Autonomous Navigation System for High Altitude Balloons (ANSHAB)

Kanika Garg
Ph.D. Candidate, On-board Space Systems
Email: Kanika.garg@ltu.se

Supervisor
Prof. Reza Emami
On-board Space Systems

SSC Coordinator
Kent Anderson
Systems Engineer

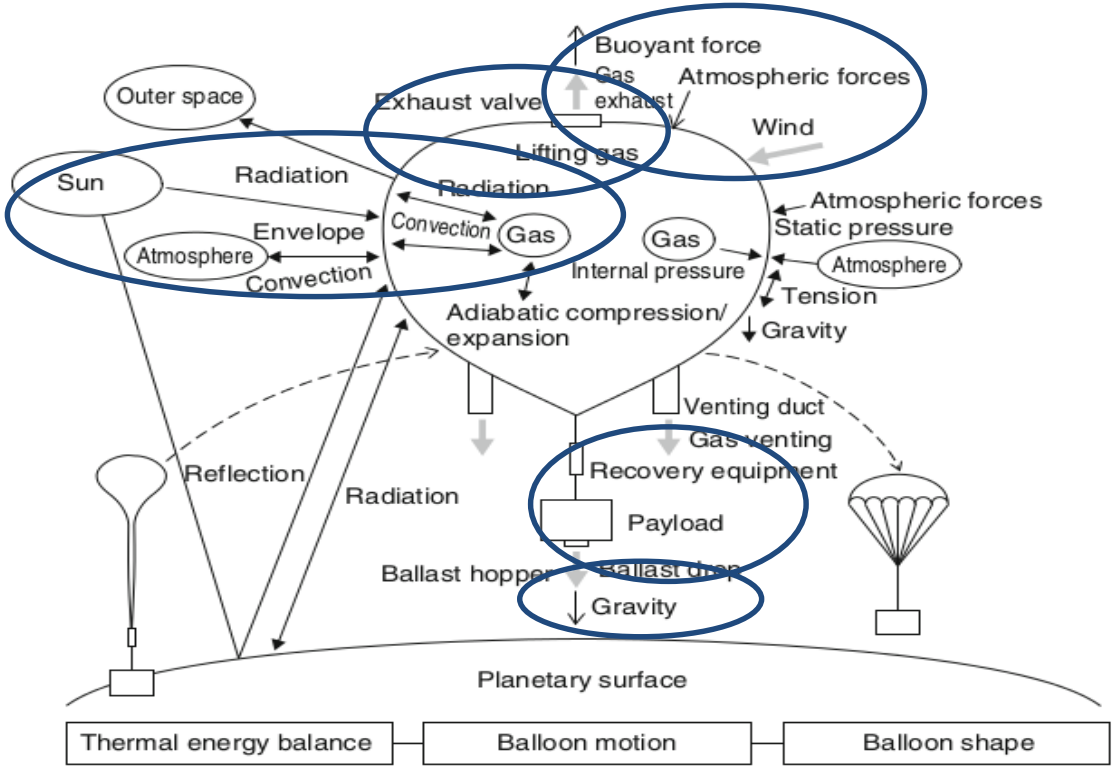
Courtesy: SSC

Presentation Outline

- Problem Definition
- Customer Needs
- Results
- Future Tasks

LULEÅ UNIVERSITY OF TECHNOLOGY

Problem Definition



Forces acting on a balloon and heat transfer into and out of a balloon (Source:Yajima, 2009)

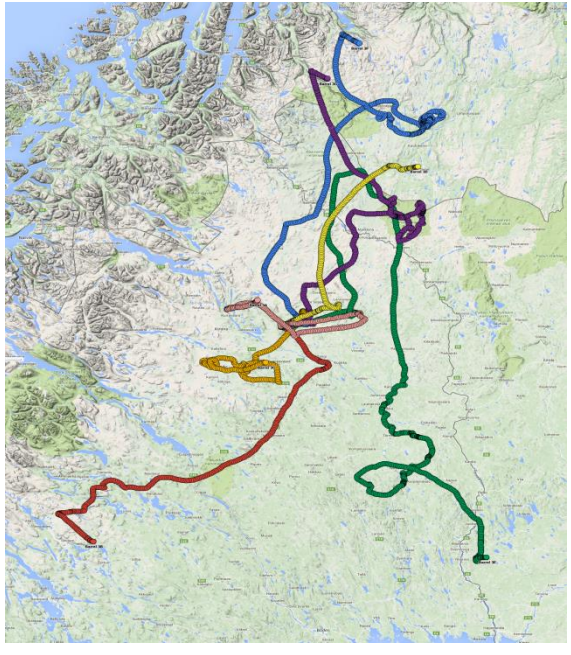
LULEÅ UNIVERSITY OF TECHNOLOGY

Problem Definition

SSC

LULEÅ UNIVERSITY OF TECHNOLOGY

Purpose and Outcome of ANSHAB



Barrel campaign balloon trajectories (Courtesy: SSC)

- The goal of the project is to lower the risks involving the trajectories for stratospheric balloon missions.
- To study and provide a methodology and technology to make the navigation of the balloons more accurate.

LULEÅ UNIVERSITY OF TECHNOLOGY

SSC Requirements

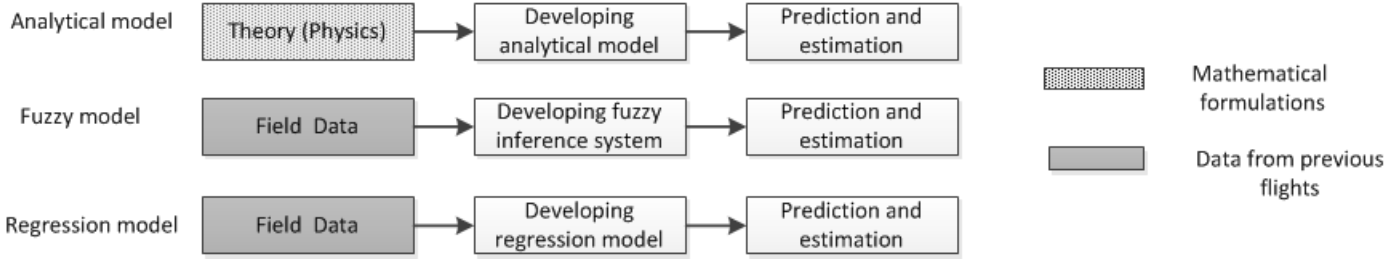
Autonomous Navigation System for High Altitude Balloons (ANSHAB)

- Balloon ascent estimation
- On/Off-line balloon trajectory estimation
- Sensor Design for measurement of winds above and below the balloon
- Recommendations for piloting

LULEÅ UNIVERSITY OF TECHNOLOGY

Balloon Ascent Estimation

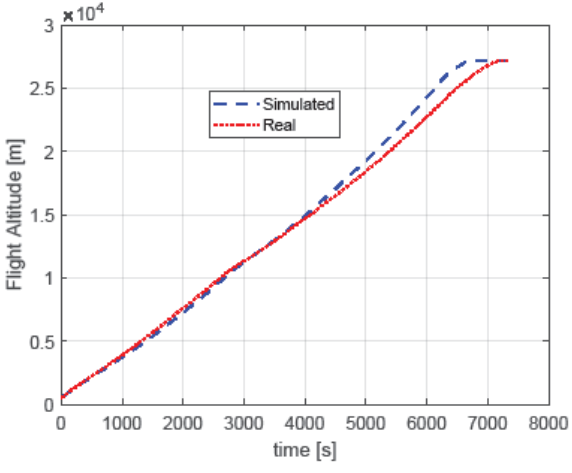
- Analytical Model: Mathematical formulations are used to describe the system behaviour
- Data Models : Building a model based on historical data



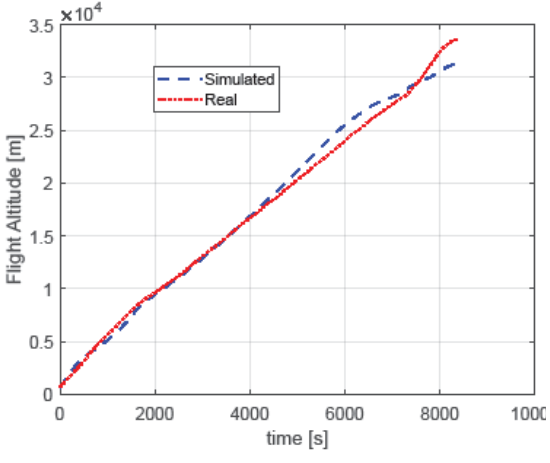
LULEÅ UNIVERSITY OF TECHNOLOGY

Analytical Simulation Results

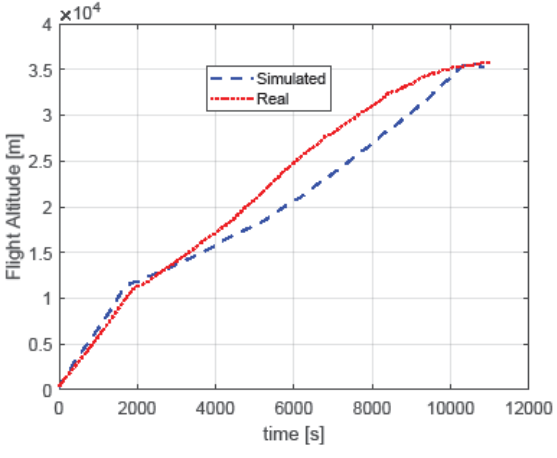
Inputs needed from user: latitude, longitude, mass of payload , free lift, date and time of year, clouds, albedo, etc,.



Balloon size: 12,000 m^3



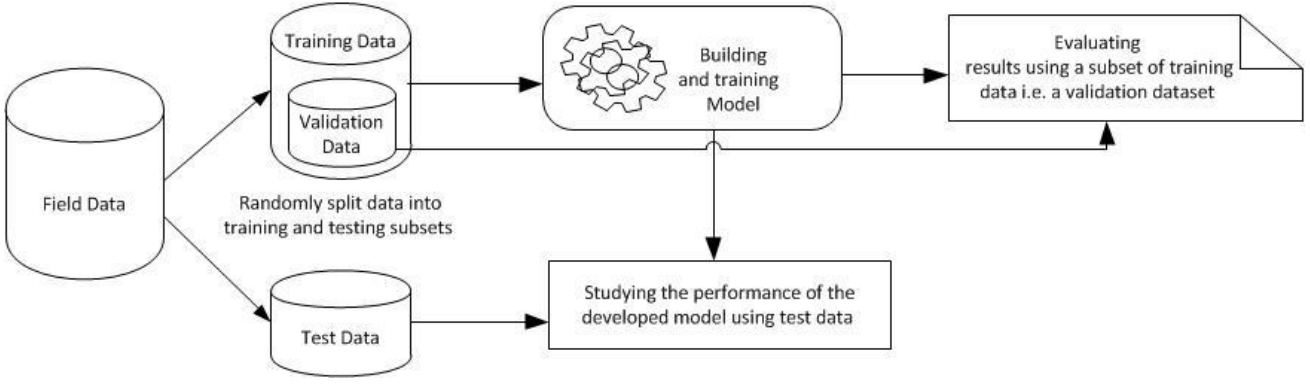
Balloon size: 50,000 m^3



Balloon size: 400,000 m^3

Balloon Trajectory Estimation- Data Models

- Unsupervised and Supervised learning is used to draw inferences from the data
- Unsupervised learning: Cluster analysis is used along with fuzzy
- Supervised learning: Gaussian process regression (GPR) is used

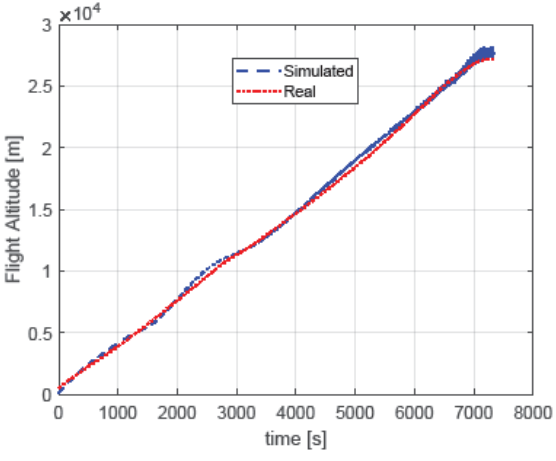


SSC

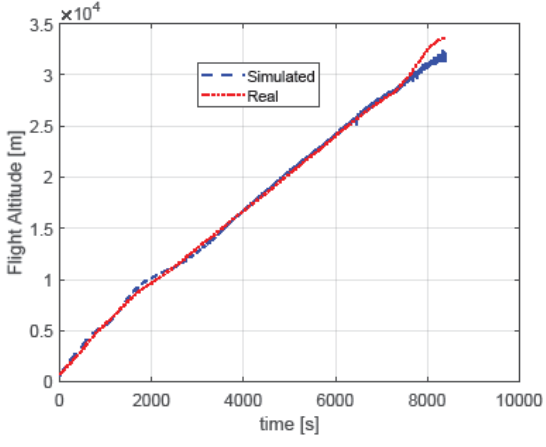
LULEÅ UNIVERSITY OF TECHNOLOGY

Fuzzy Simulation Results

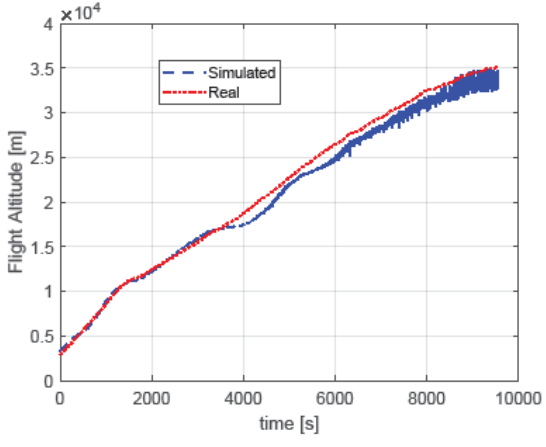
Inputs needed from user: Air temperature, air pressure, free lift, and total mass



Balloon size: 12,000 m^3



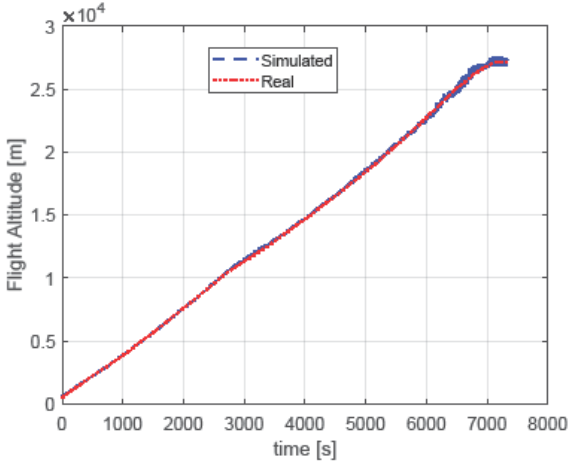
Balloon size: 50,000 m^3



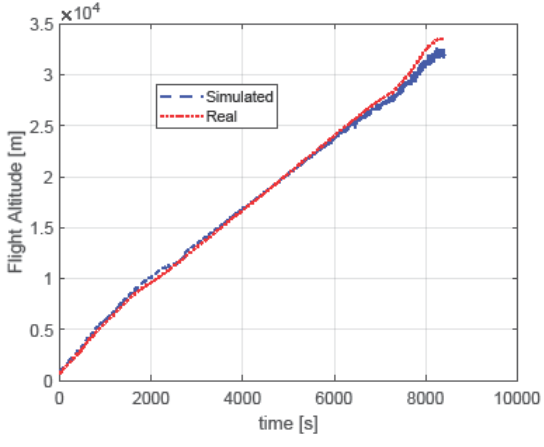
Balloon size: 400,000 m^3

Regression Model Results

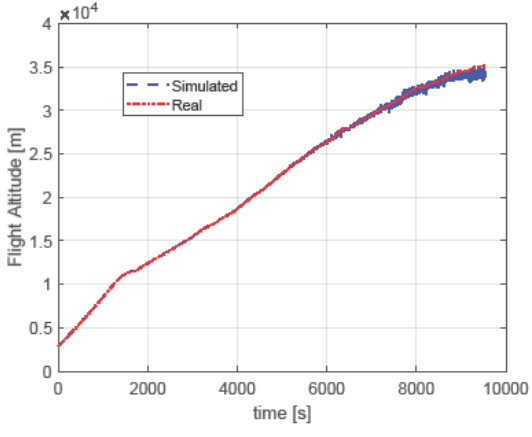
Inputs needed from user: Air temperature, air pressure, free lift, and total mass



Balloon size: 12,000 m^3



Balloon size: 50,000 m^3



Balloon size: 400,000 m^3

Comparison: Analytical, Fuzzy and Regression Model

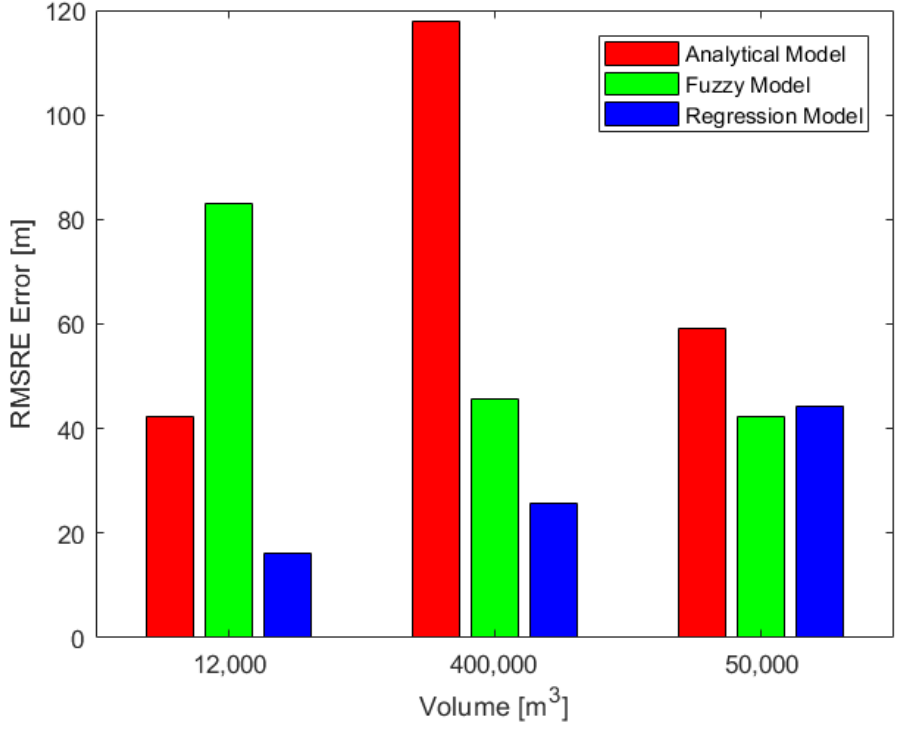


Figure: RMSRE of flight altitude estimation by analytical, fuzzy and regression model with respect to real flight

Analytical Tool- Used for HADT Campaign

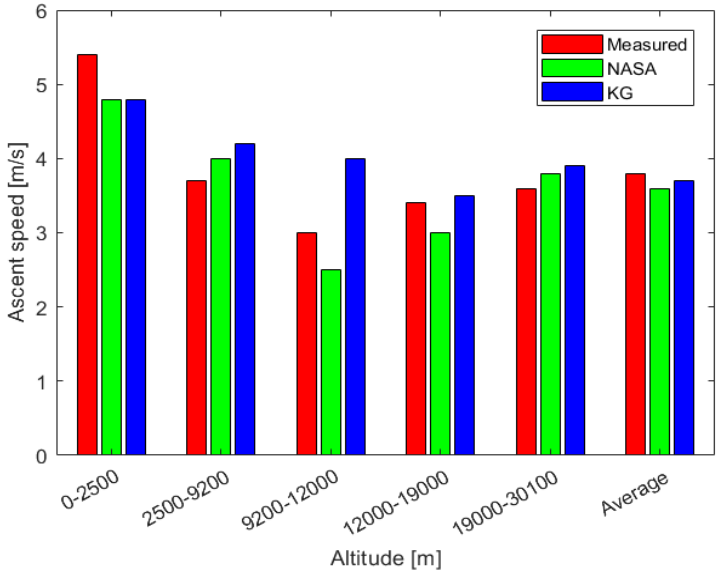


Figure: Ascent speed of real flight in comparison to estimation by NASA and developed simulation

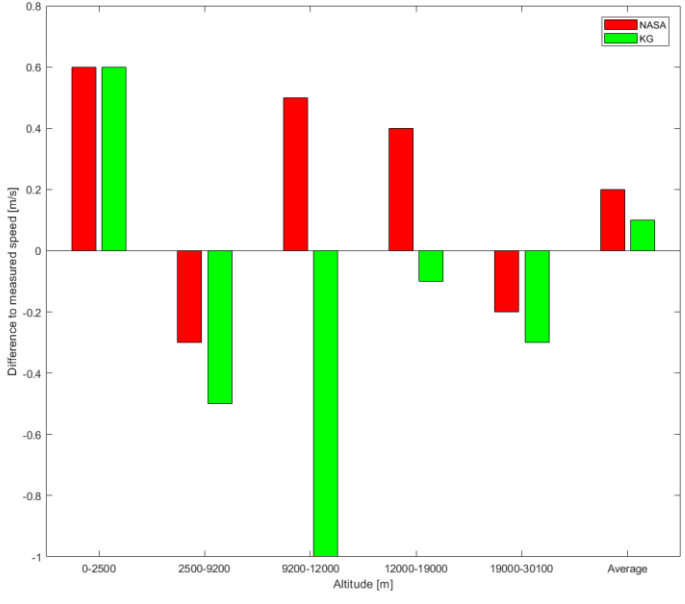
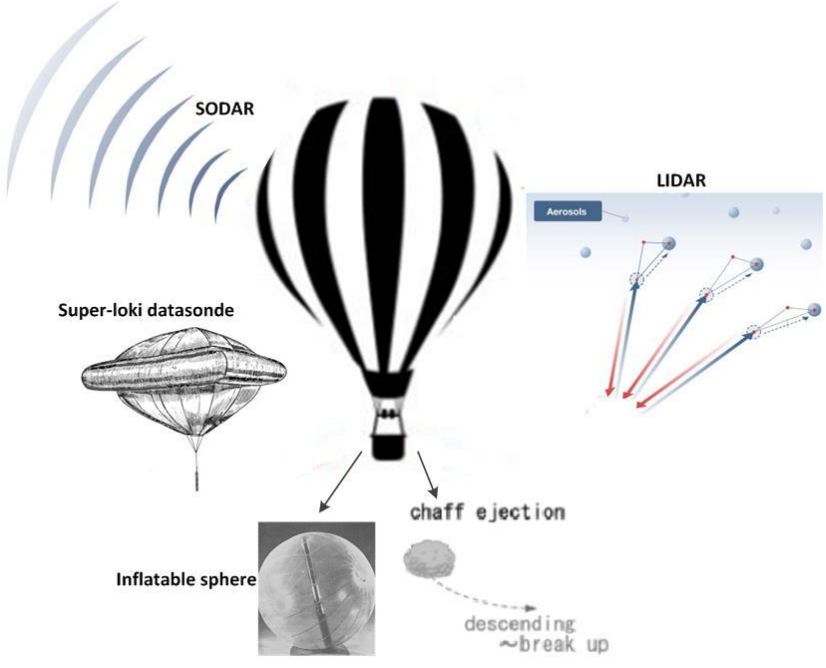


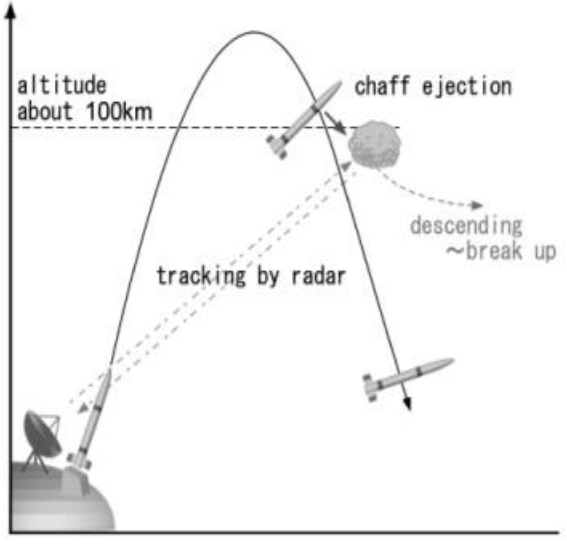
Figure: Error comparison between NASA and developed simulation model

Wind Measurement Sensor



Sensor-Design

- The experiment consists of two main phases, (1) deployment of chaff (2) Tracking of chaff cloud using radar in order to measure the wind direction and possibly the magnitude.
- Experiment is invited for selection workshop for BEXUS flight 2019



Courtesy : Yoshiko Koizum et al.

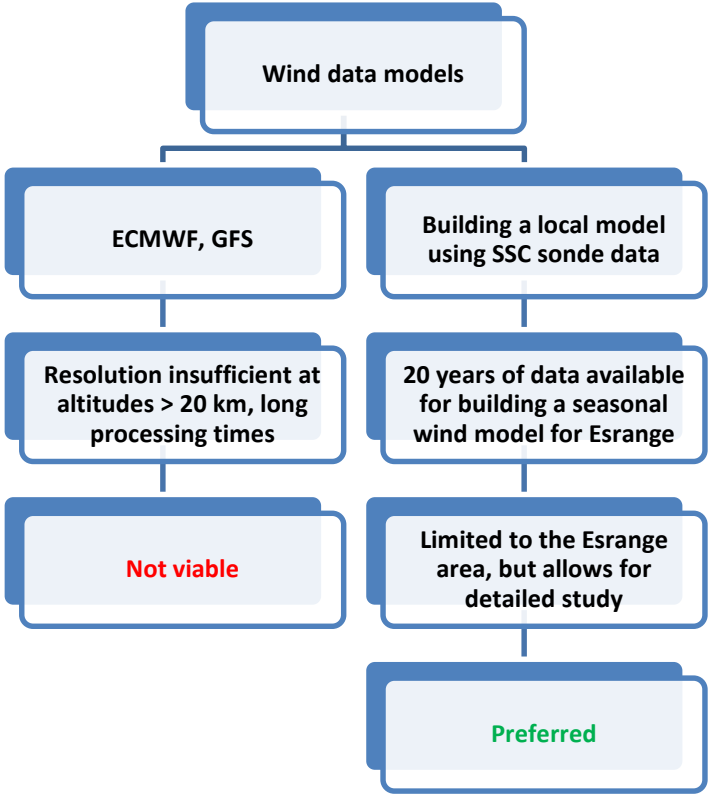
SSC

LULEÅ UNIVERSITY OF TECHNOLOGY

Light Detection and Ranging- LIDAR

- Use of Doppler wind lidar to determine the line of sight wind speed
- Use of Rayleigh scattering for particle detection in stratosphere
- Direct detection Doppler LIDAR using the ultraviolet frequency is required to measure the stratospheric winds
- At present, no such LIDAR is available commercially
- Design and testing of a suitable LIDAR is beyond the scope of this thesis work
- SSC is looking into possible collaborators

Wind Data Models



Autonomous Navigation System

- Balloon sonde data will be used for navigation system design
- Use of discrete mechanics for balloon path optimization
- Decision support system for ballast drops and gas valving

LULEÅ UNIVERSITY OF TECHNOLOGY

Future Work

1. Simulating the performance of Chaff aerodynamics in stratosphere
2. Prototyping of the wind sensor for field experiments
3. Designing the semi-autonomous decision support system

LULEÅ UNIVERSITY OF TECHNOLOGY

Knowledge Dissemination

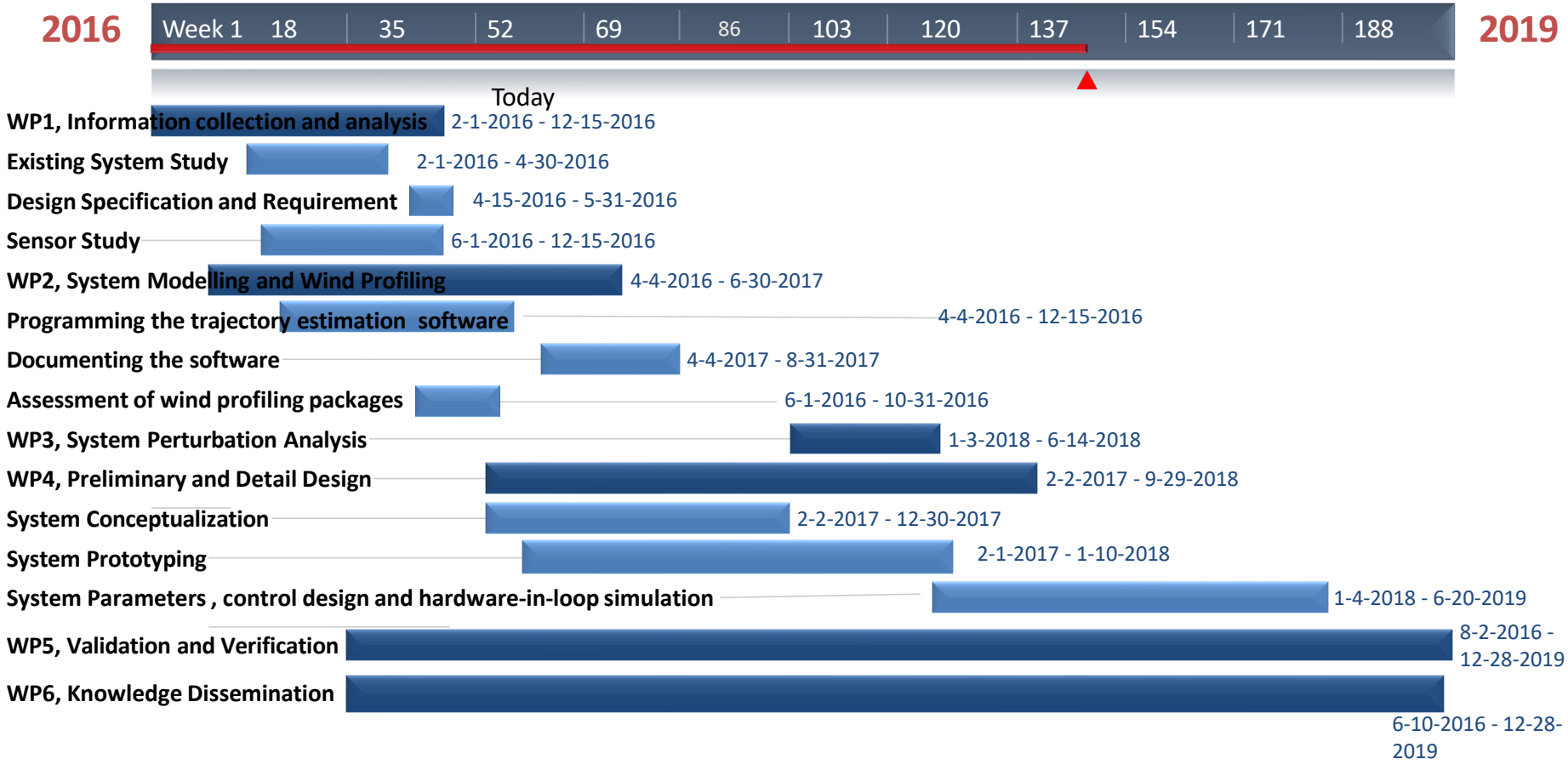
Conference Publication

1. Aerobot Design for Planetary Explorations, AIAA SPACE, 2016
2. A Fuzzy Expert System for Balloon Flight Planning, AIAA Aviation, 2018

Journal Publication

1. Balloon Ascent Prediction: A Comparison Study of Analytical, Fuzzy and Regression Models (Submitted)
2. Balloon Design Study for Different Atmosphere – Mars, Vernus & Titan (Editing)
3. Semi-Autonomous Navigation of Stratospheric Balloon Systems (In preparation)

Timeline


2016
Week 1
18
35
52
69
86
103
120
137
154
171
188
2019
Today
WP1, Information collection and analysis
2-1-2016 - 12-15-2016
Existing System Study
2-1-2016 - 4-30-2016
Design Specification and Requirement
4-15-2016 - 5-31-2016
Sensor Study
6-1-2016 - 12-15-2016
WP2, System Modelling and Wind Profiling
4-4-2016 - 6-30-2017
Programming the trajectory estimation software
4-4-2016 - 12-15-2016
Documenting the software
4-4-2017 - 8-31-2017
Assessment of wind profiling packages
6-1-2016 - 10-31-2016
WP3, System Perturbation Analysis
1-3-2018 - 6-14-2018
WP4, Preliminary and Detail Design
2-2-2017 - 9-29-2018
System Conceptualization
2-2-2017 - 12-30-2017
System Prototyping
2-1-2017 - 1-10-2018
System Parameters , control design and hardware-in-loop simulation
1-4-2018 - 6-20-2019
WP5, Validation and Verification
8-2-2016 - 12-28-2019
WP6, Knowledge Dissemination
6-10-2016 - 12-28-2019

Thank You !
Any Questions

LULEÅ
UNIVERSITY
OF TECHNOLOGY