Titan Balloon Wind Navigation

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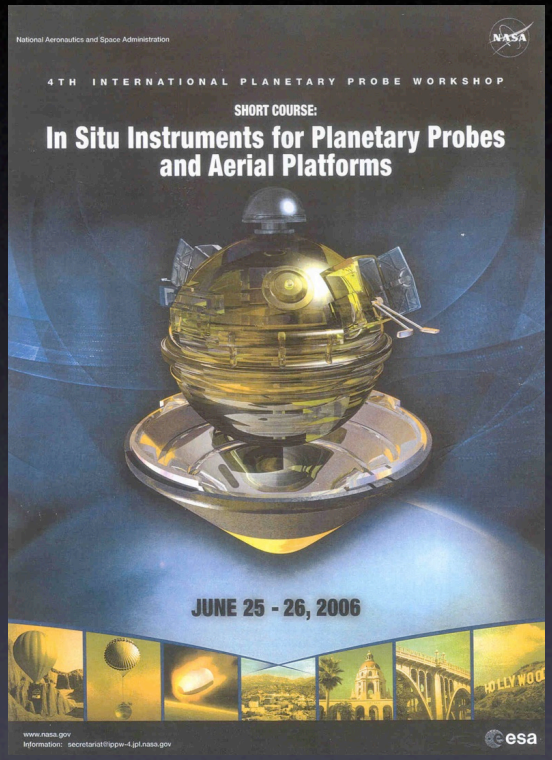
Returning to Titan

- New discoveries of surface features
- To further explore, need:

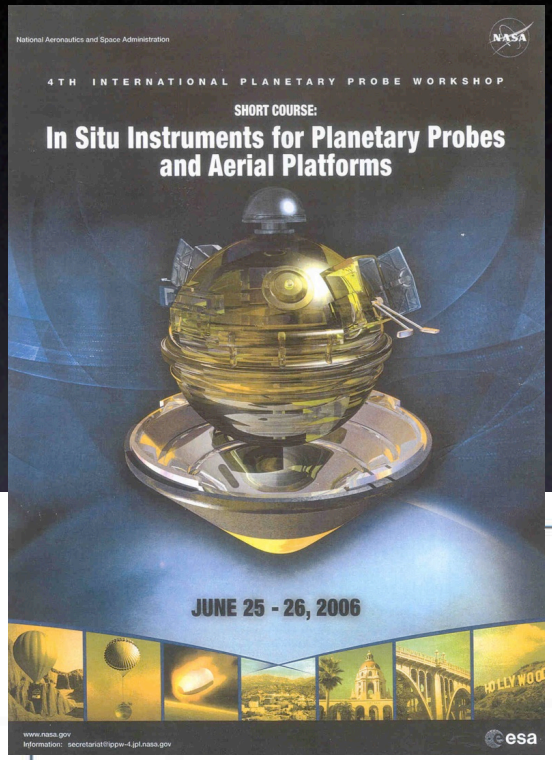
  - longer observation time and range than Huygens probe

  - closer proximity than Cassini to see through haze

Current Status



Current Status



	Atmospheric Science - Constant Altitude	Atmospheric Science - Variable Altitude	Surface Imaging Capability	Surface Sample Acquisition	Site Selection Capability
Self-propelled airship	Yes	Yes	Yes	Yes	Yes
Drifting light gas balloon	Yes	No	Yes	No	No
Drifting RTG Montgolfiere balloon	Yes	Yes	Yes	Maybe	No

Montolfière Balloon

- Satisfies long range, long duration and low altitude
- Variable altitude between 1 km to 20 km
- Independent enough for autonomy

Three Navigation Goals

- Wind assisted site-selection
  - -stable longitude
  - -stable altitude
  - -recovery
- Ground collision avoidance
- Optimization of flight path

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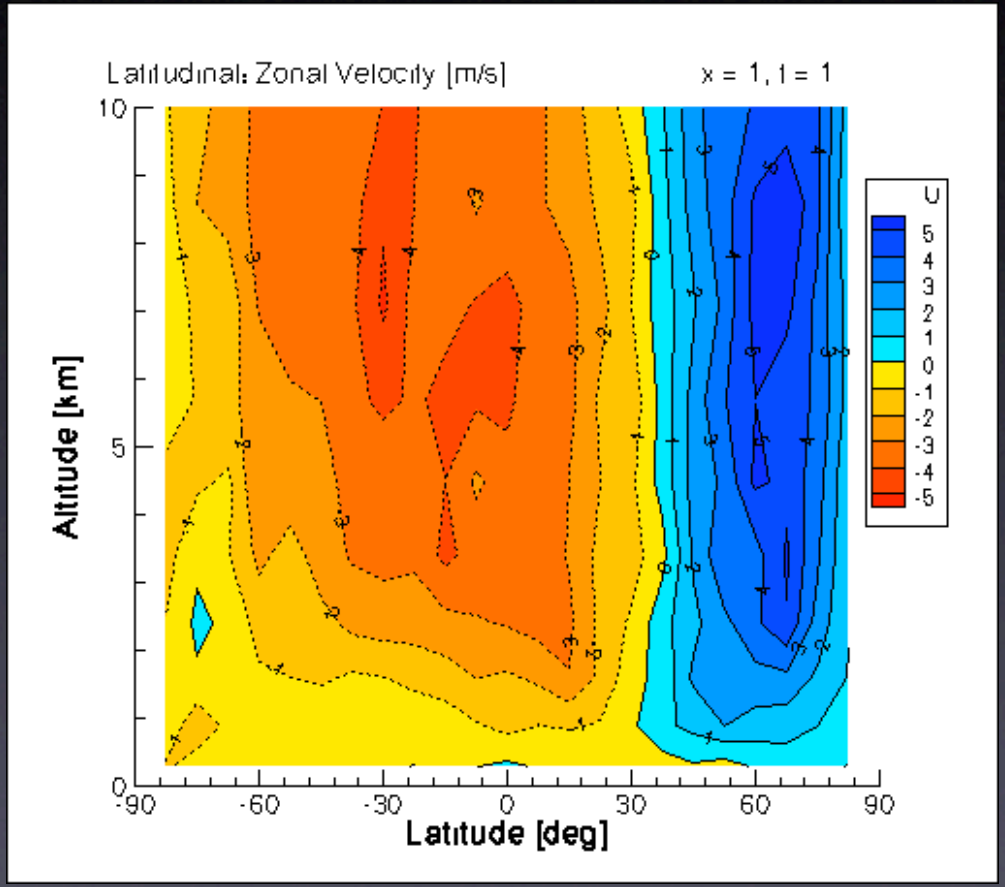
Two Wind Models

	LMD	Tokano
Accuracy Range	> 40 km	< 40 km
Predominant Winds	Westerly	Westerly
Low Altitude Retrograde Wind	Sparse	Prevalent

Tokano Model

- Movie of latitudinal contour plot in Huygens season
- Wind speeds shown at different longitudes (x) and time (t)
- Prograde / Retrograde



Utilization of Wind

- “Free” prograde ride at 10 km
- Descend by decreasing buoyancy
- Backtrack in retrograde wind to selected sites

Utilization of Wind: Demonstration

- Prograde
- Descent
- Retrograde
- Ascent

Utilization of Wind: Demonstration

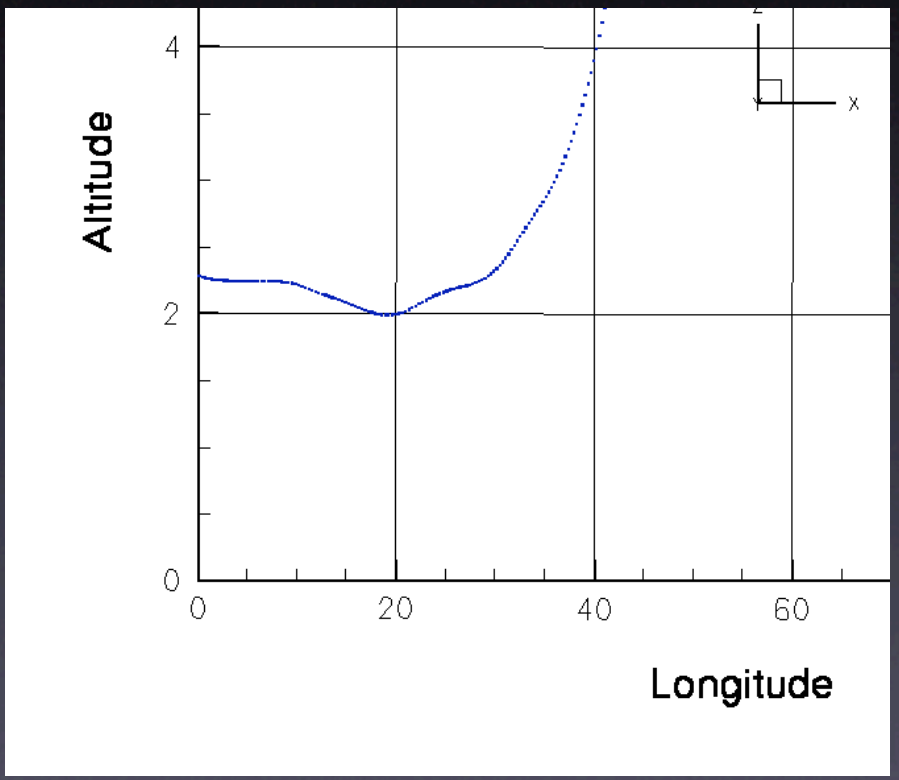
Prograde Altitude

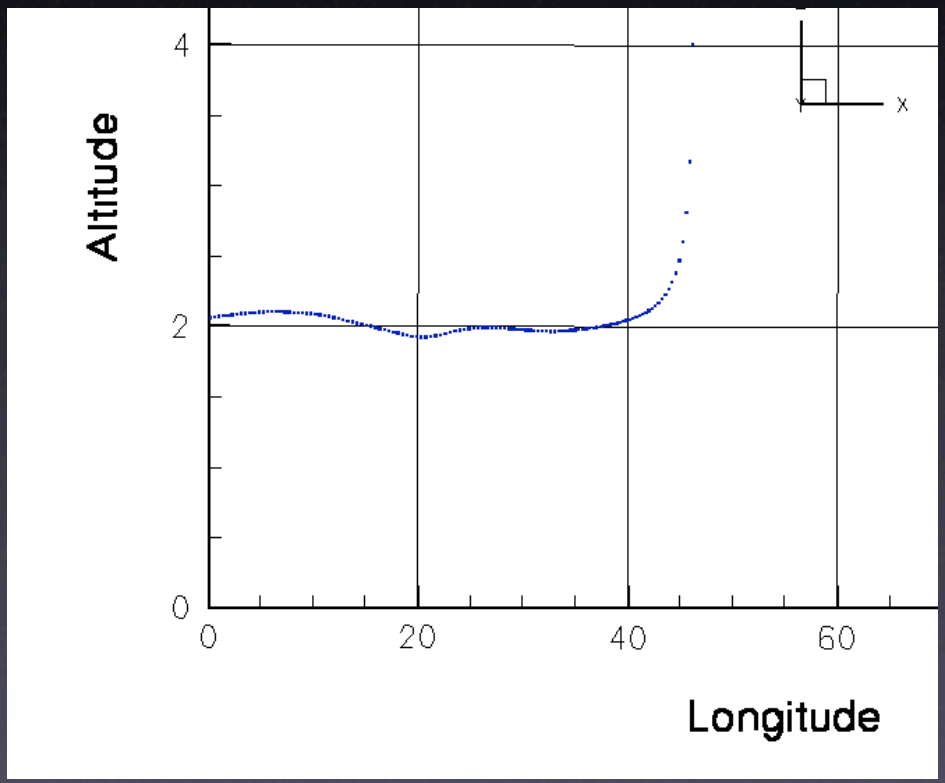
- Icing above 20 km
- Maximum prograde wind between 5 and 15 km
- Optimum prograde altitude is 10 km

Descent

- Realistic altitude control from 10 km to 1.5 km
- Max. vertical supplied velocity is 0.5 m/s
- PID controller - combination of proportional, integral and derivative controls
- Halts descent at 1.5 km

Descent





Before PID Controller

After PID Controller

Retrograde Altitude

- Gradual topography, less than 1 km
- Retrograde wind reaches 2 km
- Optimum retrograde altitude is 1.5 km

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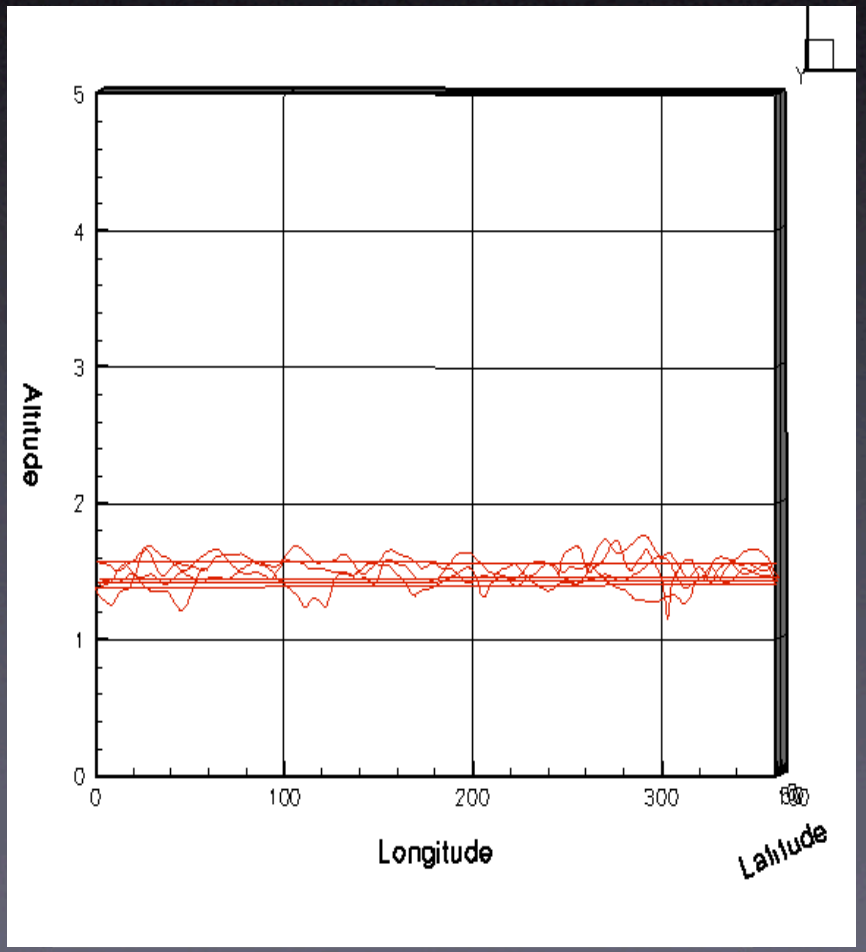
Ground Collision Avoidance

- Downward gusts into ground
- Sense altitude AGL with radar
- Compute vertical change in velocity
- Implement 0.5 m/s escape climb

Ground Collision Avoidance

- Sustained flight at 1.5 km
- Error +/- 0.3 km
- No lower than 1.2 km



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Optimization

- SQP method - only in x, z coordinate plane
- Know longitude, altitude of target
- Begin with rough path

Optimization

- Minimize $zc^{T}zc$, or vertical control
- Wind data given
- Results in vector zc, most efficient trajectory
- Only theoretical

Summary

- Started with Titan wind data model
- Vertical control enables site selection
- Safeguards avoid ground collision
- Optimized path to selected site

Further Research Ideas

- Latitudinal control
- Find launch time to optimize retrograde wind
- Complete autonomy controls

Acknowledgements

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Questions?