# DIY HUD/HMD Development
# Install in my RV8 or Your Aircraft


OSHKOSH 2024 HUD DIY HUD Brief: Contact; Cecil “TRON” Jones → TRON@flyonspeed.org

# HUD Project Presentation Summary

1. **What is a HUD?**
2. **Short HUD History**
3. **Why have a HUD/HMD in an Experimental Aircraft**
4. **Design Goals**
5. **Current Operational Experimental HUD's**
6. **FlyOnSpeed.org HUD Project Goals**
7. **System Overview & Supported Hardware**
8. **Software System Design**

# What is a HUD?

- A **head-up display** (or **heads-up display)**, also known as a **HUD** is any transparent display that allows the pilot to look outside the aircraft while also viewing critical aircraft data without requiring the pilot to also look inside the aircraft.

**Elbit Skylens (HMD)**

**F-18**

**C-130J**

**F-35 HMD**

# Modern HUD Design History

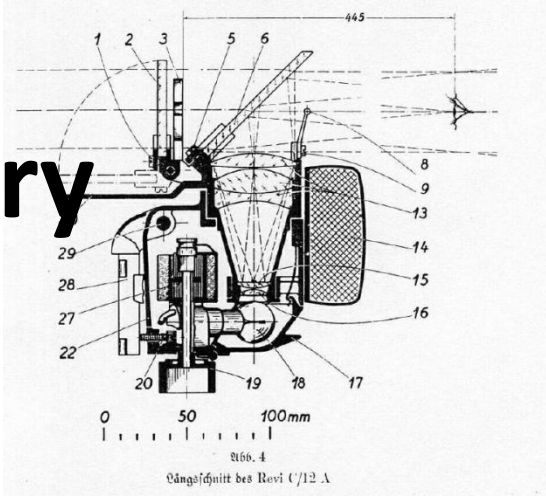


Abb. 4
Längsschnitt des Revi C/12 A

- 1 - Use CRT to generate a green phosphor image on a combining glass
- **2 - Use (LED) light source, modulated by LCD screen (or DLP) to project image on a combining glass**
- 3 - Use optical waveguides or LASER to produce images directly in the combiner.
- 4th Gen—Use a Micro-OLED transparent Color display that has its built in lens for each pixel to display images (Data/Video)


# Why have a HUD in a Experimental Aircraft?

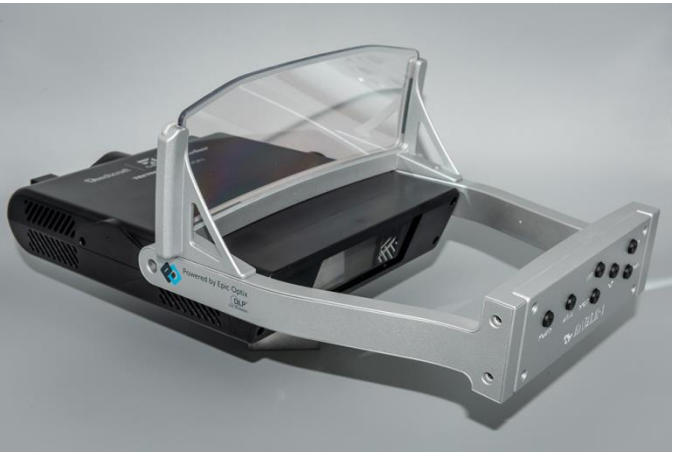
- HUDs enhance safety by providing critical flight information in the visual (Heads-Up Outside the Aircraft) Pilot Environment.

- Typical aircraft HUDs display ➡ Airspeed, **Altitude, Attitude (pitch/roll),** a **Horizon Line, Heading, Vertical Velocity, AOA &/**or ("α“ #), and **Slip/Skid** indicator.
- **Boresight/waterline** symbol,
- **Flight Path Vector** (FPV) or Velocity Vector
- **G’s, QNH, Wind Dir/Speed,** & **OAT**.
- Critical Traffic Data (TD Box -Target Designate)
- Navigation/Comm Data —(For Enroute, approach and landing)
- Critical Aircraft/Engine Data (+ Other information)

# Generic HUD Design Goals

- **Focus** – The HUD display should be focused to Infinity
- **Eyebox** – The fixed HUD produces an image inside a three-dimensional area called the eyebox. Head movement too far up/down left/right will cause the display to vanish off the edge of the HUD.
- **Luminance/contrast** – HUD should have luminance/contrast adjustments to account for Sun/Clouds/Night/etc.
- **Boresight** – Aircraft HUD symbology should be aligned with the aircraft's three axes, so that displayed data conforms to reality (typically ±7.0 milliradians), but may vary across the HUD's FOV.
- **Scaling** – The displayed HUD image (flight path, pitch & yaw), should be scaled so picture overlays outside world in an exact 1:1 relationship. Example; object 3 degrees below horizon should appear at the −3 degree index on the HUD.

# Available (Economical?) Experimental & TSO'd HUD's



**Epic OPTIX Eagle 2 (HDMI Video Input)**
**$1.5K (Made for Aircraft ⟹ Infinity)**
**Daylight usable 20K Nits, Night Compatible**

XREAL Air 2 PRO AR (Augmented Reality) HMD **$450** **HDMI Video Input**

**Made for AR ⟹ 12 ft**
**Daylight usable, Night Use is TBD**

DUAL HUD Display (Interfaces with STRATUX/ADSB via WIFI/BT) $549

(DUAL/ACS/Sportys

(Made for Cars ➡ 2 Meters)

MGF SKYDISPLAY (HUDLY v2 ?) ~$23-25K TSO

(Interfaces with TSO'd Avionics)

(Made for Cars/Aircraft ➡ 2 Meters?)

GRT Hudly Classic HUD (HDMI Video Input) (In Production but Not Available from HUDLY?)

(Made for Cars ➡ 2 Meters)

# Why use the Epic Optix HUD?

- The most important innovation in bringing a HUD to GA is to be able to produce a quality but affordable product.
- Epic Optix achieved this by:
  - Designing a HUD that's bright enough for full Sunlight readability (in Full Color using LED/DLP technology)
  - HUD Focuses to Infinity
  - Its designed to fit in the most GA/Experimental aircraft as possible
  - It is affordable at $1500, by commercial HUD standards this price is a rounding error

# Why use the XREAL AR HMD?

- AR (Augmented Reality) “Smart” Glasses are the technology of the future.
- XREAL AR Glasses bring new Micro-OLED technology to the cockpit:
  - AR allows you to both see the outside world as well as projected Data/Video simultaneously. HUD display presently does not change with head movement
  - The full color high res (1920x1280) SONY OLED 0.5” display projects what appears to be a 135” diagonal computer screen some 12 feet in front of the aircraft and the pilots eyes.
  - This low power Glass type display weighs less than 3 oz’s & fits under a Headset
  - This technology is affordable (~ $400-$500) and fits into all cockpits without any significant installation cost
  - Our FlyOnSpeed team is also working to incorporate a simple & reliable Micro Video camera head tracker to improve the HMD cockpit integration

# FlyOnSpeed.ORG HUD Project Goals

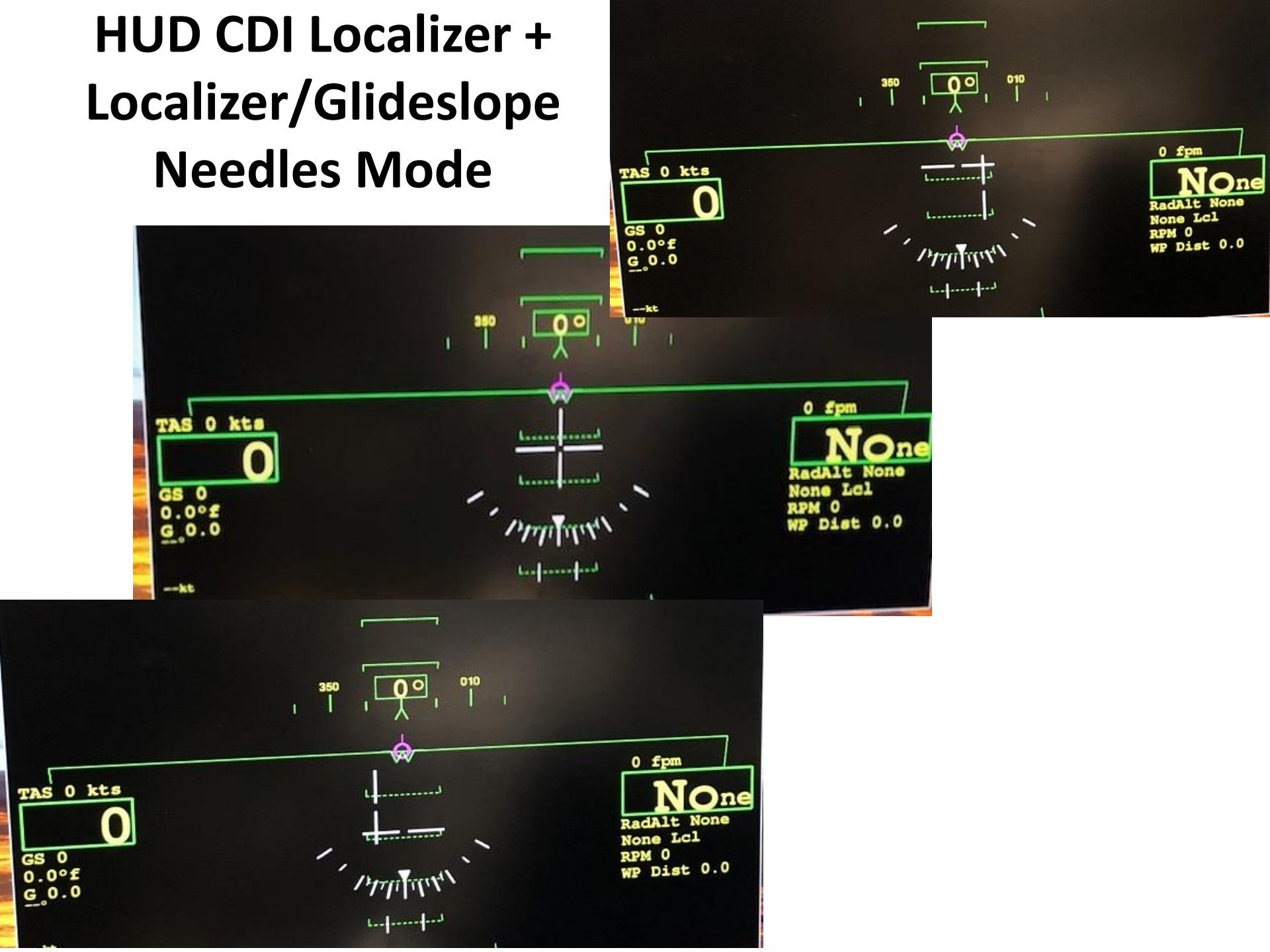
- Enhance Flight Safety
- Use affordable technology and open source (Free) HUD software
- Make it to be easily integrated with current Experimental EFIS Systems.
- Use a quality HUD that can be installed in many experimental aircraft.
- Use a capable Micro-Computer.  Currently a RASPBERRY PI 5+ ~ $80
- Do the research and development to provide a baseline HUD design
- As much as possible make the system pilot/user friendly
- Allow users so inclined to also modify  or create their own HUD designs
- Provide a path for an optional 2nd A/C display (HDMI Video), or display the HUD Camera view via the Camera or DVR outputs.

# Basic OnSpeed HUD Design Info


06/16/2023 13:51:33
N95CH
163°
TAS 126 kts
120
GS 132
78.0°f
G 1.1
-388 fpm
3093
RadAlt 3028
9:47:58 Lcl
RPM 2329
WP Dist 11.2
Rng:1800ft


06/16/2023 13:57:48
N95CH
88°
74
GS 73
87.0°f
G 1.0
337
RadAlt 124
9:54:13 Lcl
RPM 1309
WP Dist 0.4
Rng:3500ft

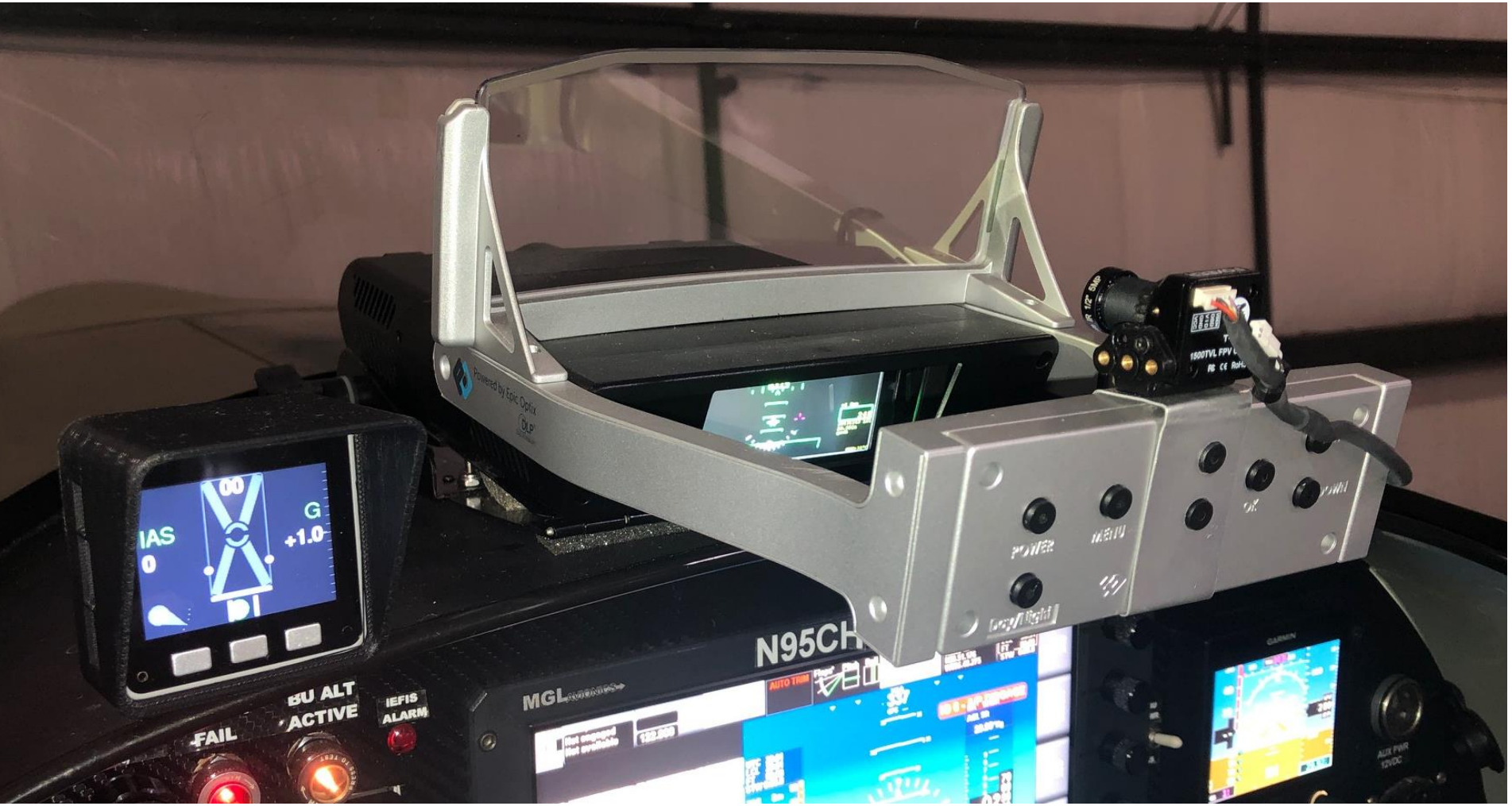
# HUD CDI Localizer + Localizer/Glideslope Needles Mode



# BFM Video

Oshkosh_HUD Video_2023.mp4

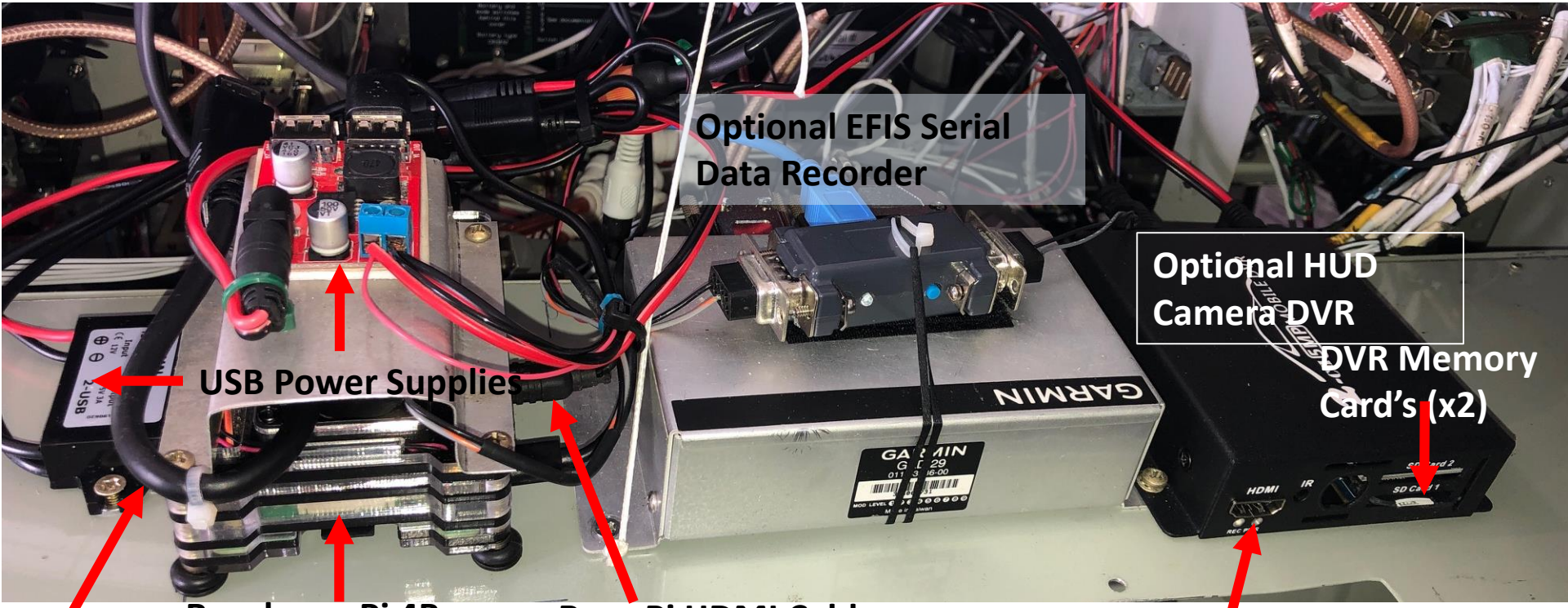
# My RV8 HUD Install
# Larger Tinted Non-Vans Canopy



# Determine Head position / Line of Sight for HUD position.

# Next determine how the HUD should be installed.

# Locate where to install your HUD Support Electronics (Required and Optional)



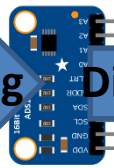
# HUD Interconnections

EFIS/NAV

Serial

ADSB-WIFI/Serial

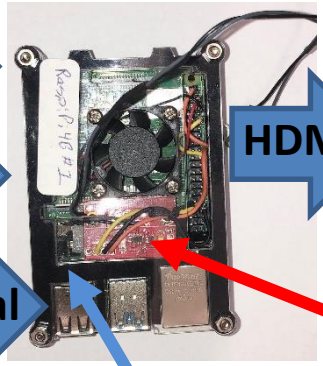
+Analog Digital



ADC1115

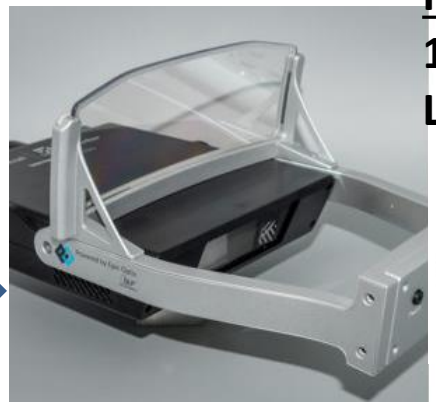
HDMI

Raspberry Pi 4B+ CPU
64GB Data Recorder



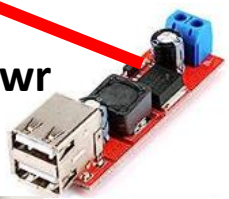
HDMI

Epic OPTIX HUD



HUD

USB-Pwr



USB-Pwr

**FPV HUD CAMERA**
16-25MM Zoom
Lens & 32 ND Filter

1080P AHD
Video Out

USB

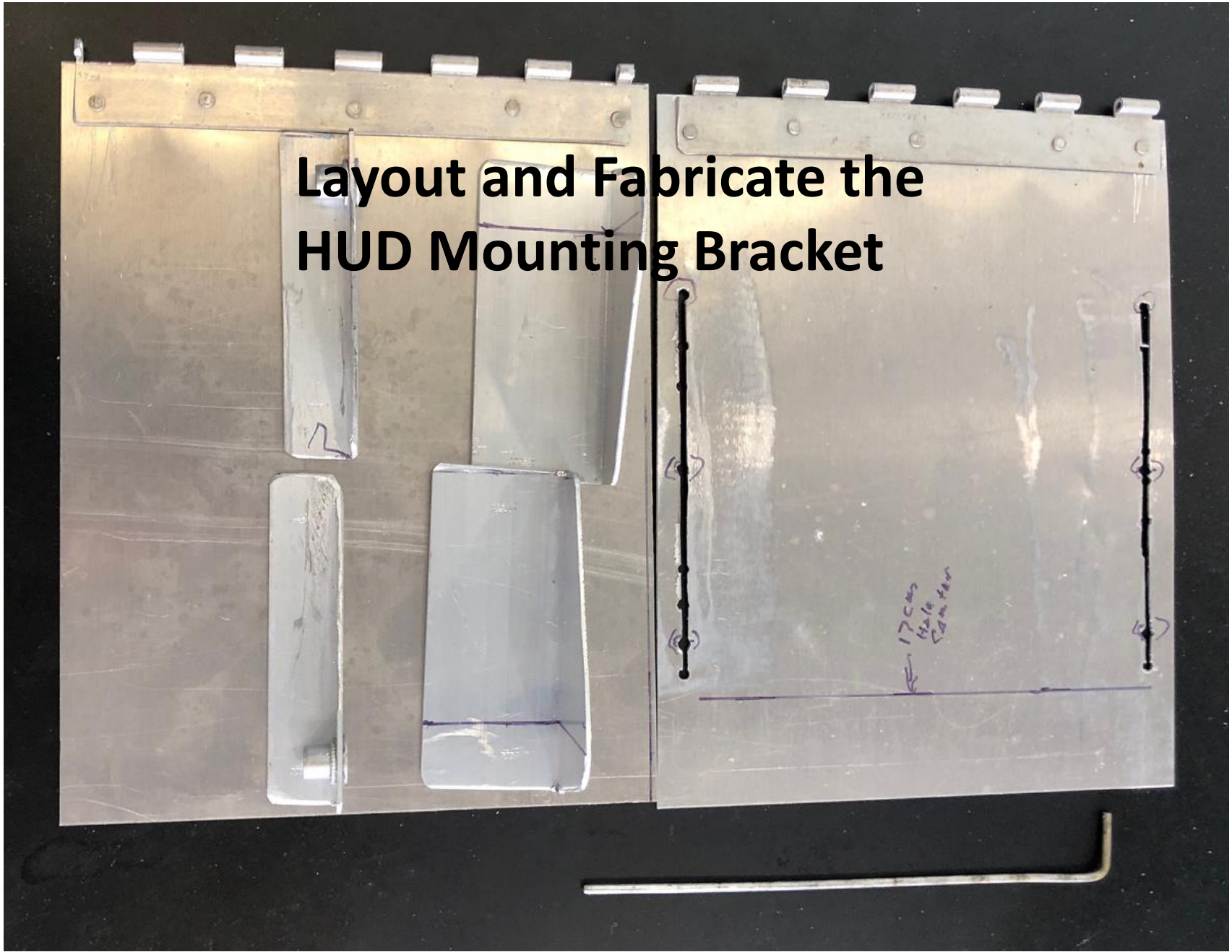
**Key Pad Ctrl**

1-Start Data Rec
2- Stop Data Rec
3- Tfc Display Cycle
4/5 Drop Buoy Tgts
6- Clear Buoy
7- Data Debug
8- LCOS Ctrl
9- FPM/Ctrl
10- TD Box/ILS

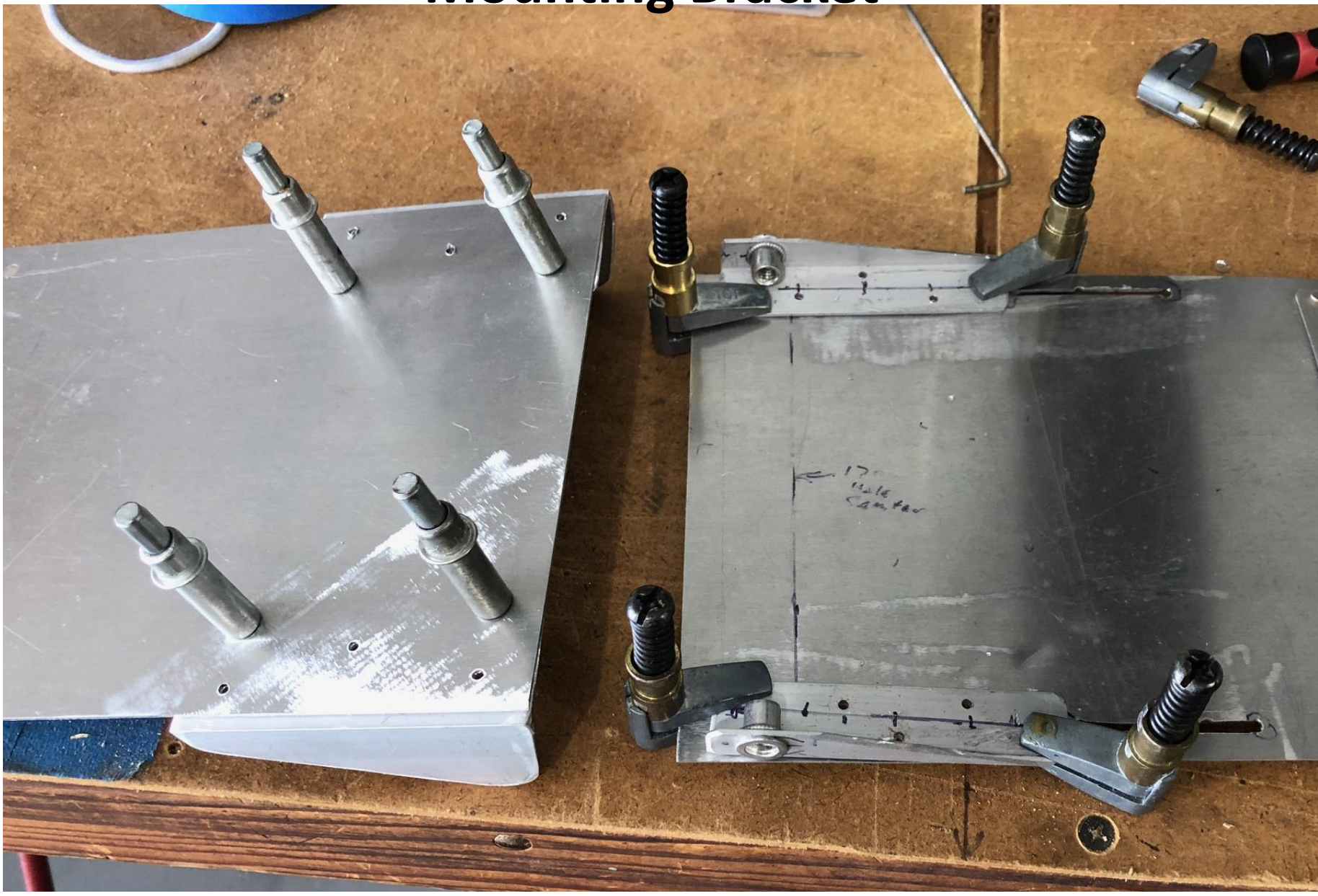
DVR

12VDC

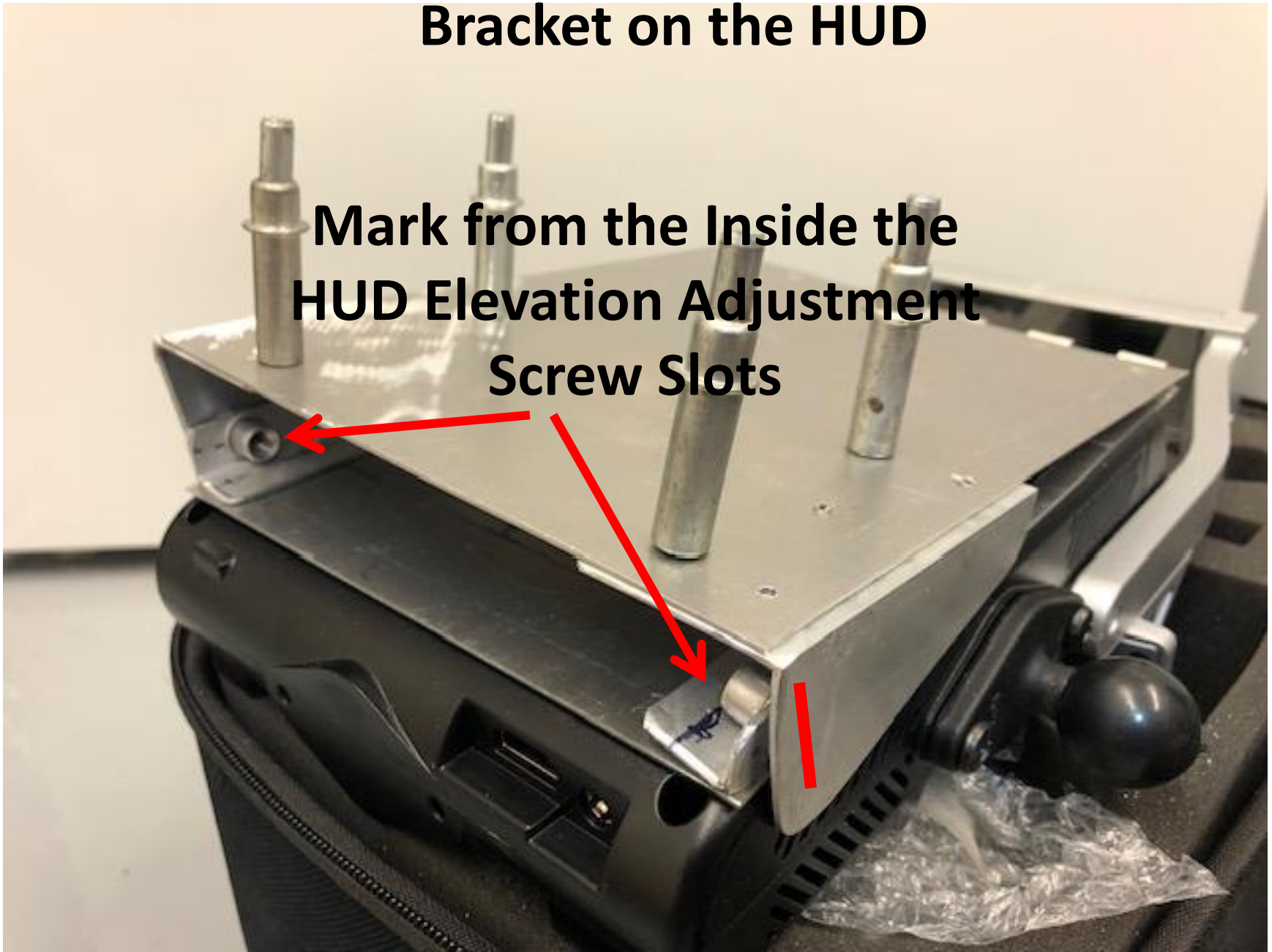
128GB SD Memory Card

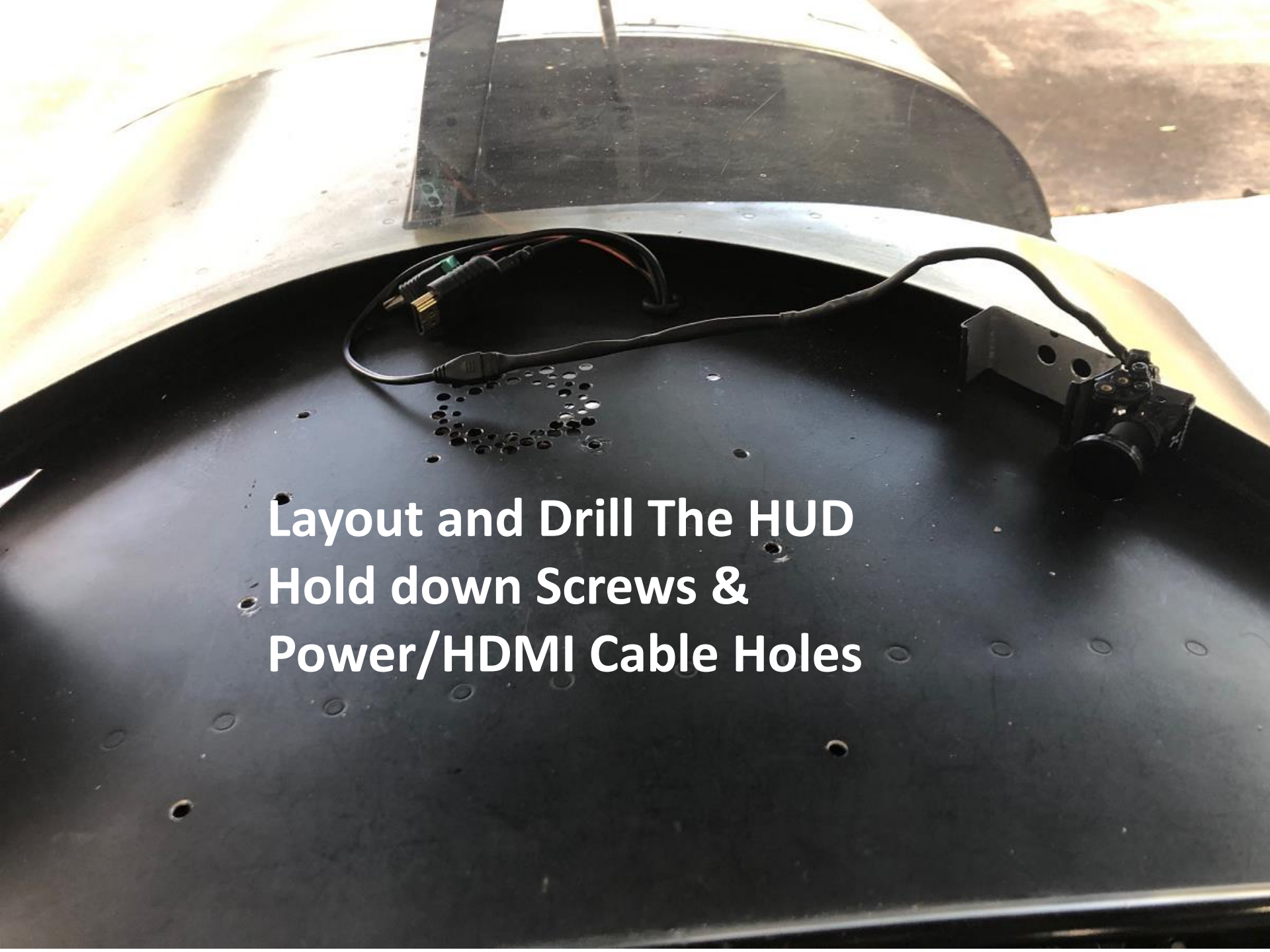

Layout and Fabricate the
HUD Mounting Bracket

# Assemble the HUD Mounting Bracket



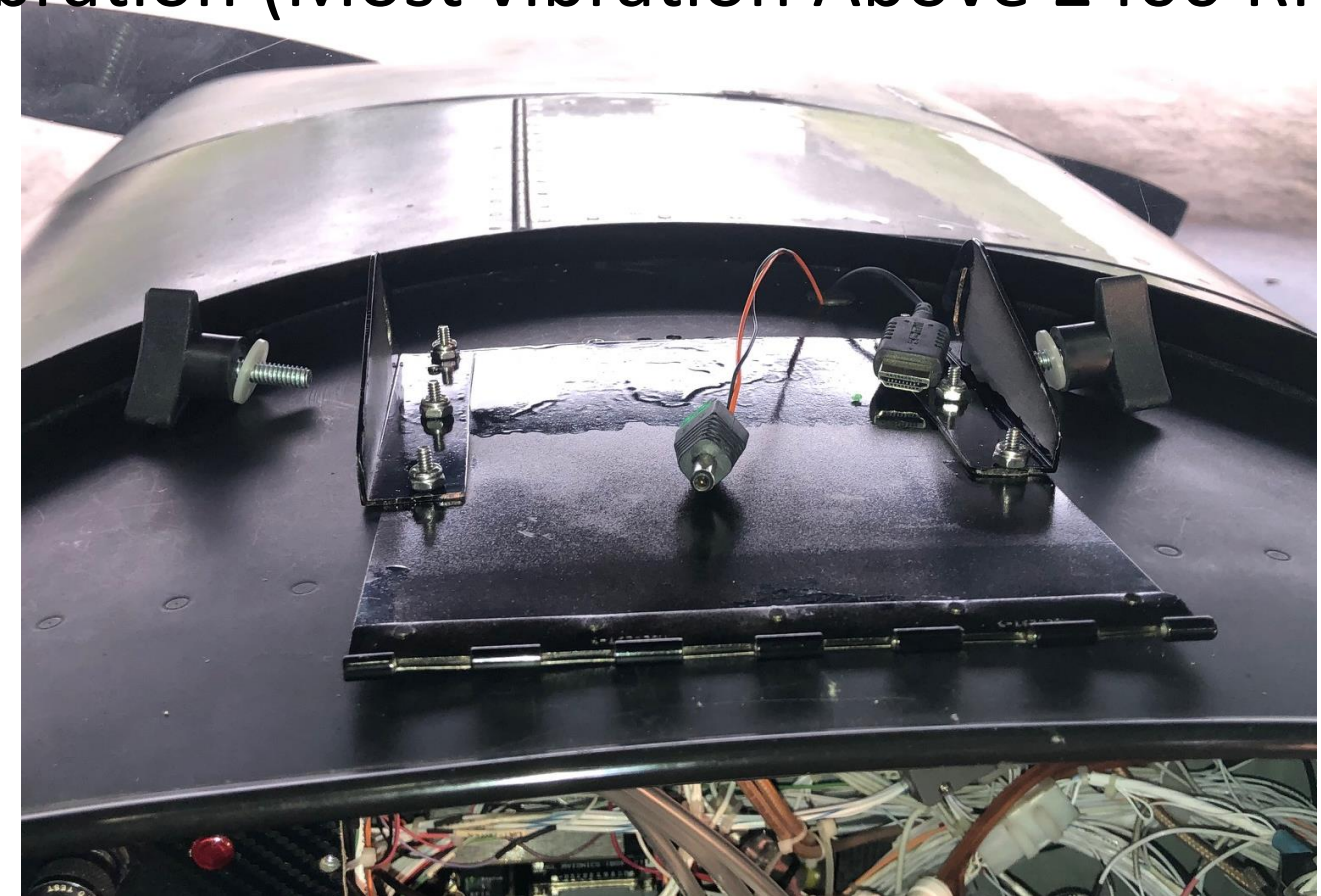
# Fit Check HUD Mounting Bracket on the HUD




Layout and Drill The HUD
Hold down Screws &
Power/HDMI Cable Holes

# Install the HUD Bracket

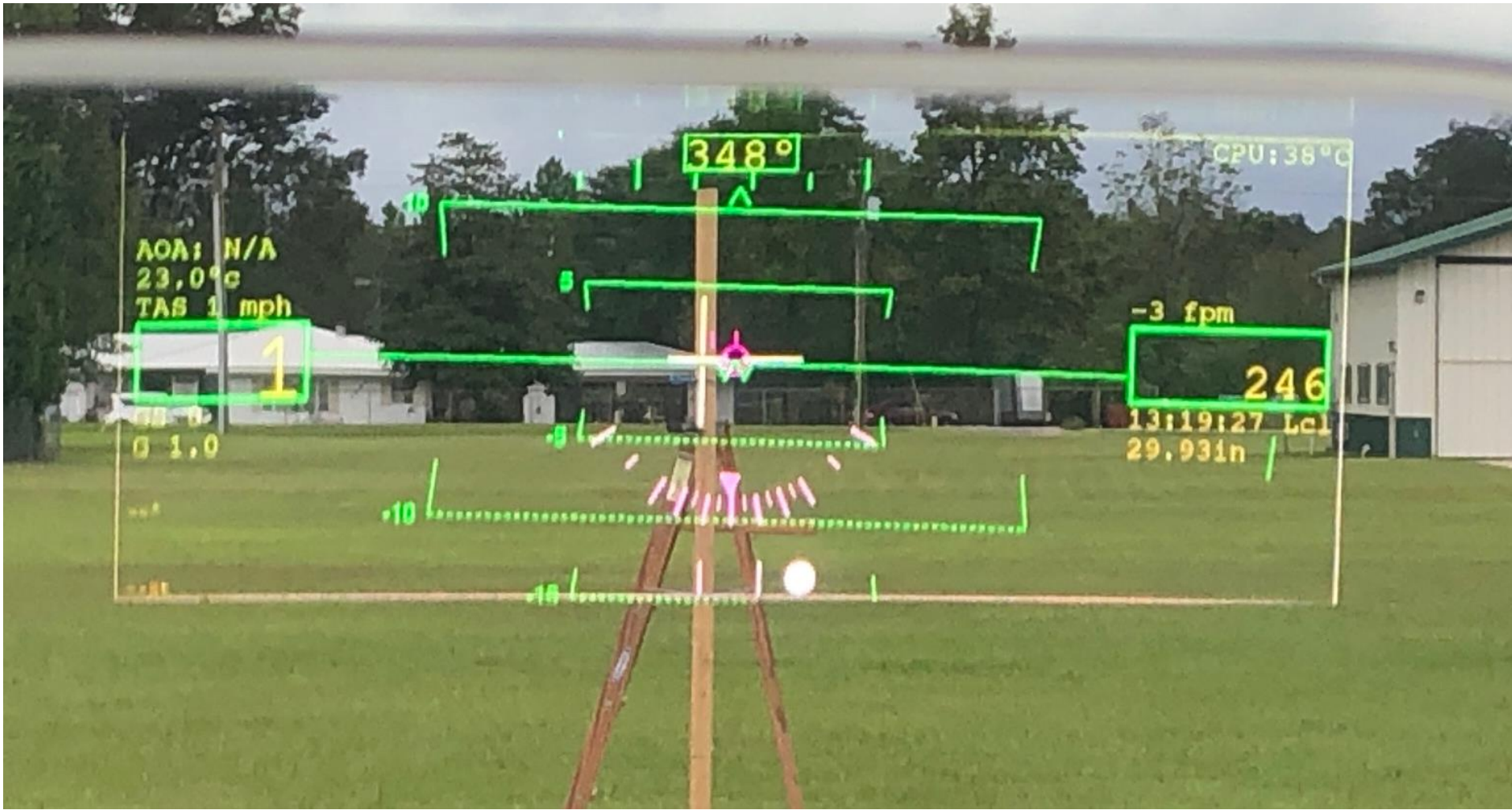
- Screws Allow Elevation Adjustment
- Piano Hinge Gives Bracket Rigidity
- Recommend to Balance Prop to reduce HUD Vibration (Most vibration Above 2400 RPM)



# Aligning the HUD Boresight

## Azimuth Gnd Install Alignment is Critical

1. **HUD Bracket Azimuth is Fixed - Elevation is Adjustable**
2. **Minor adjustments can be done in software config file**



# HUD Complete install with Camera and Mounting Bracket

# HUD Picture at Infinity
# (HUD Graphics fills screen from Pilot View Box)

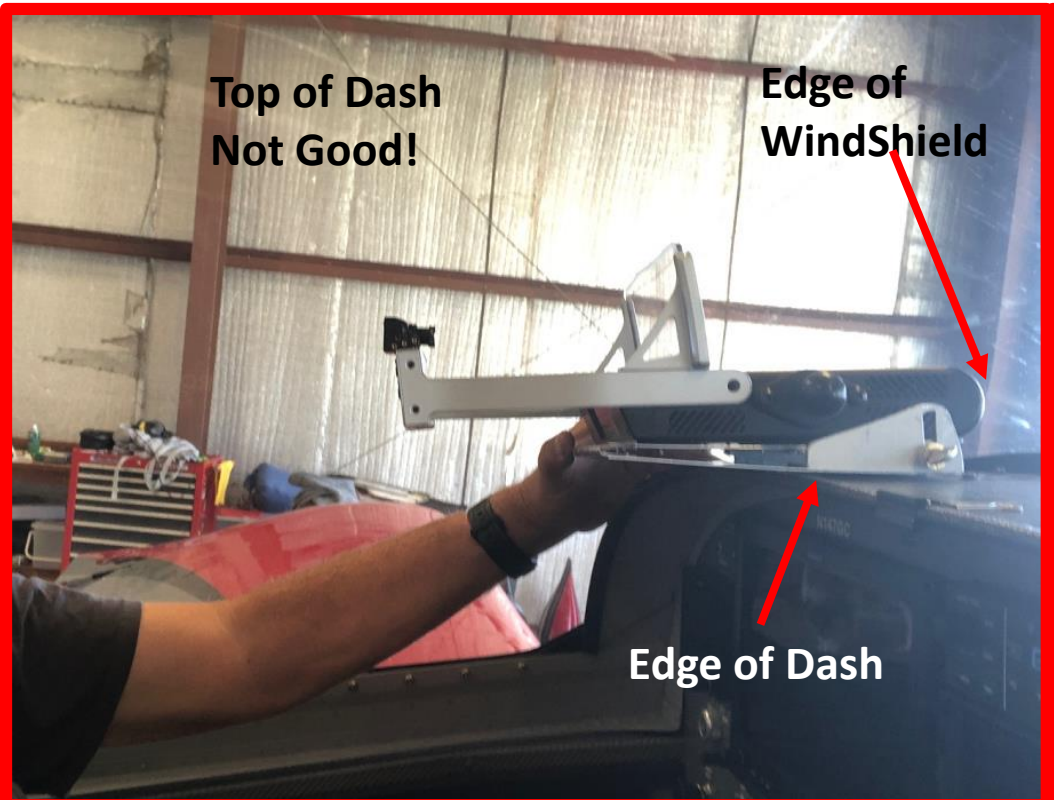
# HUD Install in RV8 with Vans Standard Windshield

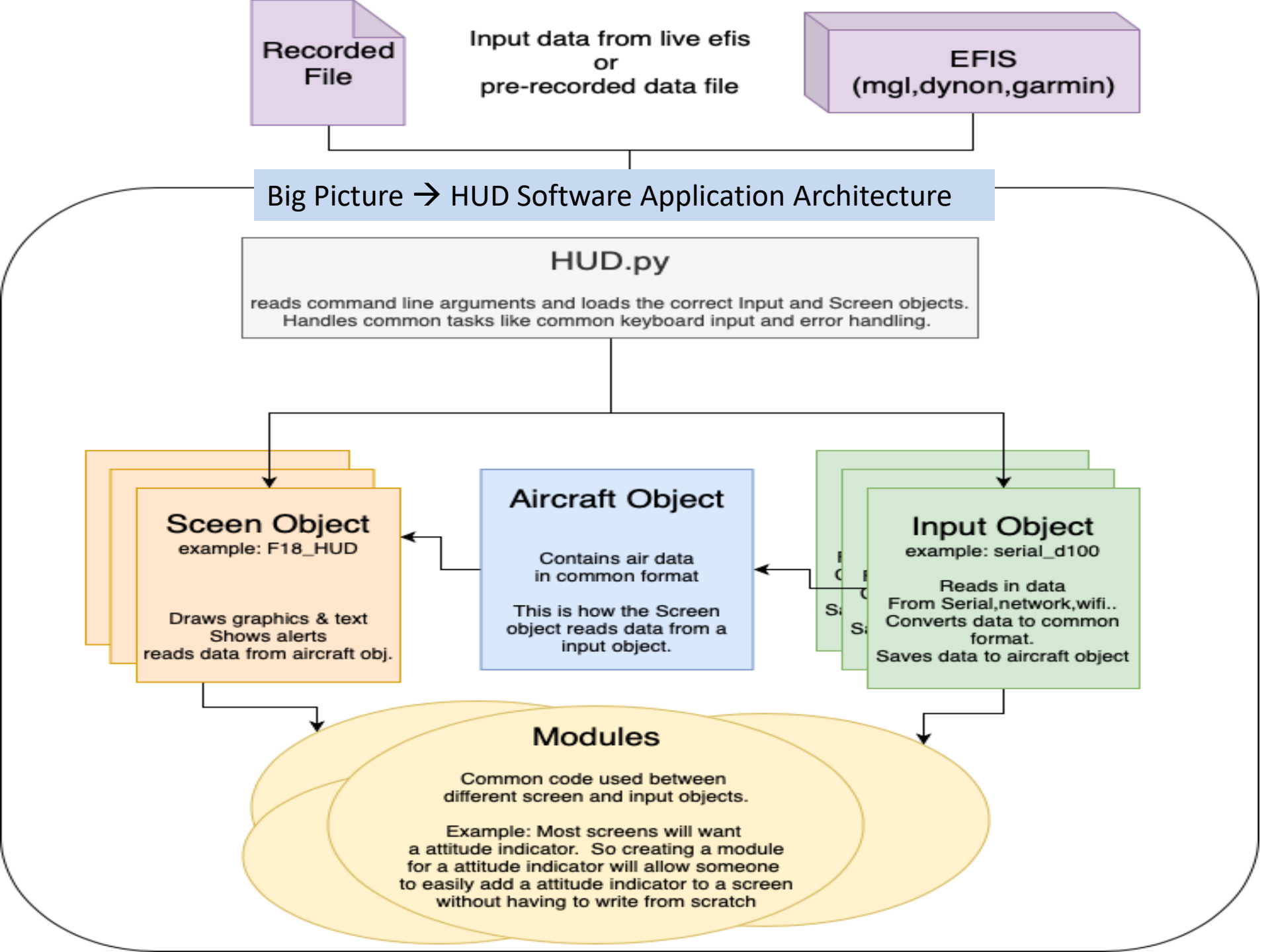
# RV8 HUD Install in - side profile

## (Vans Standard Windshield)

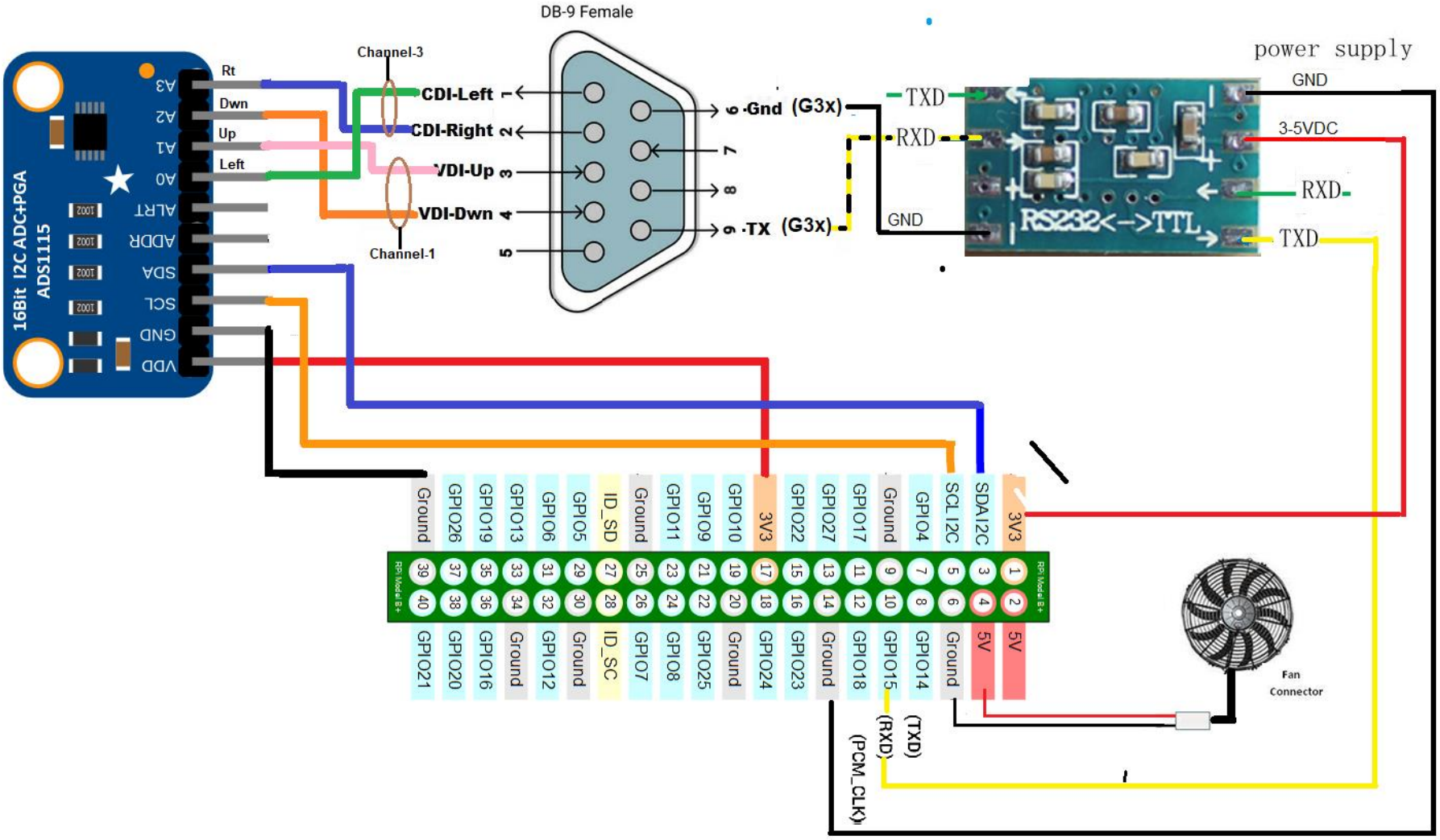
# HUD Test Fit in RV14

**To Cut and fit HUD under Dash & windshield would likely put HUD "EYEBOX" to low for normal use?**





Recorded File
Input data from live efis
or
pre-recorded data file
EFIS
(mgl,dynon,garmin)
Big Picture → HUD Software Application Architecture
HUD.py
reads command line arguments and loads the correct Input and Screen objects.
Handles common tasks like common keyboard input and error handling.
Sceen Object
example: F18_HUD
Draws graphics & text
Shows alerts
reads data from aircraft obj.
Aircraft Object
Contains air data
in common format
This is how the Screen
object reads data from a
input object.
Input Object
example: serial_d100
Reads in data
From Serial,network,wifi..
Converts data to common
format.
Saves data to aircraft object
Modules
Common code used between
different screen and input objects.
Example: Most screens will want
a attitude indicator. So creating a module
for a attitude indicator will allow someone
to easily add a attitude indicator to a screen
without having to write from scratch

# Raspberry Pi connected to ADC1115 + RS232 connected → EFIS (+ ADSB via WIFI)



# FlyONSPEED Head Up Display Project

## *Featuring the most cost effective & Highest Quality Gen Aviation HUD Available Today*

## The Epic Optix EAGLE 2 HUD

Note: Any HDMI or NTSC/PAL compatible HUD/VIDEO Display can be used.


Why have a HUD in an Experimental Aircraft?

# How to get the Software

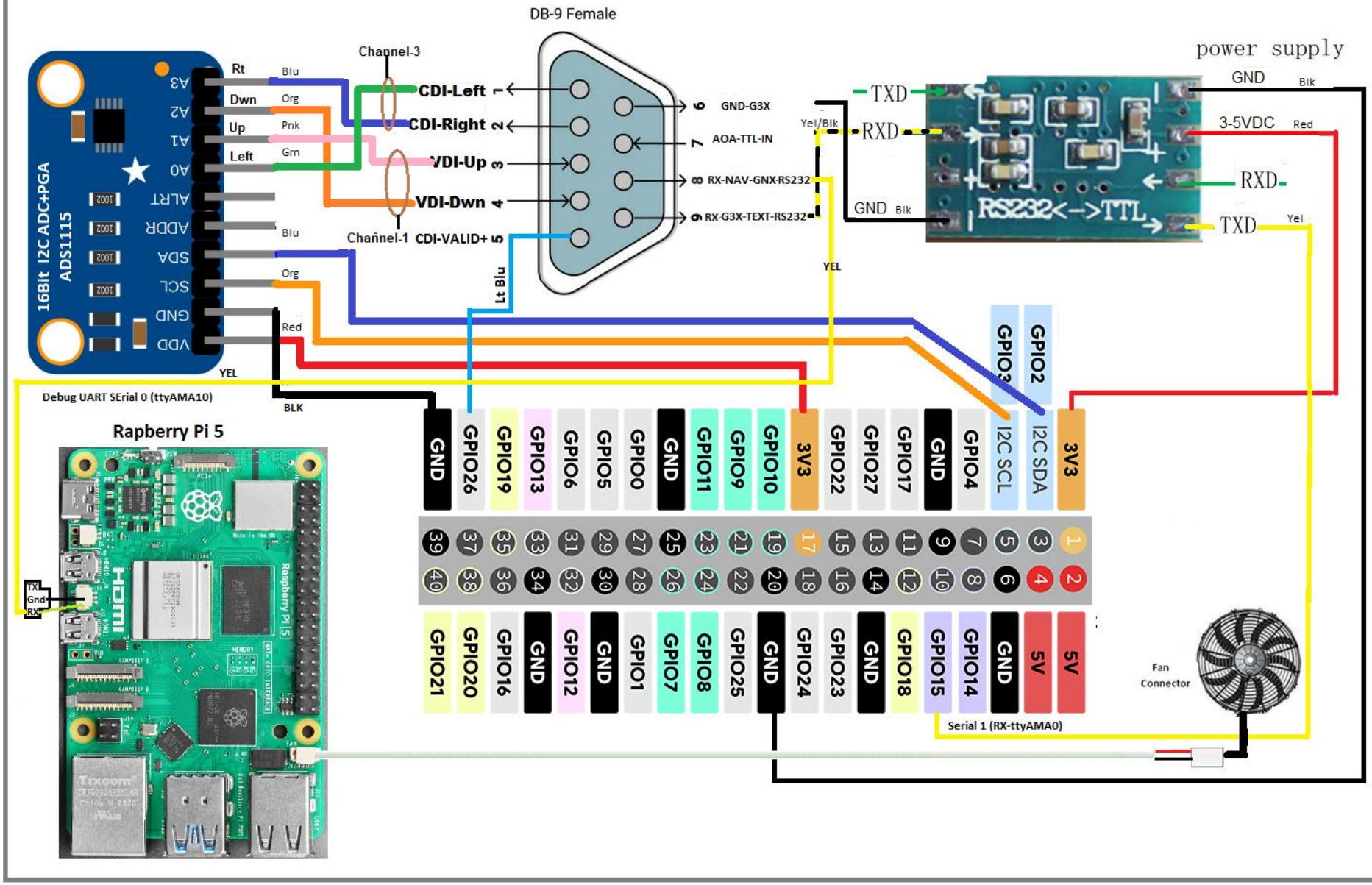
Go to the Google Drive Link below and download our free HUD software.

- The link contains both the HUD/HMD Raspi5 SW image and the directions for writing and using the Raspberry Pi 5 HUD/HMD Software Image to a Micro SD memory card.
- The actual file is fairly large (2.17GB Zipped), and unzips to approximately 8GB including the instructions. This will run fine on a RaspBerry Pi 5 4GB CPU. The 8GB is the approx. size of the memory card the image was saved from, but you should use at least a 16GB Micro SD Memory card to write the image back to as some 8GB memory cards will be too small. While downloading a 2.17GB file takes time, its far faster than formatting and loading from scratch all the software required to run the HUD program.
- The SW Demo Config File is set for G3x & MGL EFIS but can be easily changed
- **HUD_Raspi5_8GB_14Feb24_Zipped_Image**
- **https://drive.google.com/drive/folders/1R4SjE_foUbUYr6_6DubKYNR5OtGSoxwQ?usp=sharing**

# QUESTIONS??

**Raspberry Pi to 16Bit ADC1115 + RS232 connected to EFIS**
**Wiring Connected to IFR Nav** Rapberry Pi 5 Wiring

**As of 20 Feb 2024**



# FlyOnSpeed AOA Raspberry Pi 5 Software Features Include:

- Supports serial from MGL, Garmin G3x, Dynon Skyview & D100, and GRT
- Supports wifi from Stratux, iLevil BOM, iLevil 3, uAvionix Echo UAT, Dual XGPS190, Dynon ADSB wifi, etc.
- Software and instructions available for Free on Google Drive & Github
- Users can use provided HUD screens or build custom EFIS or HUD screens
- Record flight log to and Playback from external USB drive (fast forward playback avail)
- All screens look and work the same for all supported data input.
- All display screen sizes and ratios supported. (set through config)
- Touch screen support
- 30+ FPS on Raspberry Pi 5 (Frame rate impacted by Data and Graphics)
- Remote keypad / user input support. (USB 10-key number pad works good)
- Display flight data in Knots, Standard, Metric, F or C (set in config)
- Designed for Raspberry Pi but also runs on Mac OSx, Windows, and other linux systems.
- Can display CDI needles for NAV and approaches. (With Analog→Digital Chip & CDI Needles Input) or direct NAV Data
- Use multiple data sources (IE. Serial, Wifi, Analog inputs at the same time)
- Shows traffic as scope display, or target flags (When ADSB traffic source input available)
- User dropped buoy targets for virtual dogfighting
- Has BFM mode (Basic Fighter Maneuvers) for 1v1 with cooperative wingmen
- Has HUD color Camera & DVR for post flight debriefs
- Text Debug mode (Helpful to see the actual raw data values during playback)
- Now updated to Python 3!

# FlyOnSpeed HUD Project

EFIS/NAV/ADSB

IFR-Lat/Vert +

HUD (Epic Optix)

HUD CAMERA

DVR

Raspi 5

HUD Control Key Pad

1-Start Data Rec
2- Stop Data Rec
3- Tfc Display Cycle

4/5- Drop Buoy
6- Clear Buoy
8- LCOS Ctrl

9- FPM/ Ctrl
10- TD Box/ ILS

**Available Systems OnSpeed HUD (Raspberry Pi) can Integrated with**

1) Garmin G3x - Serial
2) MGL iEFIS - Serial
3) Dynon D10/D100/Skyview -Serial
4) OnSpeed AOA - M5 Serial Protocol
5) iLevil BOM, iLevil 3 --> WIFI (AHRS/ADSB-Traffic)
6) Stratux --> WIFI (AHRS/ADSB-Traffix)
7) uAVIONIX ECHO UAT (In/Out) --> WIFI (ADSB/Traffic)
8) Dual XGPS190 --> WIFI (AHRS/ADSB-Traffic)
9) Dynon ADSB --> WIFI (ADSB/Traffic)
8) Missing GRT
9) Garmin/Avidyne/King/etc - NAV Lat/Vert Analog Needle Display

# FlyOnSpeed AR HMD/HUD Project

EFIS/NAV/ADSB

IFR-Lat/Vert +

**EFIS Aircraft DATA**

HDMI HUD Display

**Raspi 5**

HUD Function Control

1-Start Data Rec
2- Stop Data Rec
3- Tfc Display Cycle
4/5- Drop Buoy
6- Clear Buoy
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8) Dual XGPS190 --> WIFI (AHRS/ADSB-Traffic)
9) Dynon ADSB --> WIFI (ADSB/Traffic)
8) Missing GRT
9) Garmin/Avidyne/King/etc - NAV Lat/Vert Analog Needle Display

# FlyOnSpeed.ORG HUD Project Goals

- Enhance Flight Safety by helping pilots build a Heads Up Display (HUD) using data from their existing EFIS or other sources.
- Do the research and development to provide a flight tested HUD design that uses affordable technology driven by open source (Free) HUD software that is easily integrated with current Experimental EFIS Systems.
- Use a quality HUD that can be installed in many experimental aircraft.
- Use a capable Micro-Computer.  Currently a RASPBERRY PI 4B+ ~ $80
- Make the system pilot/user friendly  as much as possible.
- Allow users so inclined to also create or modify their own HUD designs,
- Provide a path for an optional 2nd A/C display (HDMI Video), or display the HUD Camera view via the Camera or DVR outputs.

# How to use GitHub

1. Create a GitHub account (Free)
2. Sign into https://github.com/flyonspeed/efis_to_hud
3. Download instructions for setting up Rasp-PI
4. Perform a “git pull” to download current HUD programs
5. Select HUD program to use (test with sample HUD Data)
6. If ready to help program coordinate with Chris and myself.