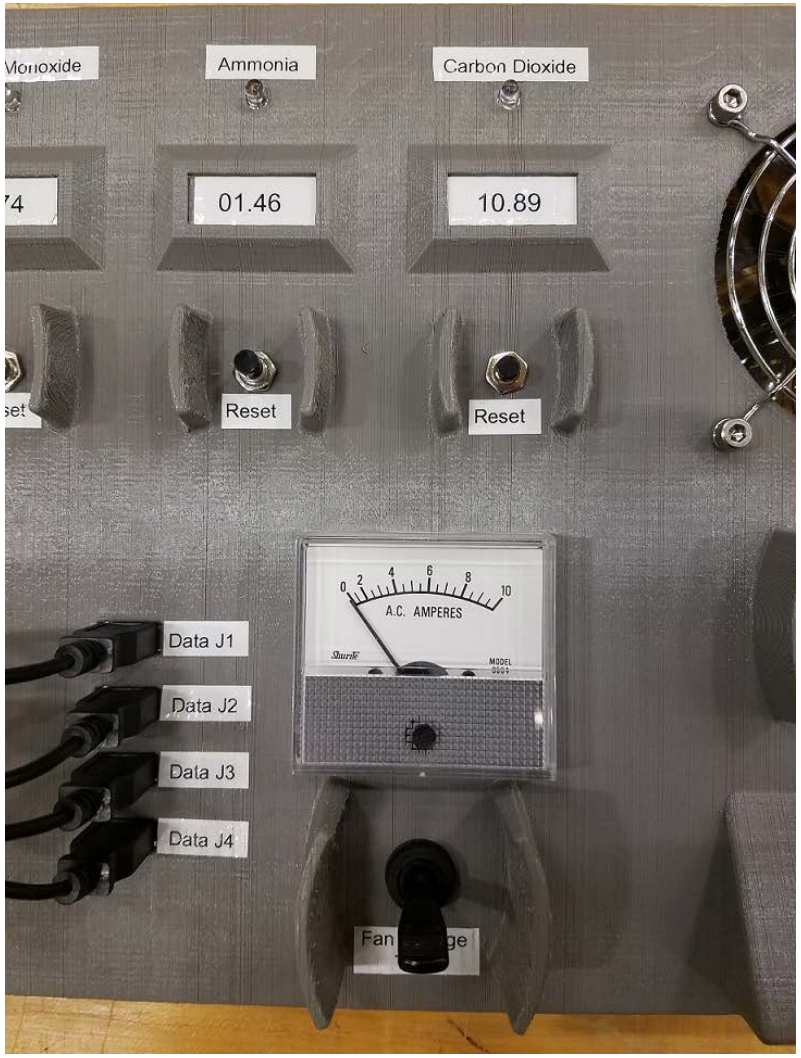


HFIT's corner/edge radius tool

Cotton glove inspection for burrs

Examples of HFIT's positive impact on design

Barrier Guards



Connector Spacing / Access

Examples of HFIT's positive impact on design

Labeling

Before HFIT

After HFIT

Examples of HFIT's positive impact on design

Tools of the Trade

- White glove
- Calipers
- Push-pull force gauge
- Sharp edge radius gauge / card
- Micrometer

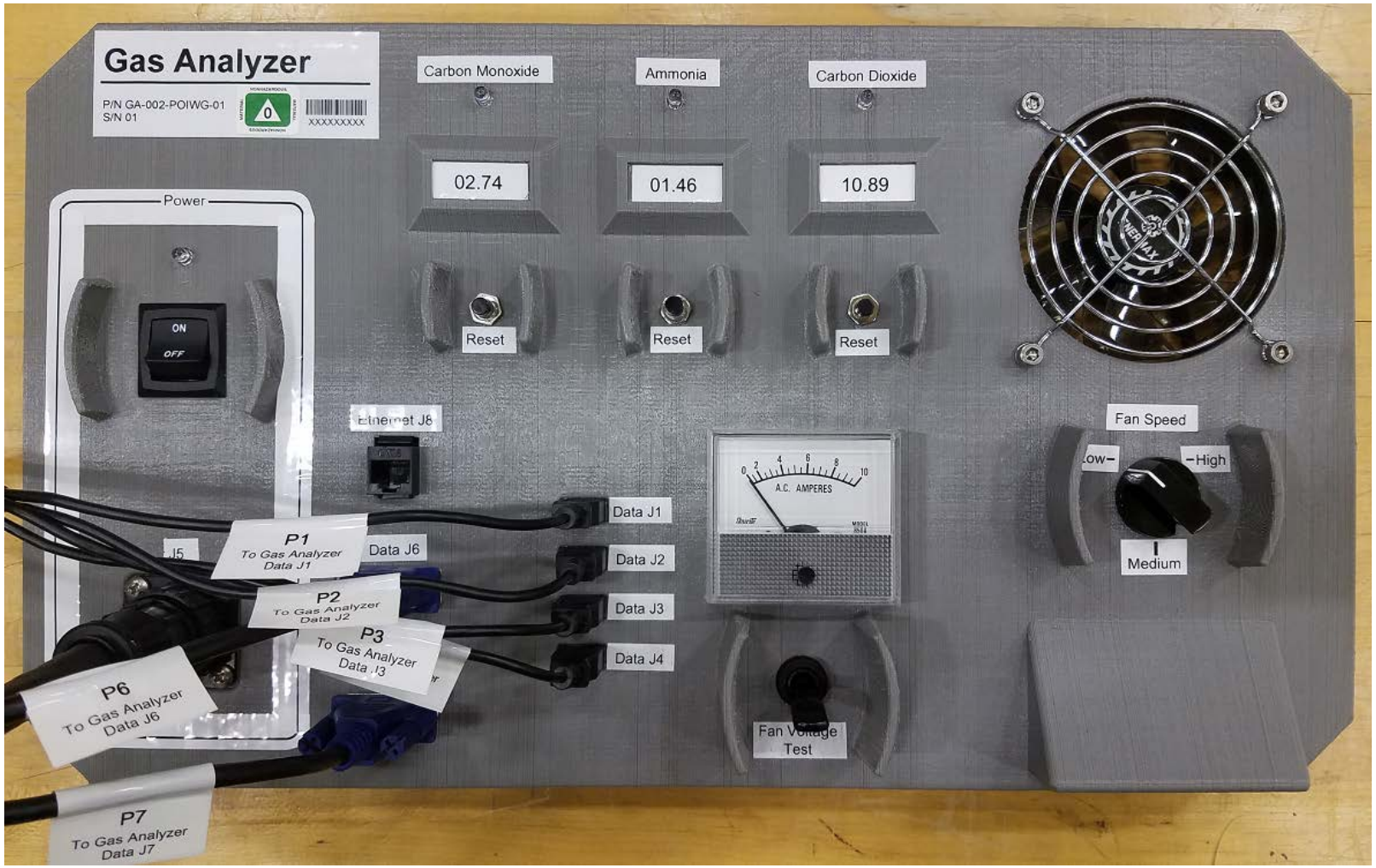
Final HFIT evaluation and verification

Final HFIT Evaluation Stage (Verification).
PD has implemented all the actions and recommendations from the Initial HFIT Evaluation.

HFIT and FOD Crew Rep again exercise all the crew interfaces, this time using mature draft procedures.

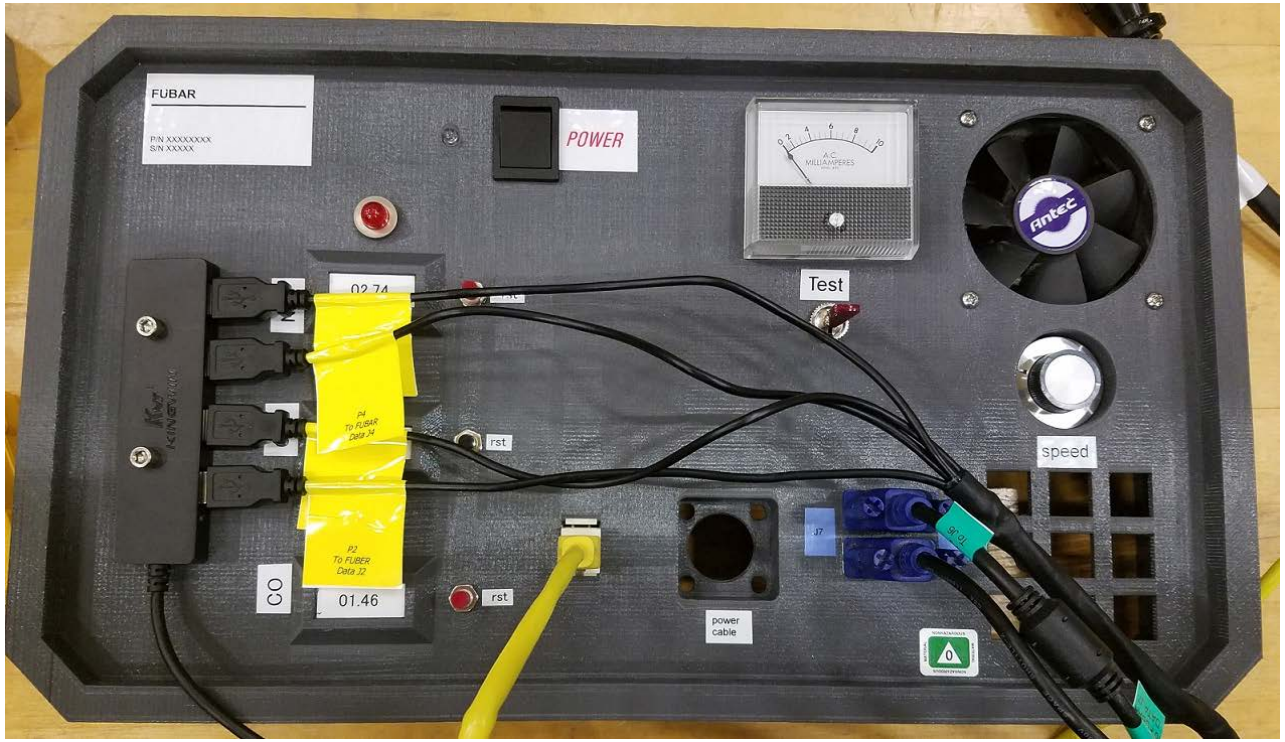
HFIT verifies and notes compliance with all the requirements. Compliance with guidelines noted (not required). Any non-safety related minor requirements violations previously pre-coordinated are accepted on Form 882.

HFIT submits the final HFIT CoC to the PD and Payload Integration Manager to be recorded in the VERITAS verification database. HFIT process is finished.



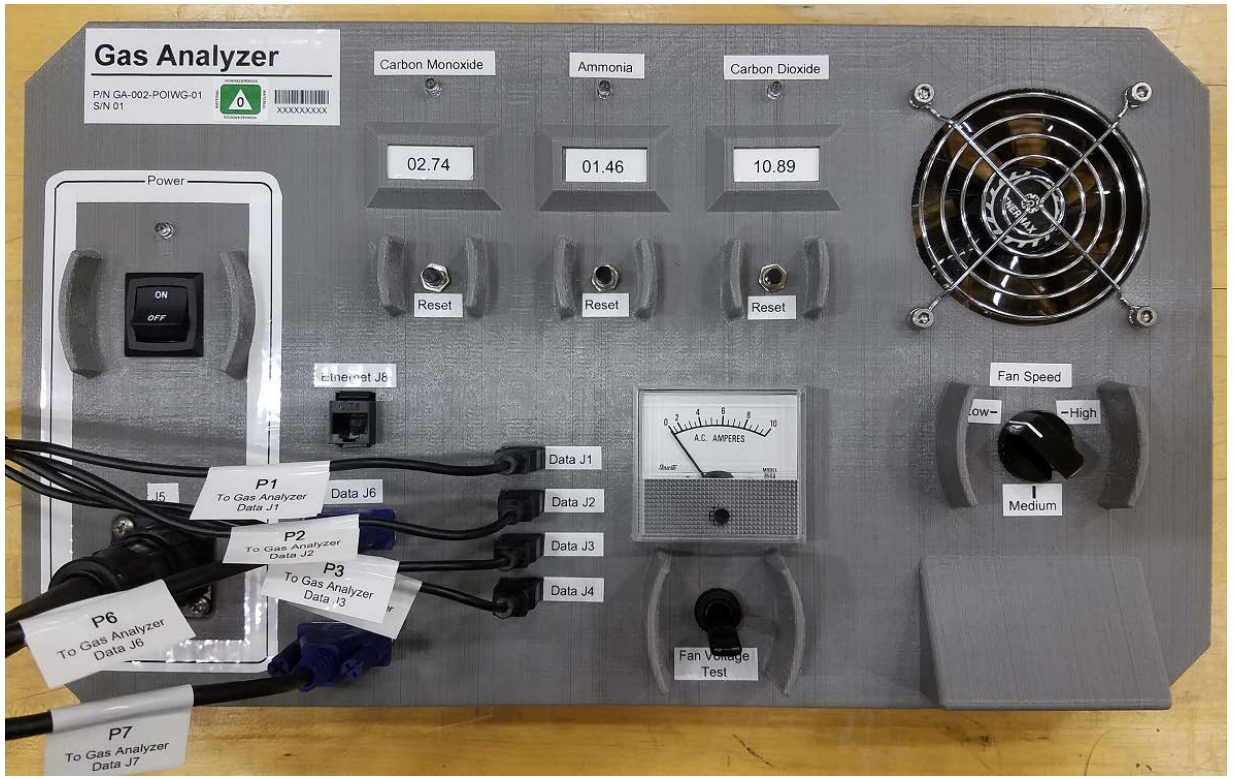
Let's Review - Before and After HFIT highlights

BEFORE



- Unprotected fan and large vent holes could entrap and injure crew's fingers.
- Unnecessarily recessed power connector, dial make crew operation difficult.
- OpNom is an acronym, and label is too small.
- Red and yellow used incorrectly in labeling and LEDs.
- Cables and their labeling obstruct port labels and gas LEDs and displays.
- Various Labeling is ambiguous.

AFTER



- Fan is protected. Vent holes reduced in size and faced downward.
- Power connector and Fan Speed dial unrecessed, labeled clearer.
- OpNom is a human-friendly name, larger, includes hazard label.
- Green LEDs used for nominal operation, Orange LEDs used for payload alerts (malfunctions), labels are black and white.
- Cable routing improved to reduce obstructing ports and gas LEDs.
- Labels made clearer.

Summary

- Early involvement of Human Factors personnel on flight hardware projects enables:
  - Identification of crew interface issues early when it is cost effective to influence design.
    - This saves the hardware developer money by avoiding late design changes
    - Saves money by avoiding Program Level waivers for Human Factors requirements violations
  - Best of all, Human Factors involvement leads to hardware that is better designed for the user - the flight crew, that is safe and efficient for them to operate. This maximizes science return, allowing the hardware developer and principle investigators to achieve mission success.
- Thank you for your time!
- Questions?

HFIT Points of Contact

To initially request HFIT support, please contact the group mailbox.

HFIT Group Mailbox: jsc-hfit@mail.nasa.gov

Payload HFIT Representatives

- Laura Duvall: 281.483.0244 (NASA FCI System Manager)
- Rich Ellenberger: 281.483.5238 (NASA FCI System Manager Deputy)
- Jenae Aber: HFIT Lead
- Antonius Widjokongko: HFIT team member
- Lauran Johnson: HFIT team member
- Sean Schimelpfening: HFIT team member
- Pam Fournier-Gonzalez HFIT team member