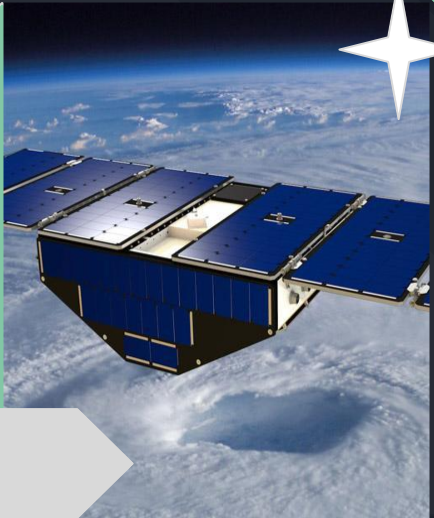
Guided Parachute Recovery

AIAA Region IV 2025

Presented By: Christal Biney & C'lette Coronado

Additional Team Members: Megan Cowan, Travis Provence, Igor Lucic

Introduction



PROBLEM

↪ Lack of a reliable method to direct a high-altitude balloon payload to a preselected recovery location

SOLUTION

↪ A GPR system that focuses on reliability, low cost, replicability, scalability, & ease of use

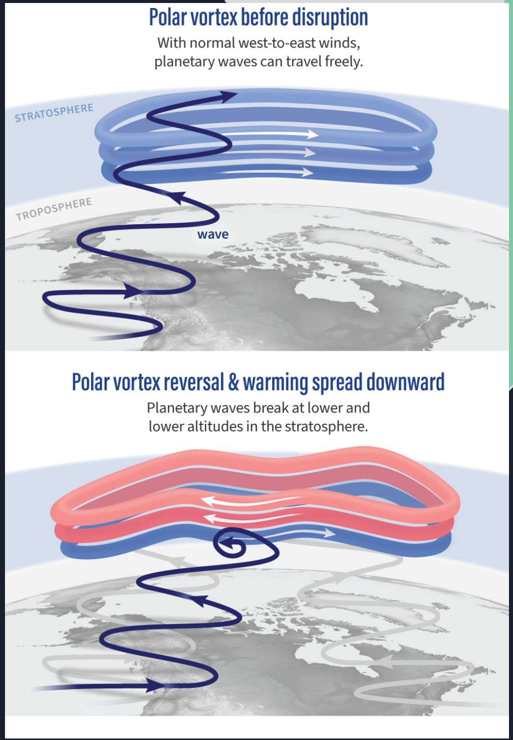
Background

Balloon Payload Experiment Challenges:

↪ 254 km/h lower stratosphere 254 km/h.
↪Even with reliable flight tracking recovery can be difficult.
↪Payloads may land in inaccessible areas, delaying or preventing recovery.
↪Potential for loss of research instruments and time due to distant landings.

Proposed Solution:

↪Develop fully autonomous guided parachute system.
↪System guides payload to a predetermined landing area.



Images from changing stratosphere winds from climate.gov

Past Projects and Lessons Learned:

San Jose State University (2012):

- ↪Guided parafoil system for targeted payload return.
- ↪Faced issues using only GPS for heading; lacked additional sensors.
- ↪Testing limited to drone drops.

University of Illinois Urbana-Champaign (2020):

- ↪Developed Poppins system, an autonomous weather balloon.
- ↪Testing limited due to the COVID-19 pandemic.

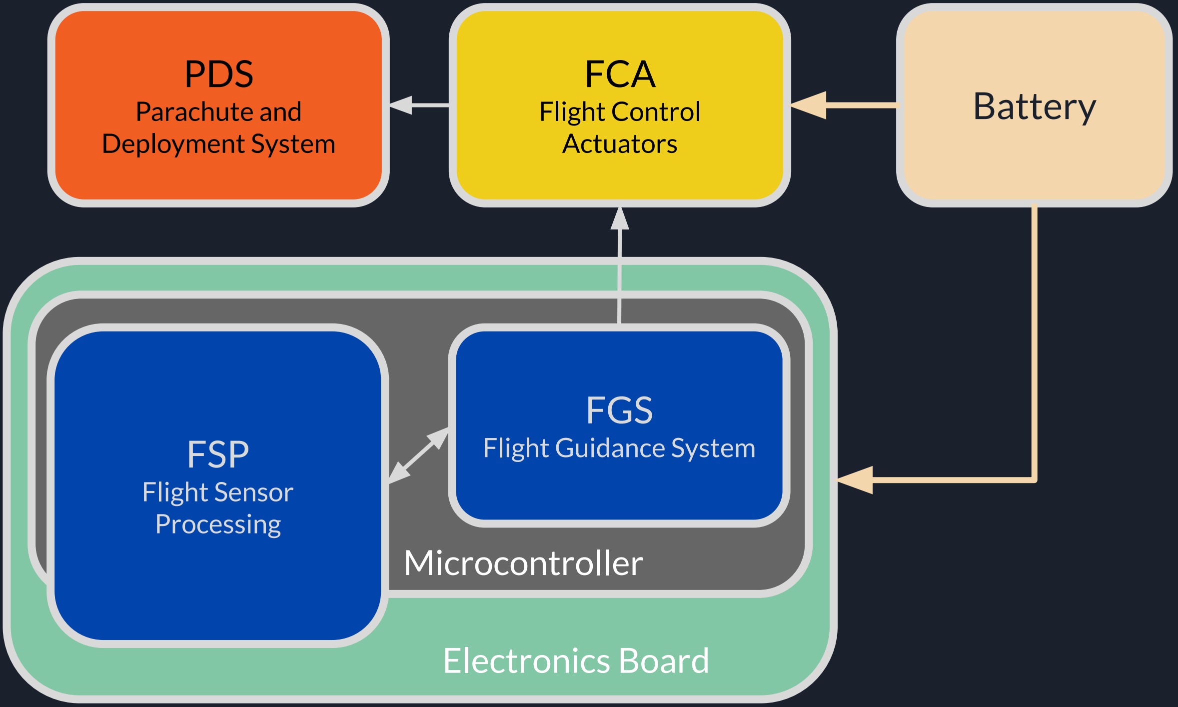
George Fox University (2009):

- ↪Created the Miniature Aerial Delivery System, Snowflake.
- ↪Used similar base sensors as in the current design.
- ↪Carried payloads of only 4-5 lbs.
- ↪Achieved a mean landing distance of 48m from the target.
- ↪Best results: 5 out of 9 drops within 26m of the target.
- ↪Testing done via helicopter drops up to 1220m altitude only.

San Jose State University (2012) Payload

Design

Subsystems Block Diagram



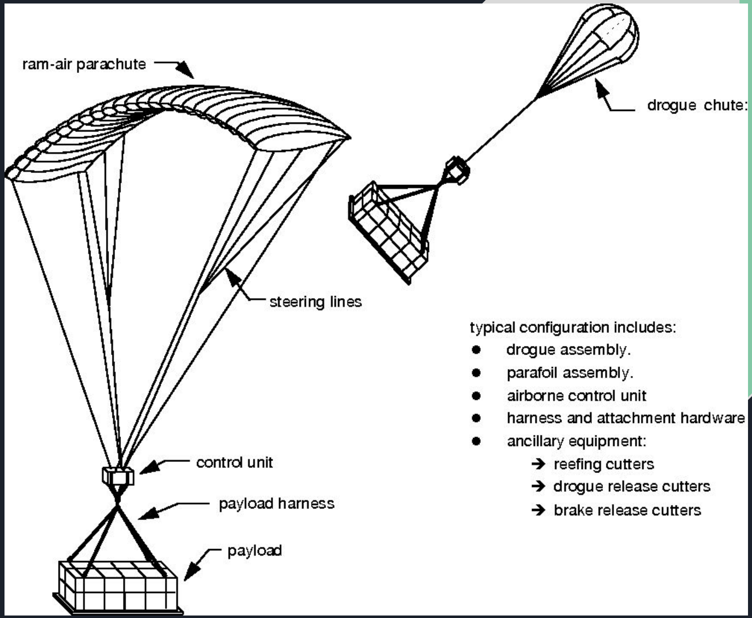
Concept of Operation

Mission Start	Release Criteria Met	Falls to predetermined altitude	FGS Activates	Performs Flare maneuver
Launch and Ascent	**Balloon release and drogue deploys**	**Main Parachute Deploys**	**Guided descent**	**Landing and recovery**

Parachute Deployment System (PDS)

↪Ram-air style parachute
↪Two-stage deployment drogue
↪Model produced by Paul Mini Parachute company
↪Main parachute made in-house from old parachutes

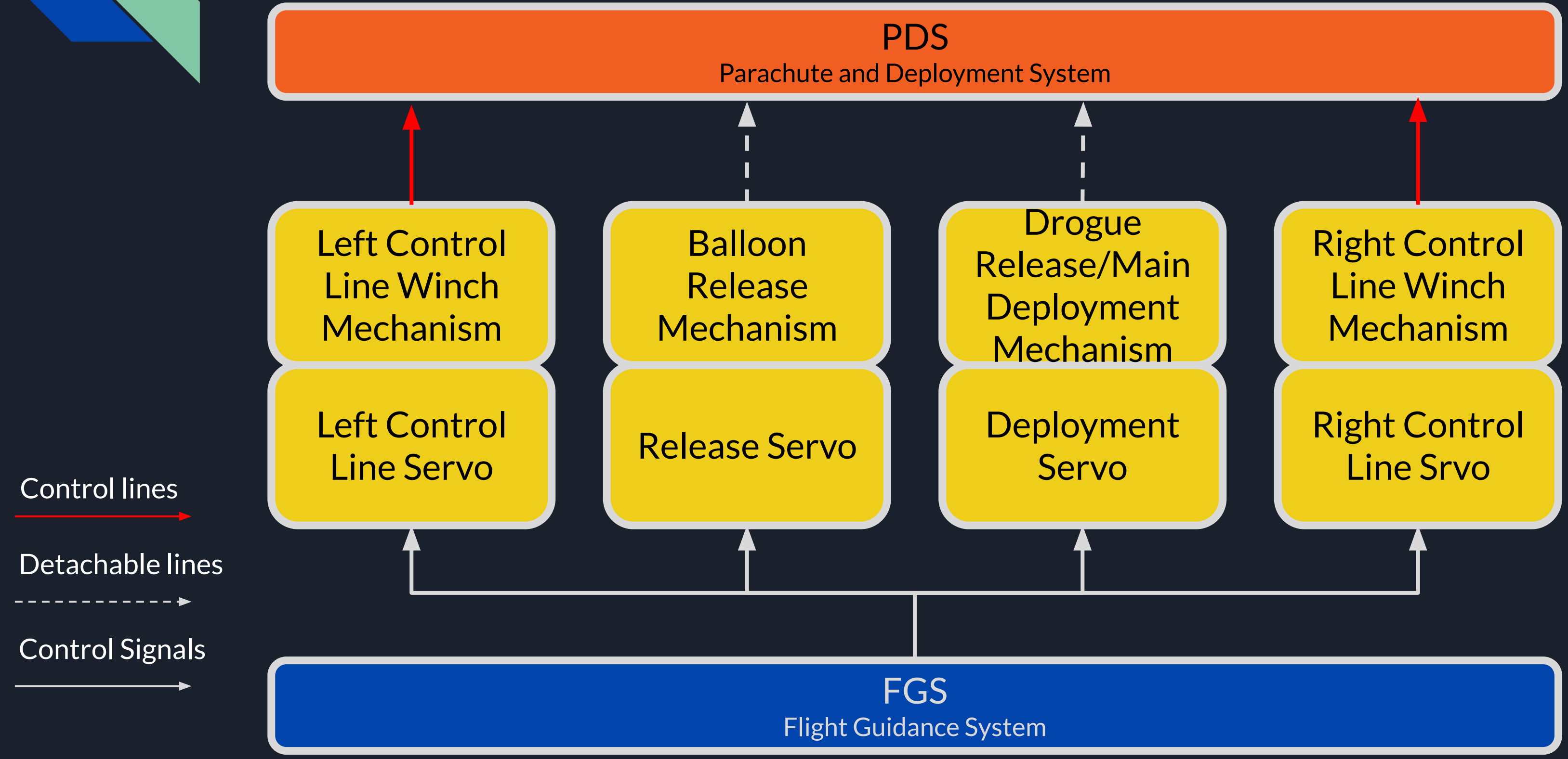
Model parachute provided by Paul Mini Parachute



Example of a Ram-Air style parachute

Flight Control Actuators

FCA Block Diagram

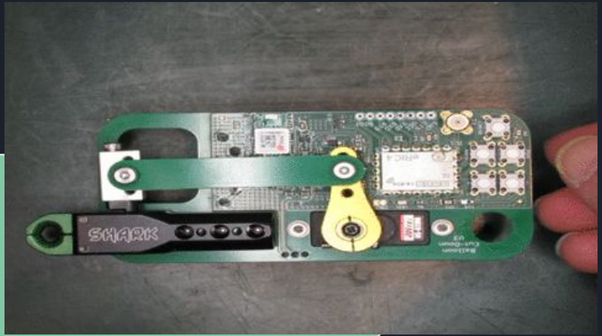


Balloon Release Mechanism

FUNCTION

↪ Separate the main payload from the balloon at:

- ↪Predetermined altitude
- ↪ Target distance from landing site
- ↪Balloon bursts during ascent



SYSTEM DESIGN

↪ Actuation Components:

- ➔ 35 kg·cm **high-torque**, 270-degree RC **servo** (ANNIMOS).
- ➔ LWANO Archery Compound **Bow** Release **Aids Trigger**

↪Thermal Protection:

- ➔ Styrofoam Insulation

Parachute Steering Actuator System

FUNCTION

↪ Ensures controlled descent and precise landing after balloon release and parachute deployment

SYSTEM DESIGN

↪ Actuation Components:

- ➔ **Two independent servo** actuators for precise control
- ➔ **360° rotation** allows for continuous brake line adjustment

↪Designed to withstand parachute tension, wind, and high-altitude conditions

Flight Sensor Processing

Data Collection

WHAT'S COLLECTED?

↪ Latitude, longitude, altitude, and heading

SENSORS

↪ Barometer

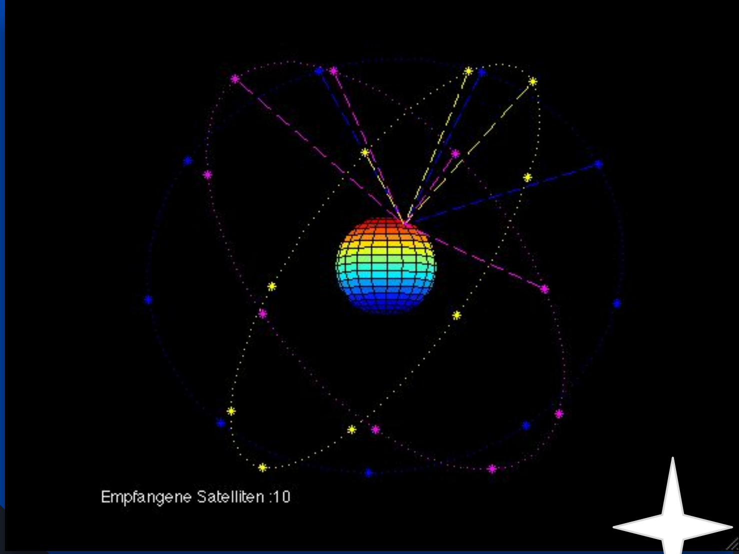
↪ Inertial Measurement Unit (IMU): BNO085

↪ GNSS tracking systems (GPS, GLONASS, Galileo, and BeiDou)

HARDWARE

↪ Battery & voltage regulation circuit

↪ Circuit Board → Custom PCB for lighter weight



Data Transmission

SOFTWARE

↪ KiCAD: utilized for designing circuit schematics and PCB layouts

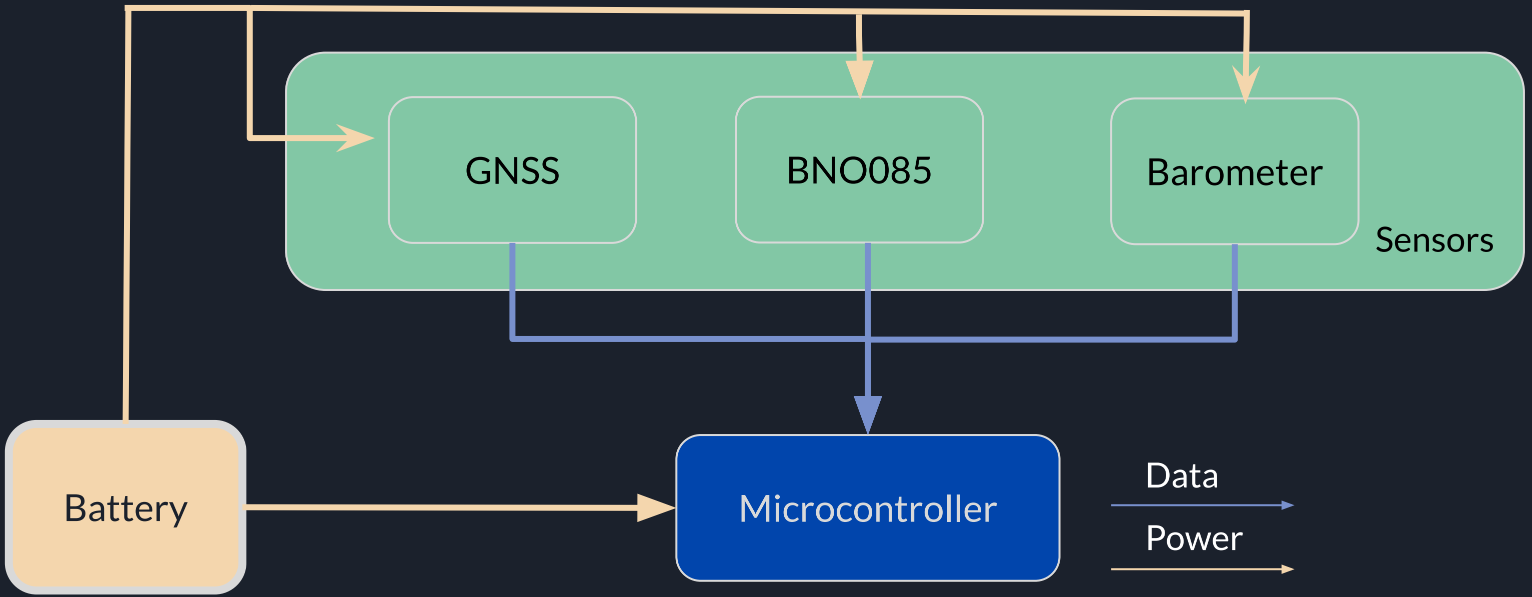
↪ Autodesk Inventor: assists in modeling the physical compartment layout

↪ The code for acquiring and sending our desired data is available on Github

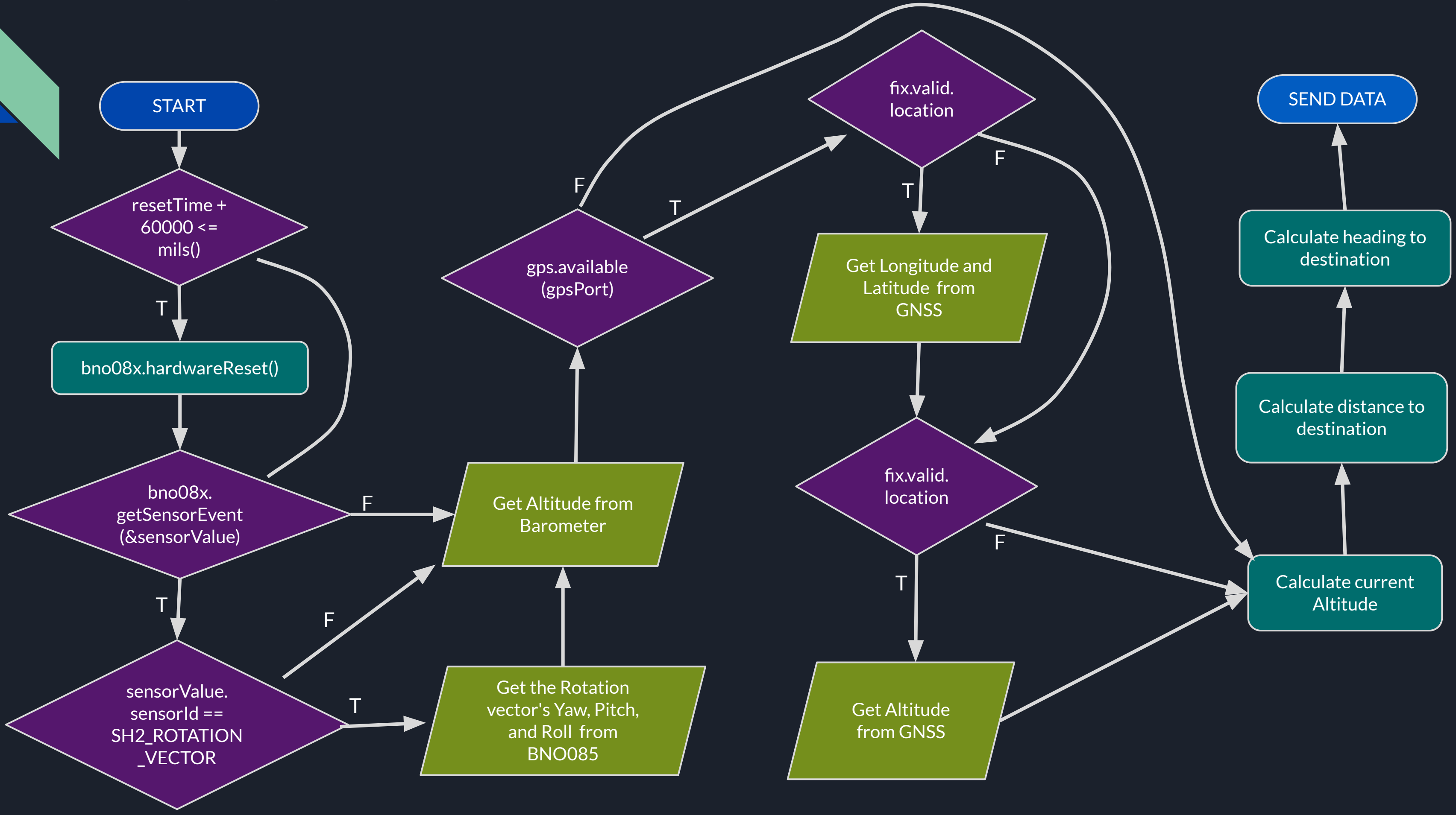
RECEIVING DATA

↪ Flight Guidance System (FGS)

FSP Block Diagram



During Flight Loop Flow Chart (modified from paper)



Flight Guidance System

PURPOSE:

↪ **Guides** the payload to a predetermined location

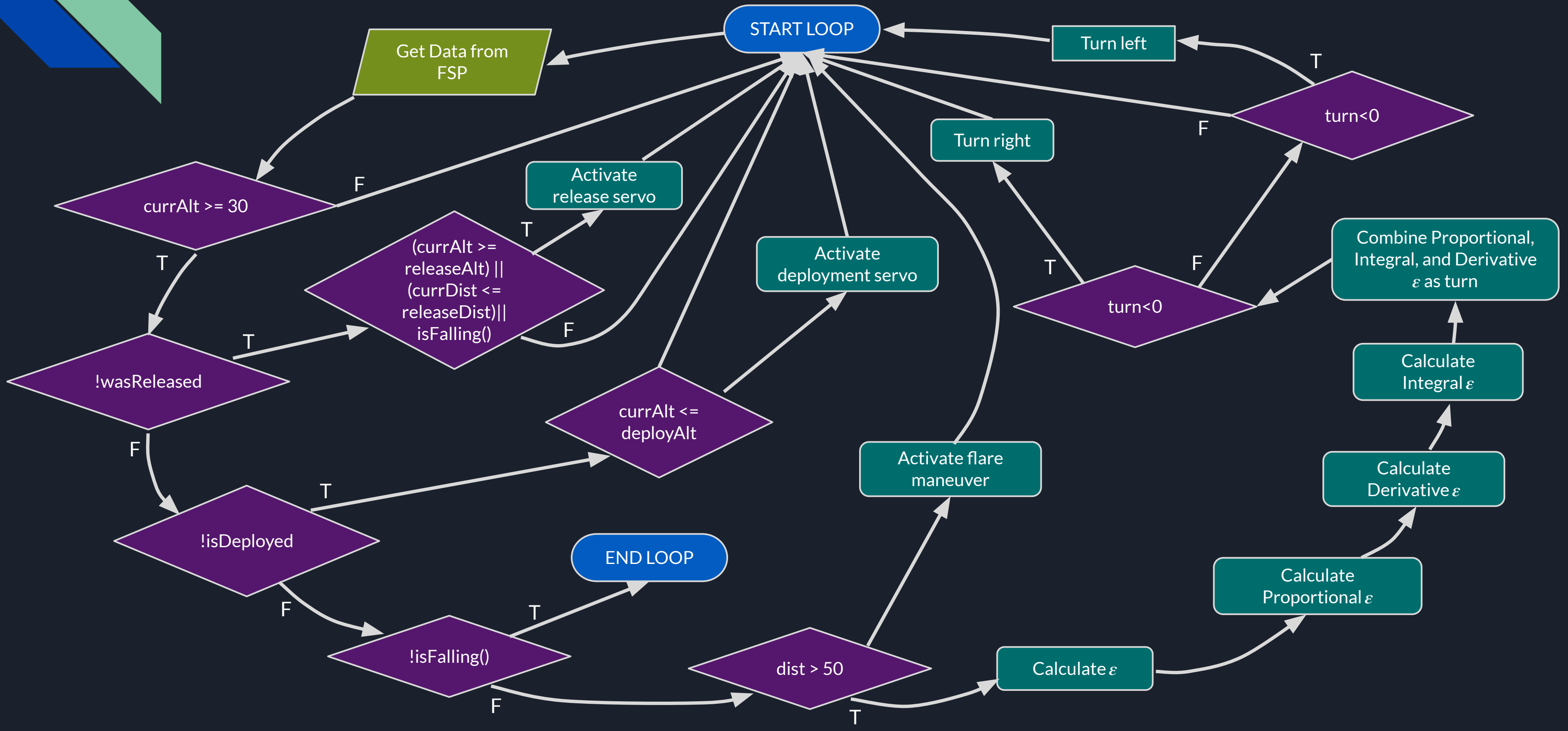
↪ Uses data from FSP to **send commands** to the FCA

↪ Provides continuous **steering**

↪ Users must **input desired parameters**, such as target location, before the flight

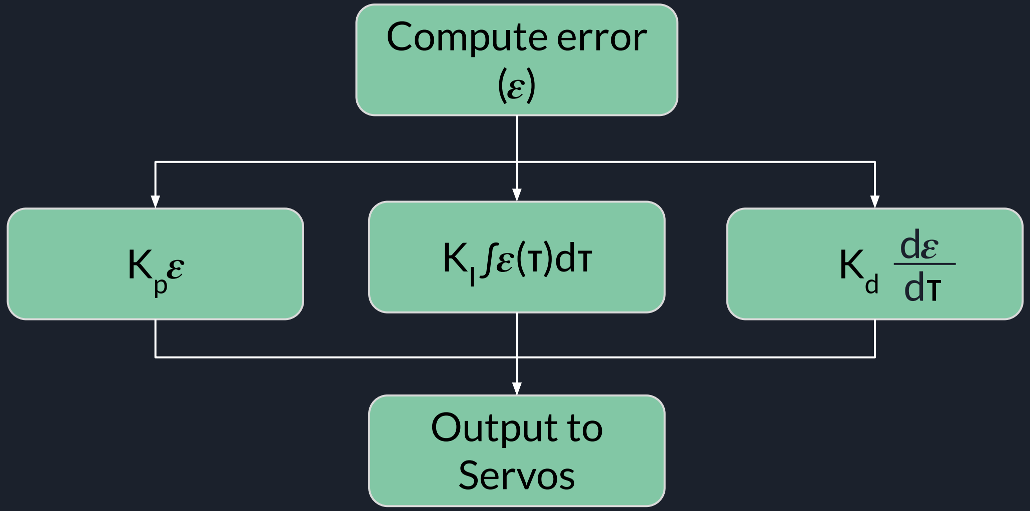
↪ Coded in **Arduino** and is open source, accessible on GitHub

Flight Loop Flow Chart (modified from paper)



Proportional-Integral-Derivative (PID) Controller

Once the parachute is deployed, the system will implement a PID controller.



ε : the difference between the desired heading and the current heading

The PID controller consists of three components:

➔ 1. **Proportional** accounts for present sensor data.

➔ 2. **Integral** adjusts for cumulative error using past sensor data

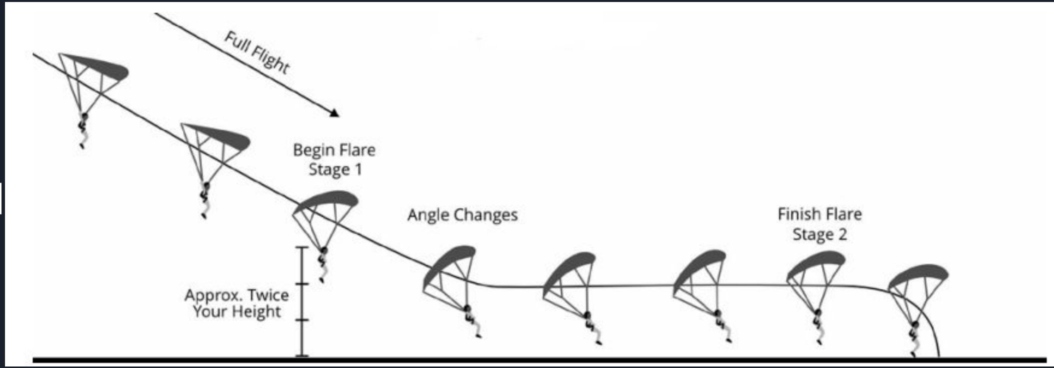
➔ 3. **Derivative** predicts future sensor data to improve stability and avoid overshoots.

The Flare Maneuver

USE: When approaching the target area pull on both left and right brakes simultaneously

PURPOSE:

- ↪ To decelerate
- ↪ To increase lift
- ↪ To soften the impact with the ground
- ↪ To enhance payload survivability



Future Work

↪ Building the prototype

↪ Bench-testing the subsystems

↪ Integrating the systems

↪ Performing balloon launch tests to tune the guidance system

Acknowledgments

We, the Guided Parachute Recovery team, would like thank the following people for their help and support:

↪ Dr. Edgar Bering & Dr. Andrew Renshaw, for their leadership and mentorship in the Undergraduate Student Instrumentation Program

↪ Michael Cowan, for serving as a technical consultant in the development of the project

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Questions?