# Problem statement/summary

<WIP> A multi-purpose target tracking platform intended for ground stations, and ground based assets.

# Requirements list

|  |  |  |
| --- | --- | --- |
| # | Sec. | Description |
| 1 | A | Carriage should be able to perform all of the below requirements with a mounted device of mass <> and a maximum MOI of <>. |
| 2 | B | Carriage must be able to obtain a maximum of 374 deg/sec of slew in any direction with an allowed 0.25 second acceleration from rest period. |
| 3 | B | Carriage must have an at-rest positional accuracy of +/- 0.00014 degrees |
| 4 |  |  |

# Derivation of requirements

## Section A: Mounted Payloads

An unknown number of objects could be used on this device and generalized mass and moment of inertia properties must be selected in a generalized yet rational function. Various large potential candidates for mounted payloads are shown below. These candidates include a camera for close to medium range video capture, a telescope for video capture and observation of distant objects, a medium sized Yagi antenna for directional communications, and a medium sized 50-watt solar panel for power collection. These candidates represent a variety of (but not conclusive or complete list of) different applications and the respective payloads that would be used for such applications. The selection of these specific candidates was performed with subject matter expert advice.

A picture containing telescope

Description automatically generated

**Figure 1B: Celestron telescope tube (mounted off axis)**

A picture containing object, antenna, line

Description automatically generated

**Figure 1C: VHF Yagi antenna**

A picture containing white, appliance

Description automatically generated

**Figure 1D: 50 watt 12 volt solar panel**

A table of estimated or provided mass and inertia properties for all objects is shown below. The estimated values were created using generic physics equations and uniform mass distribution assumption. The location of the axis for the greatest moment of inertia was assumed to pass through the presumed mounting location of the candidate.

**Table 1: Payload candidates**

|  |  |  |
| --- | --- | --- |
| Payload | Mass | greatest MOI |
| Camera |  |  |
| Telescope | 4.3 kg | 0.0316 kg-m^2 |
| antenna | 5 kg | 4.177 kg-m^2 |
| Solar panel | 3.5 kg | 0.098 kg-m^2 |

The largest values for both mass and moment of inertia, plus an arbitrarily chosen 15% factor of safety is used as the requirements for the payload compatibility. These values are \*INSERT VALUES HERE\*. We can add an arbitrary 15% factor of safety and thus the mass and moment of inertia expectations are \*INSERT VALUES HERE\*, respectively.

## Section B: Slew Rates and Position Accuracies

For any practical application, Frog Brain will need to satisfy the orientation and slew rate accuracies in order to properly direct the payload. Positional accuracy is typically associated with long distance observation and slow slew rates. Slew rate is typically defined as a maximum value and assumed to be continuous and not jittery. We can start by selecting the maximum distance for our tracker to expect to track something. A good metric for determining this is altitude and elevation, assuming the tracker is kept to the ground. Frog brain is intended to track aerospace objects primarily, so this is a fitting distance derivation. But different objects require different levels of accuracy, for example, recording an aircraft requires a zoomed in camera with very high accuracy and is relatively close, as little as 5,000 ft away, whereas pointing an antenna at a spacecraft can allow for up to many degrees of inaccuracy, but satellites are many kilometers away. Listed below are various trackable examples, their assumed minimum elevation, and approximate altitude. These values are derived by the author’s personal expertise and/or low intensity research.

**Table 2: Angle accuracy driving scenarios**

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Max Altitude | Min Elevation | Method of accuracy |
| General aviation tracking | 18,000 ft | 45 deg | Camera frame width |
| Satellite comms | 500 km | 20 deg | Antenna beamwidth |
| Solar tracking | N/A | 20 deg | Small angle theory |
| L3 amateur rocket takeoff | 3,000 ft | 70 deg | Camera frame width |
|  |  |  |  |
| Scenario | Overall distance | Object width | Positional accuracy |
| General aviation tracking | 25,456 ft | 52 ft | 0.00014 degrees |
| Satellite comms | 1,462 km | N/A | 2.50000 degrees |
| Solar tracking | N/A | N/A | 18.0000 degrees |
| L3 amateur rocket takeoff | 3,192 ft | 17 ft | 0.00037 degrees |

For camera frame width methods, the approximate size of the object is taken, and it is assumed that the camera zoom is enough to fit 9 of this object in frame. Thus, the camera can be centered on a location within +/- 4 objects distance from the target and still have the entire object within view of the camera.

For antenna beamwidth we simply use the beamwidth of a standard cubesat ground station antenna, no arithmetic needed.

For small angle theory the assumption is that as long as two vectors A and B are within a small angle to each other then the length of projected vector A onto B will be approximately the same magnitude as the parent vector, vector A. if we want to remain within an angle which has a projected magnitude of no less than 95% its parent vector, that corresponds to roughly 18 degrees.

Of the above positional requirements, the most stringent is 0.14 milli-degrees for general aviation tracking. For slew rates we will only determine a maximum target rate, and not a minimum target rate. High slew rates are associated with close and/or high-speed passes by the tracker.

**Table 3: Maximum slew rate scenarios**

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Velocity at closest approach | Object closest approach | Slew rate |
| Satellite overhead pass | 7.7 km/sec | 200 km | 2.2 deg/sec |
| General aviation takeoff | 40 m/s | 20 m | 115 deg/sec |
| Balloon payload landing | 5 m/s | 200 m | 1.4 deg/sec |
| L2 amateur rocket ascent | 30 m/s | 4.6 m | 374 deg/sec |

Satellites usually orbit at approximately 7.7 km/sec in low earth orbit as altitudes ranging from 200 km to about 1,000 km for low earth orbit. A Cessna 172 has a takeoff speed of around 40 m/s, and a reasonable observation distance is from a hangar, just off the taxiway. A balloon payload can be chased and could be seen from any distance, but with good GPS telemetry a 200-meter range is reasonable and a 5 m/s descent rate is also common. Amateur rocketry comes in all shapes and sizes, and technically because the rocket is grounded at closest approach its speed would be zero. Videos of amateur rocketry by the YouTube channel BPS space was used and it was interpreted that maximum slew occurs around the 60 m/s point in the speed profile, so half that value was used. The HARA organization requires that human observation for up to G motors be 30 feet. Higher motor distances were not specified in my source, but I will assume 30 feet since a robot can be closer to a launch than a human.

The result is a maximum slew rate of 374 degrees per second, or just over 1 revolution per second. Angular acceleration values will not be required, instead a simple, arbitrarily chosen acceleration time from rest of 0.25 seconds is selected and may change later.

## Section C: Falls, Impacts, and IP rating

The device is expected to be grounded or operated on a stable mobile platform. This can subject the mechanism to various climates, weather, impacts, dust, and wildlife. It is important to define strict survivability and durability requirements so that the mechanism need not be rebuilt every time it is damaged.

# Revisions

|  |  |  |
| --- | --- | --- |
| Rev code | Description | Date |
| 0.0.0 | Created document | 4/28/2023 |
| 0.1.0 | Core requirements derived and approved for release | 4/29/2023 |
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