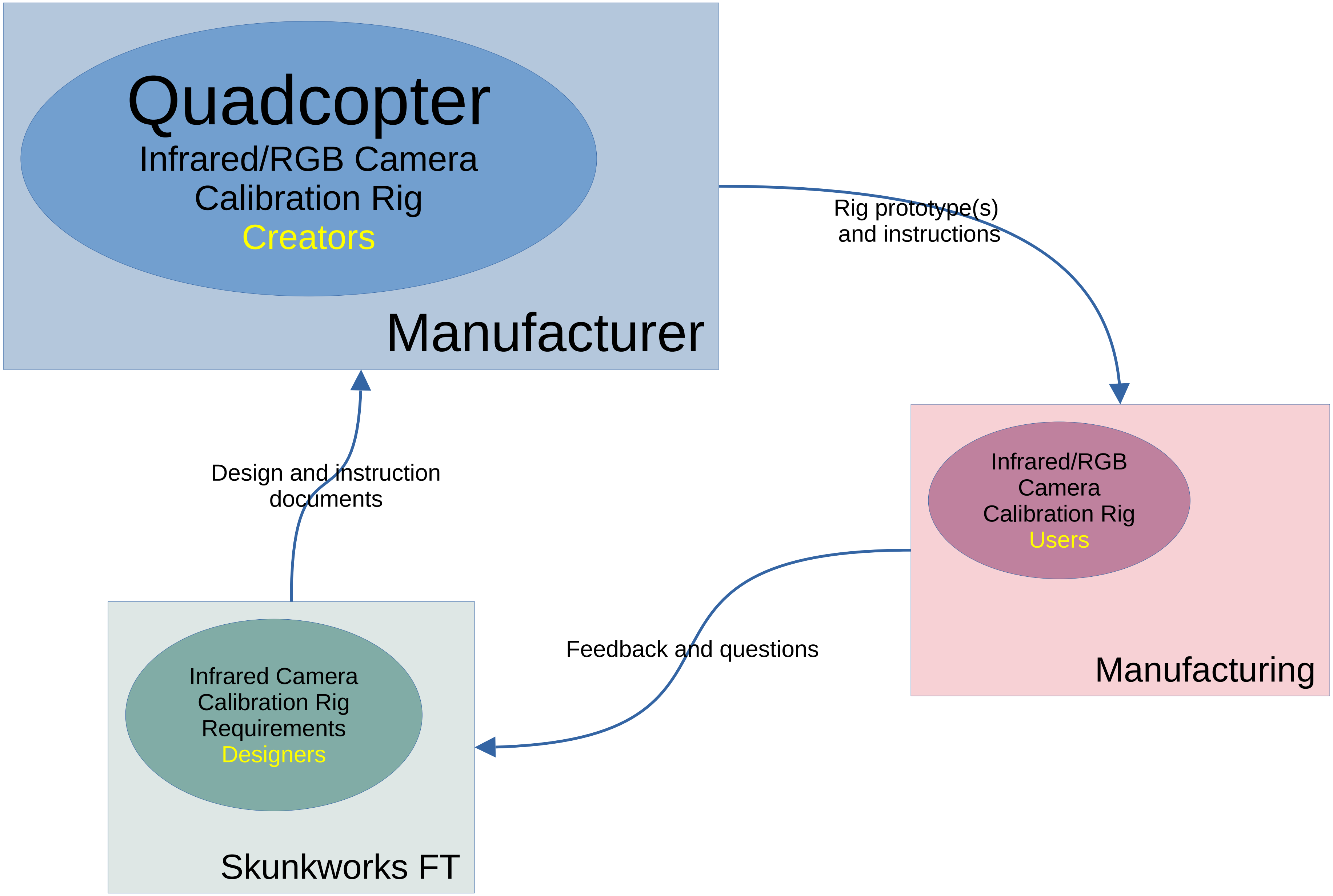
Example Analysis Document

Camera Calibration for GPS-absent Navigation

Level -1: “Actors”



Level 0: “Product”

Infrared or RGB Camera Calibration Rig

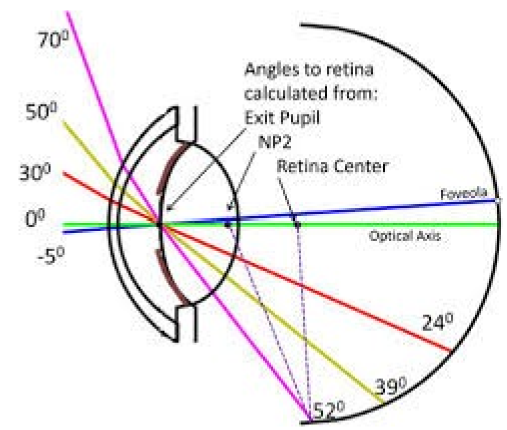
The difficulty of manually calibrating a quadcopter’s thermal-IR or RGB (“optical”) camera can pose a significant obstacle if done manually. We propose an tool or “rig” that will insert consistency but also help us refine processes.

A camera calibration rig’s purpose is to automate and simplify parallel line calibration to eliminate the fisheye perspective.

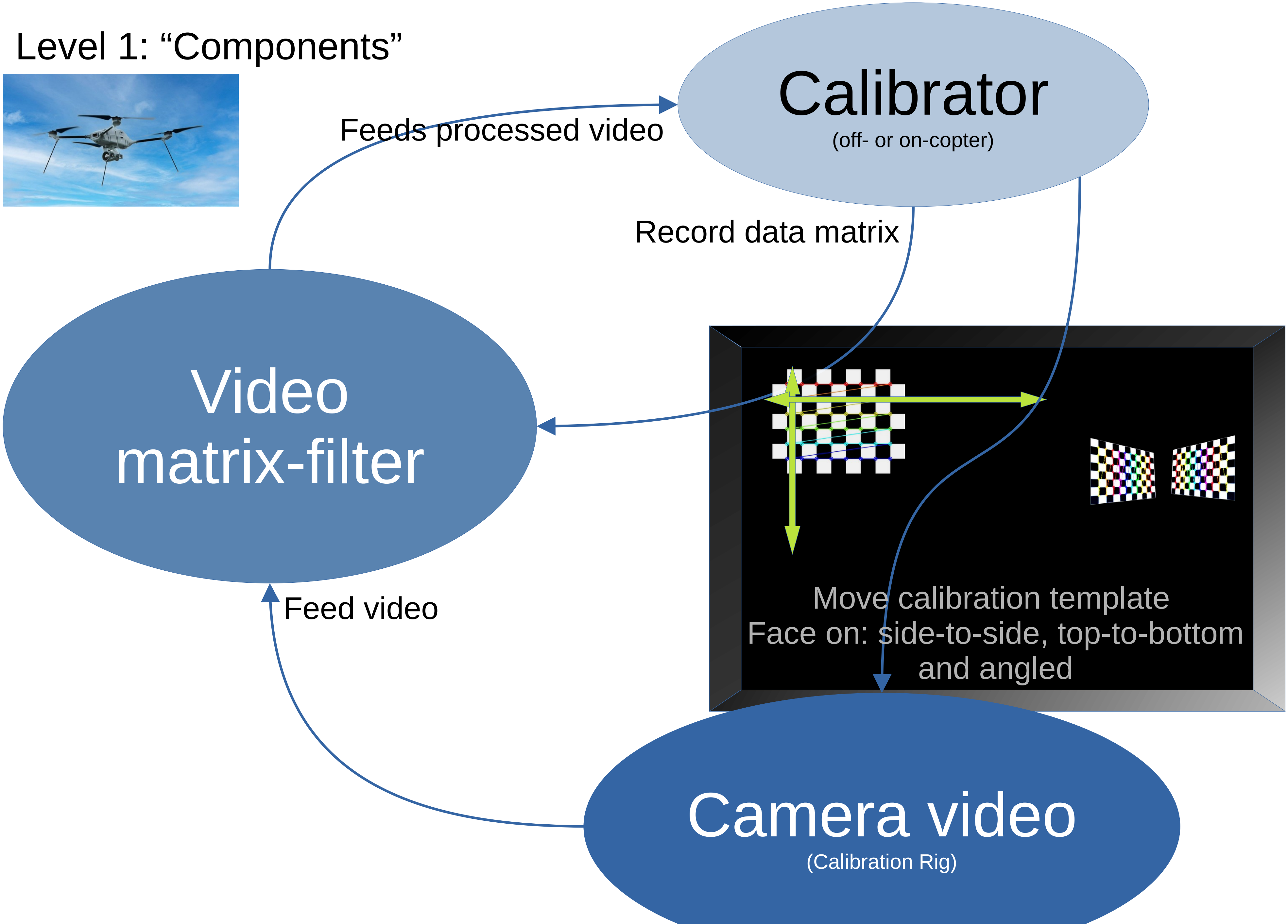
Cameras in any form that are used to trace a path in the absence of GPS require a “linear” (“rectilinear”) perspective. The problem with shallow, near 180° optics is that lines are curved (“fisheye” or “curvilinear”) and distance accuracy is nearly lost. To the point, all cameras that use wide-angle optics encounter these problems and special algorithms must be used to restore proper perspectives.

This is where optical calibration begins, but the temptation is to do it manually.

NOTE:
It is important to point out that the reason our eyes do not have a curvilinear optic, despite the fact that we can see nearly 170-190° side-to-side view is because the refracted light is projected on a curved screen, i.e., the retina. The brain also fills in the gaps caused by optic flaws and deficiencies. To demonstrate, extend your arms straight with your thumbs up. Move your right arm clockwise to the right while keeping your focus on the left thumb until your right thumb is no longer visible to you peripheral vision. Reset and repeat with your left thumb. *The resulting angles will naturally not be the same, and glasses can interfere.*



Level 1: “Components”



[1]Image source: https://markhedleyjones.com/media/projects/calibration-checkerboard-collection/calibration-checkerboard-collection.svg
[2]Image source: https://cs.uwaterloo.ca/~dvogel/cs889s15/exercises/e7_calibration.html

Level 2: “Calibration Rig”

Focal target
(heated bed)

Move focus

Enable

Video
(camera)

There is no need to build a rig from scratch when the industry already has 90% of what we need. We can use a cheap 3D printer to:

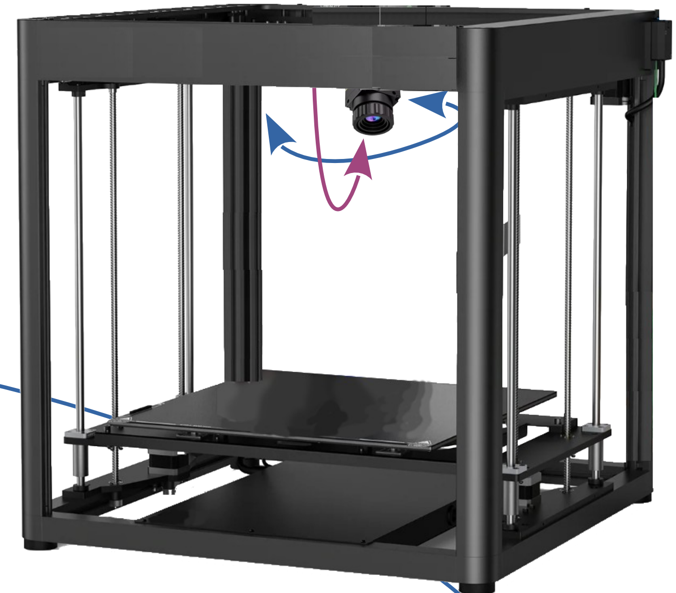
- ✓ Use the platform as the template grid.
- ✓ Heat the template grid with insulating squares to show as “black” and an insulating boarder.
- ✓ Move the platform up and down to simulate distances.
- ✓ Replace the filament extruder with the camera.
- ✓ Move the camera along an X-Y axis.

The last 10% is reachable with two extra servos under the platform or at the camera mount, tipping the image to provide perspective.

3D printer needs:

- ✓ Heated bed
- ✓ Movement:
    - X-axis filament extruder head and Z-Y-axis bed *or*
    - X-Z-axis filament extruder head and Y-axis bed *or*
    - X-Y-Z-axis filament extruder head

Level 2: “Calibration Rig” (cont.)



Focal target
(heated bed)

Move focus

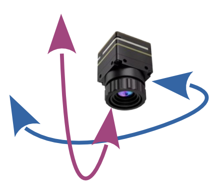
Move the camera X-Z
Elevate heated bed
Tip heated bed

Enable

Video
(camera)

The fundamental concept is that a cheap cage-based 3D printer can be repurposed to calibrate an IR or optic camera. Most of what is needed is the servos that move the camera and heated bed. The bed will be covered with a checkerboard of insulating tiles. The IR camera detects heat so those squares that are bare of insulation will show hot.

** has also required a lilted view to provide a perspective control. To accomplish this, either the camera or the bed needs to tilt in two axes (X-Z). The camera will be easier. In either case, two additional servos will be needed.



Additional 3D printer needs:

- ✓ Perspective control:
  - Bed rotates X-Y,Y-Z up to 45° *or*
  - Camera rotates X,Z up to 45°