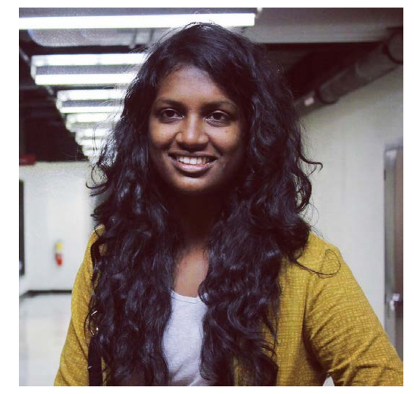
Dock-In-Piece: A Quadcopter, A Moving Overhead Platform, Synergy


Paul Michael Calhoun


Keerthana Subramanian Manivannan


Bishwamoy Sinha Roy


Rushat Gupta Chadha

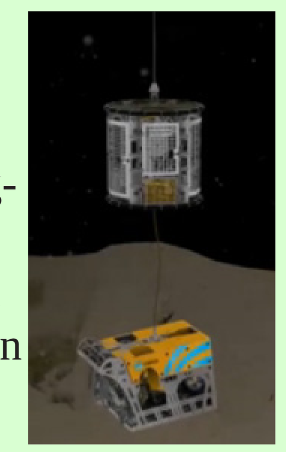

Aishanou Osha Rait

Carnegie Mellon University · SCS Carnegie Mellon, School of Computer Science · FMC Technologies · The Robotics Institute

Our Problem, Our Goal, Our Use Case

Customer: FMC Schilling Robotics

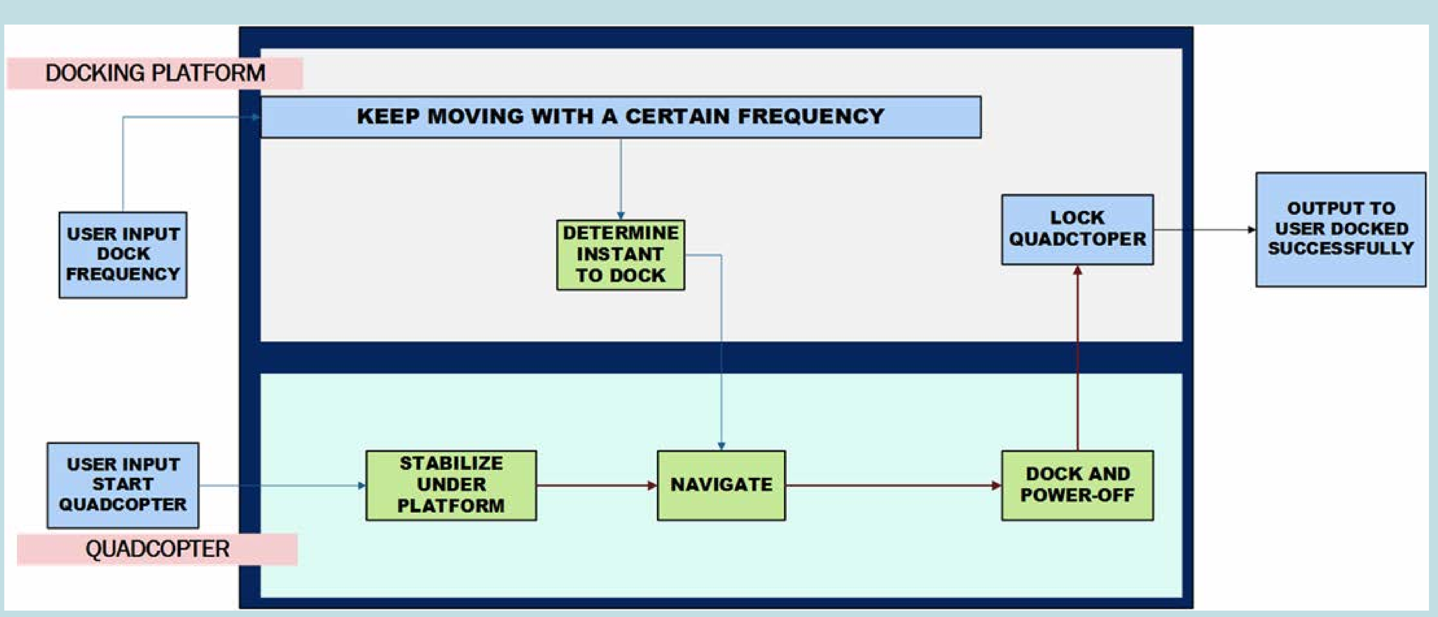
Problem Statement: Schilling needs to dock their Remotely Operated Vehicle (ROV) to their Tether Management System (TMS). The ROV detaches and deploys from the bottom of the TMS when the system is at depth. The TMS is negatively buoyant and is suspended from a ship and as the ship heaves on the surface of the water, the TMS heaves up and down. ROV Operators must dock and latch the ROV to the underside of the moving TMS prior to resurfacing. This can be very challenging even with experienced operators.



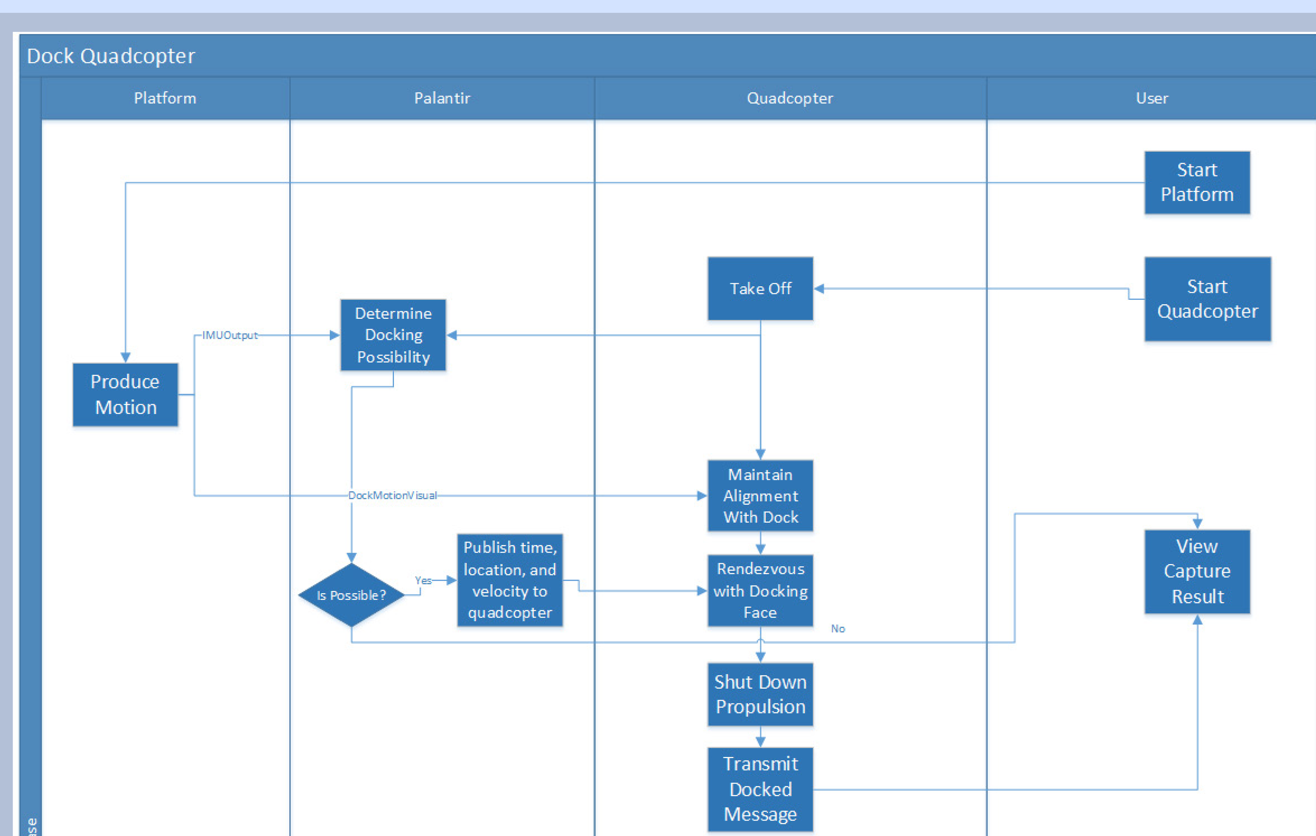
Goal: Autonomous docking of a quadcopter to the underside of a suspended moving platform. The quadcopter simulates an ROV, the TMS is simulated by the moving platform, and the underwater environment is simulated by functioning in a GPS degraded environment.

Use Case: An undersea variant of our autonomous system design is used on their ROV to dock to their TMS, reducing the need for human intervention in the process. This will improve safetly, decrease costs, and add more useful life to their vehicle.

Functions and Flow: Our Design

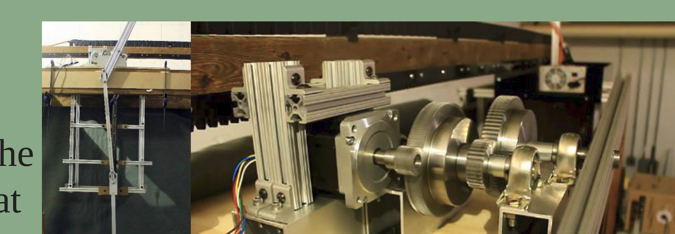


Our Functional Architecture



Our Activity Flow

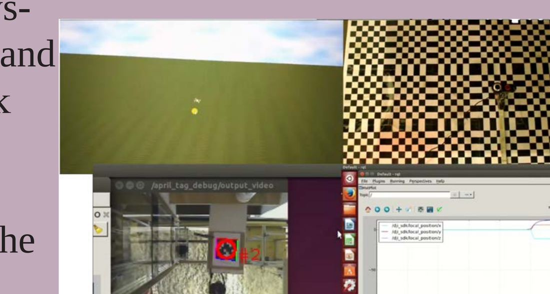
The Hardware: What We Used and Built



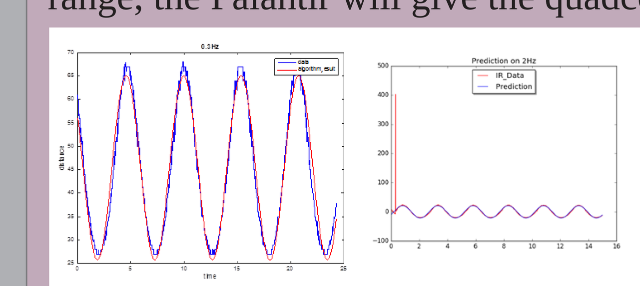
The mechanical design is a slider crank mechanism and the platform is connected to the slider. As the crank rotates the slider moves up and down, causing the desired harmonic motion of the platform. A stepper motor can creates rotations at different speeds. The frequency of up-down motion of the platform can vary between 0.15 to 0.3 Hz. An IR sensor on the docking structure transmits the dock's motion characteristics to the Palantir, while four more IR sensors on the platform monitor the distance from the quadcopter in order to know when it has docked. The platform has a Velcro pad which engages with the quadcopter. The docking structure also incorporates a monocular camera, which is used in conjunction with the Palantir to orient and center the quadcopter.

The quadcopter system is built on a DJI Matrice 100 with Guidance package. The Guidance provides the N1 flight controller more stable velocities using optical flow. The N1 Flight controller runs low level control algorithms, while the single board computer (Odroid XU4) runs higher level processes.

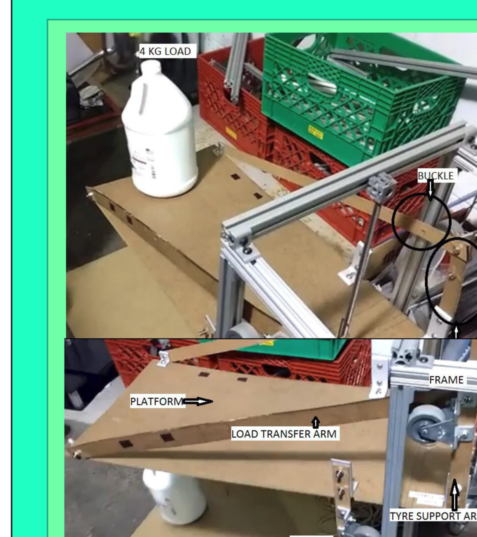
The Software: What We Made It Do



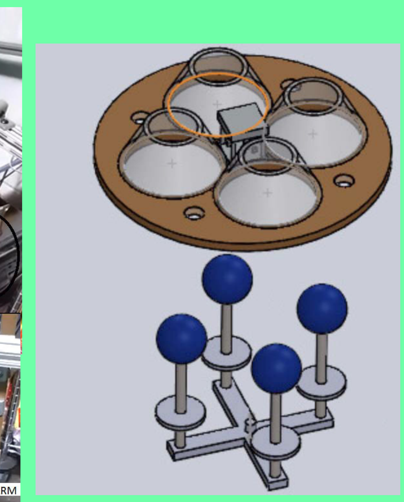
The Palantir is the main data processing subsystem, taking in data from the IR, dock camera, and Matrice flight sensors. The data from the dock IR is fitted to a sinusoid, which allows prediction of the dock's position and velocity at any given time. The monocular camera provides the quadcopter's position relative to the dock, and the M100's flight information can be used to tell what velocity the Matrice is going, its collision avoidance status, and its altitude. The relative position is used to center and orient the quadcopter, then the prediction model is fed into the docking algorithm. If the dock is going too fast, the Palantir will not allow the quadcopter to dock. If the dock's motion is within the allowed range, the Palantir will give the quadcopter a time and velocity. The quadcopter reaches that upward velocity at the given time, matching speed with the platform and docking with minimal jarring.



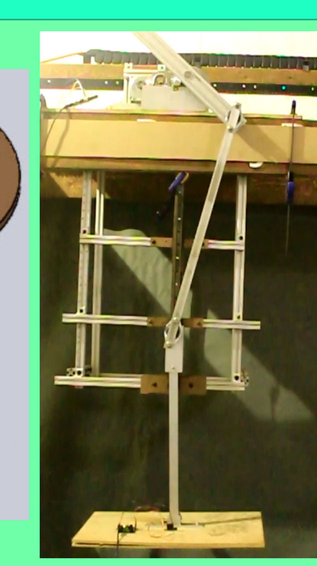
Demos: The System At Work



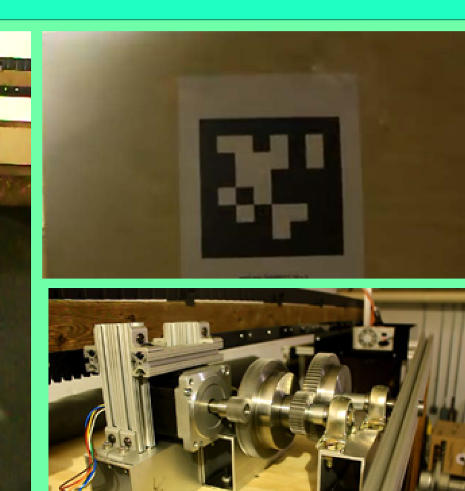
The dock progressed from a Ball Screw prototype



With a purely mechanical locking mechanism



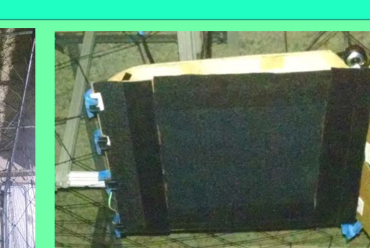
To a crankshaft with an IMU to detect motion



And an April Tag on the Dock, which was moved by a stepper motor and a 12.5:1 set of gears

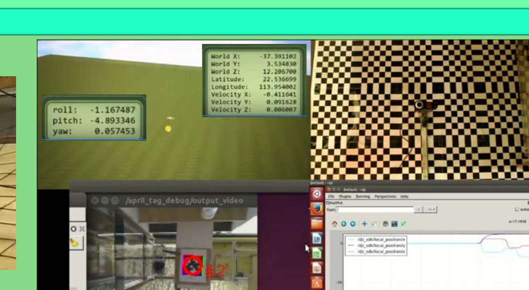
It first used a Nicadrone electropermanent magnet Then rare earth permanent magnets

Moved it to the ceiling, added a camera so it could read an April Tag on the quadcopter

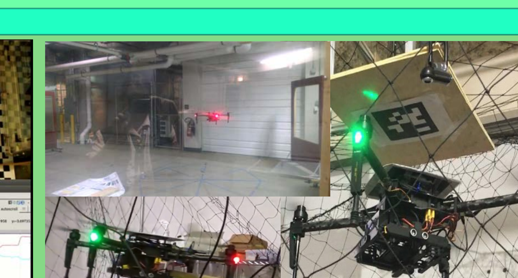


And finally switched to Velcro for locking the quadcopter to the platform, with a set of IR sensors to tell when it happened

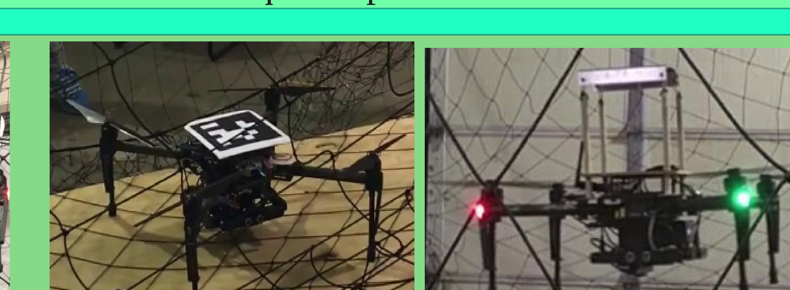
We started out with a basic Matrice 100 and Guidance...
And quickly made some alterations



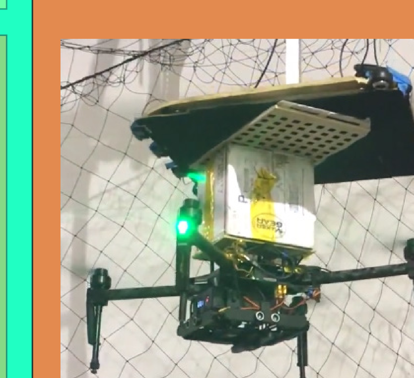
There were a lot of simulation demos, especially when getting the quadcopter to work with the CV section



And for awhile we didn't trust it much. Even when we had the automation working well we kept it in a net (and poked it with a stick)



Then we decided to put the April Tag on it, and started trying out locking mechanisms, magnets turned out to be fun to work with but Velcro worked best.



Integration!

Future Work: What We'd Do Next

- Propulsion Control turns off quadcopter when IR sensor grid on Dock senses the quadcopter has docked
- Multiple harmonics on the dock motion frequency
- Ability to dock to a platform moving at different amplitudes
- Construct more robust locking mechanism on quadcopter
- Improve quadcopter robustness and safety by putting an enclosure around the rotors
- Improve centering on platform during docking