Trajectory Prediction & Control: *Latitude & Altitude Control*

David Gregory
National Scientific Balloon Facility
P.O. Box 319; FM 3224
Palestine, Texas 75802-0319
david@master.nsbf.nasa.gov / Phone # (903) 723-8028

Topics

- Background
- Trajectory Simulation and Prediction
- Trajectory Control
- Altitude Control

Background

- Long Duration Balloon (LDB) flights (21-day duration) exhibit latitude excursion during flight as determined by stratospheric wind velocities
- ULDB flights (60+ day duration) are likely to exhibit larger latitude excursions
- Method for predicting trajectory before and during flight is a ULDB programmatic requirement
- Trajectory control may provide flexible operation strategies, increased probability of mission success, and new science opportunities

Trajectory Prediction And Latitude & Altitude Control

What is needed

- Accurate trajectory forecasts to several days out
- Methods to control latitude trajectory
- Altitude control systems
- Enhancements that can benefit current zero pressure balloon flight operations

Today's State of the Art

- Trajectory prediction good for 1-3 days out.
- Latitude control - none
- Altitude control - ballast / lifting gas release

Technology Goals

- Trajectory prediction several days out
- Control over flight trajectory
- Enhanced altitude control

Trajectory Simulation and/or Prediction

- **Benefits:**
  - Preflight Analysis
    - Launch site selection
    - International agreements / notifications
    - Safety
    - Launch Window
    - Flight Window
  - Real Time Analysis
    - Overflight
    - Flight termination decisions
    - Payload recovery operations
    - Would provide input data for future trajectory control systems

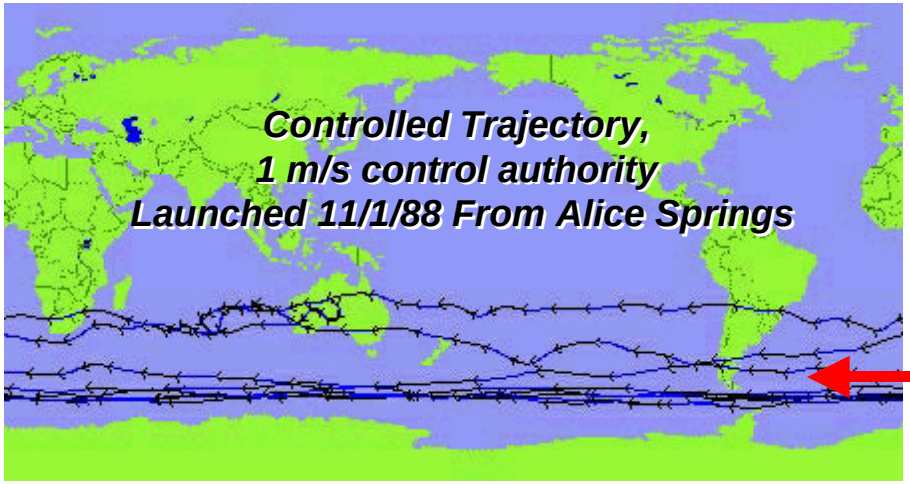
Benefits of Trajectory Control for ULDB Operations

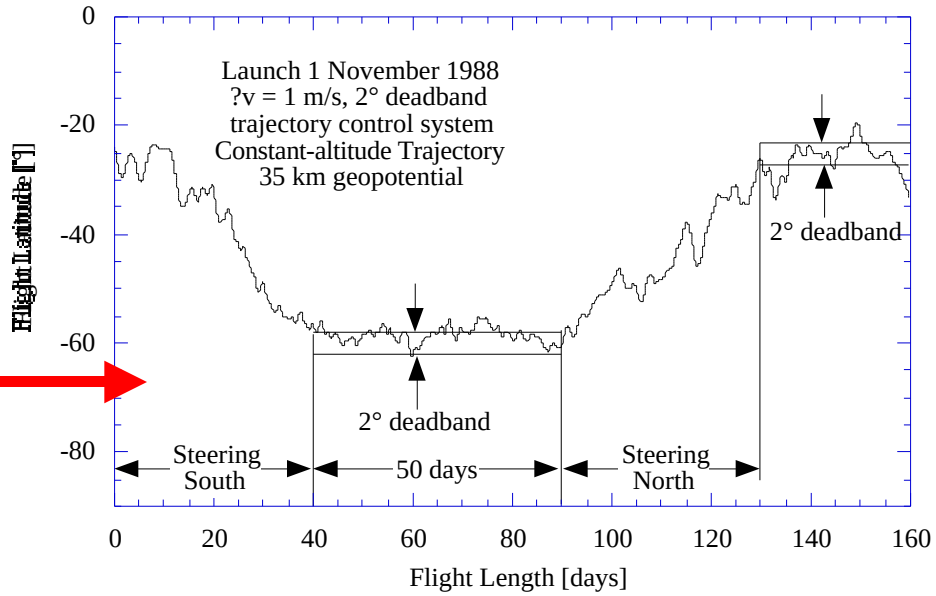
- Reduce latitude excursions
- Avoid geopolitical overflight situations
- Target payload recovery areas
- New opportunities
  - Multiple Latitude Trajectory From Single Launch Site

Potential Impact of Trajectory Control

Constant Altitude Simulated Trajectories With Latitude Control

Fly to Desired Latitude and Return





Potential Trajectory Control Modes

- Large velocity change over short duration - More complicated to implement
- Most Likely Solution - Small velocity change over long duration, eg:
  - Control sails / vanes atop apex fitting (or other locations)
  - Altitude variation to select favorable winds
  - Tethered aerodynamic surfaces below balloon to exploit wind variation with altitude (requires accurate real-time knowledge of atmosphere)

Benefits of Altitude Control for ULDB Operations

- May be used to effect trajectory control
- Some science may desire varied altitudes on a single flight
- Enhance balloon vehicle flight performance

Potential Altitude Control Modes

- Alternate release of ballast and lifting gas
- Control of lifting gas temperature
- Variable superpressure anchor balloon
- Lower payload or sensors on tethers to probe various altitudes (not a trajectory control technique)
- Radiation Controlled Balloon (RACOON)
  - Captures upwelling IR flux from planet to remain aloft at night (would be extremely beneficial for zero pressure balloons)

Summary

- Improved trajectory simulation and prediction will improve preflight and in-flight operations planning
- Latitudinal trajectory control may enhance mission success
- Altitude control may enhance science and provide a means for trajectory control