Progress Report: Applications of Uninhabited Aerial Vehicles for Cryospheric Science

Suborbital Science Missions of the Future Workshop
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Science Questions from ESE Climate Variability and Change Road Map

- “What changes are occurring in the mass of the Earth's ice cover?”
- “How is global sea level affected by natural variability and human-induced change in the Earth system?”
- NASA's Cryospheric Sciences Program addresses these with four components: sea ice; terrestrial ice sheets; glaciers and ice caps; land snow cover

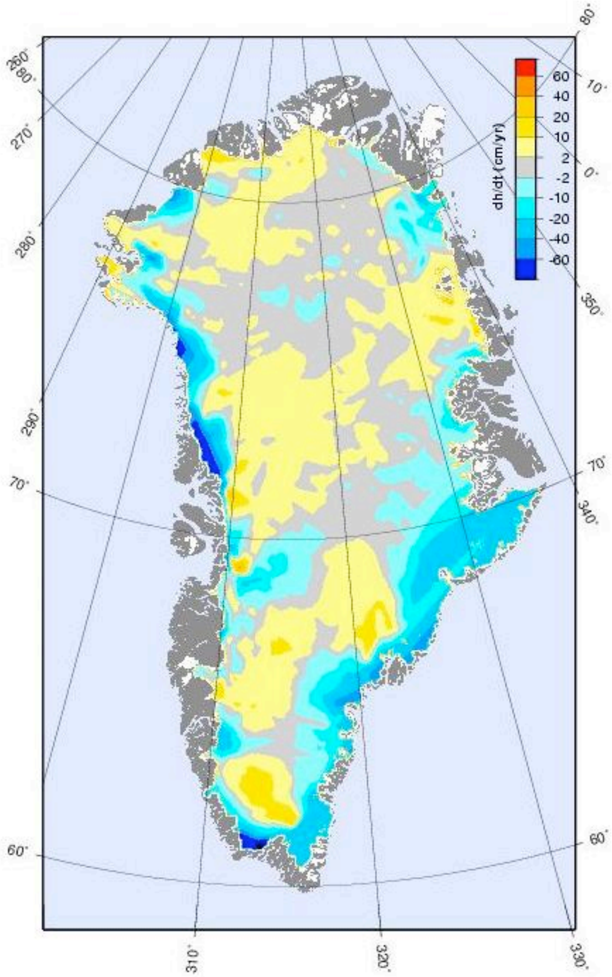
Ice Sheet Measurements

- Surface elevation and its rate of change
- Ice velocity
- Grounding line location
- Ice thickness
- Surface melt detection
- All but ice thickness can currently be measured from orbit; temporal/spatial limitations with surface elevation

Suborbital Measurement Priorities

- Ice thickness
  - Low-frequency radar
  - University of Kansas Coherent Antarctic Radar Depth Sounder (CARDS)
- Surface elevation
  - Scanning lidar is preferred
  - Scanning necessary for remeasurement of individual transects
  - NASA's Airborne Topographic Mapper (ATM)

Addressing the Science Questions



- Scanning Lidar
  - Direct mass balance assessment
  - Contribution to sea level change
- Radar depth sounder
  - Mass flux
  - Glacier dynamics

Why Suborbital?

- Elevation Change / Scanning Lidar
  - ICESat approaching accuracy of airborne lidar measurements
  - Spatial/temporal coverage lacking
  - Airborne lidar good for calibrating orbital lidar

- Ice Thickness / Radar Depth Sounder
  - Currently no orbital capability
  - Spatial resolution
  - “Wet” ice difficult, even for suborbital sensors

Roadmap for UAV-Based Ice Sheet Remote Sensing

- Downsize NASA's ATM sensor for UAV operation
- Develop an airborne radar depth sounder capable of sounding “wet” outlet glaciers
- Downsize the resulting radar
- Conduct an early demonstration with rudimentary capability, in 2007-8 (IPY)
- Build toward comprehensive surveys of remote Antarctic glaciers in 2010-2015 time frame

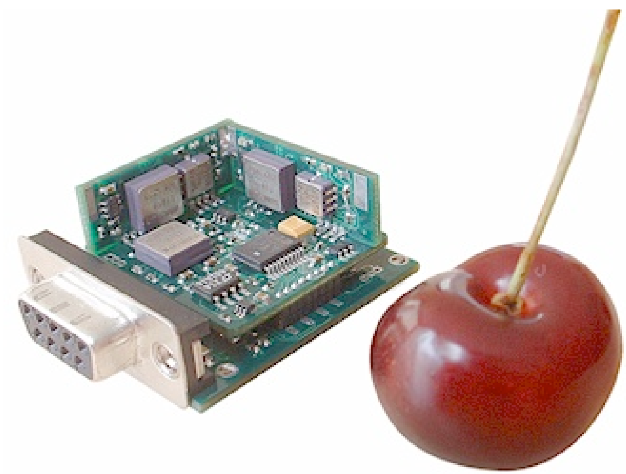
Payload Requirements

- Radar depth sounder – TBD!
- Scanning laser altimeter system: 3 components
  - High-accuracy GPS
  - Precise aircraft attitude – inertial or GPS
  - Scanning laser and data system
- Need estimated weight and power requirements

Evolution of GPS Hardware

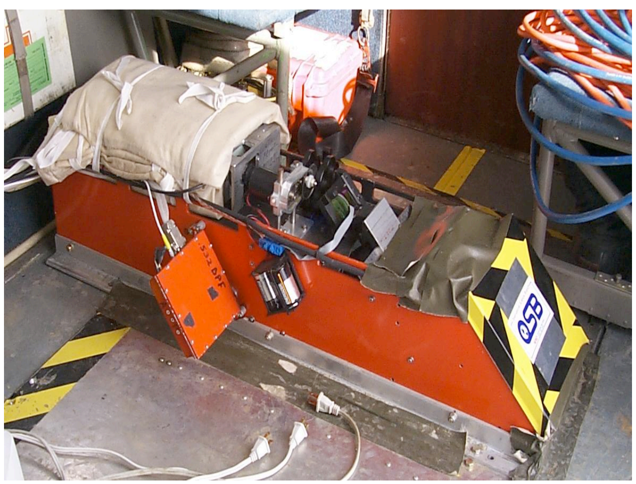
- First generation
  - Ashtech Z-12/19” rackmount PC
  - ~40 lbs, 200 watts
- Current generation
  - Ashtech Eurocard / single board Linux computer
  - 4 lbs, 15 watts
- Future
  - Downsize to 2 lbs/10 watts or better

Evolution of Inertial Hardware



- Old: Honeywell / Litton-92 / Litton-100 INSs
  - ~100 lbs
  - Very expensive
- New: Small IMUs, like the CloudCap Crista
  - Negligible weight and power consumption
  - Inexpensive

Evolution of the Scanning Lidar



- ATM-1
  - ~1000 lbs +
  - Required large airframe
- ATM-2/3
  - <100 lbs, plus data system
  - Flies in Twin Otter
- ATM-4, EAARL
  - Full-waveform recording
  - Flies in Cessna 310

UAV-Suitable Scanning Lidar

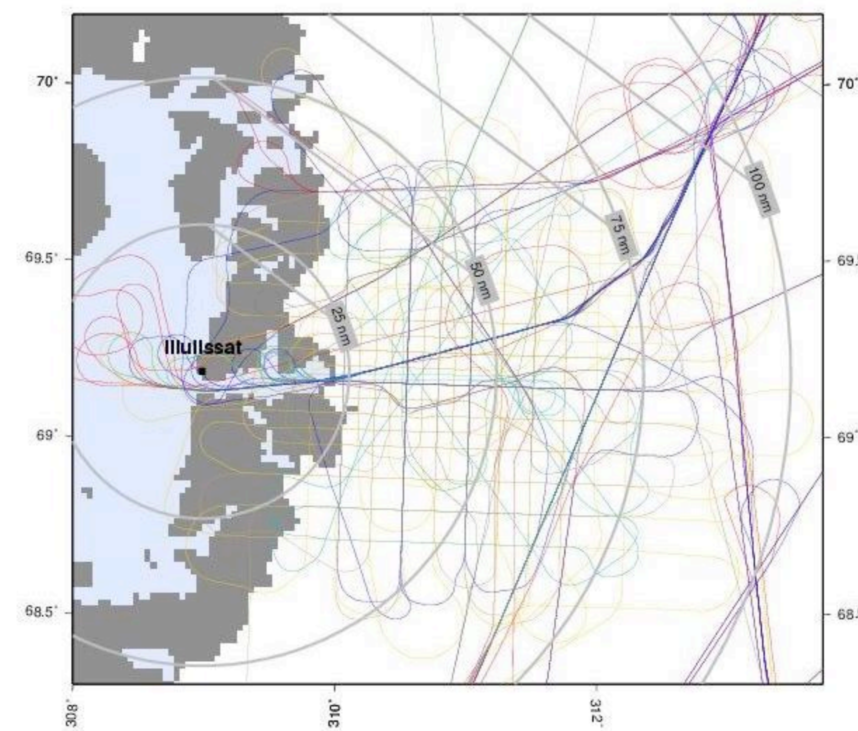
- WFF concept – the "Beer Can Lidar"
- Commercial options, such as Optech?
- Needs development support!
- GOAL: 10s of lbs, small size, low power consumption

Mission Concepts – Where to Fly?

- Arctic
  - Greenland, Arctic Canada, Svalbard, Alaska
  - All within reach of large manned aircraft such as P-3, much reachable by Twin Otter
  - Much science to be done, ideal for UAV development
- Antarctica
  - Very remote, few facilities for large aircraft
  - Huge distances
  - Of profound scientific interest

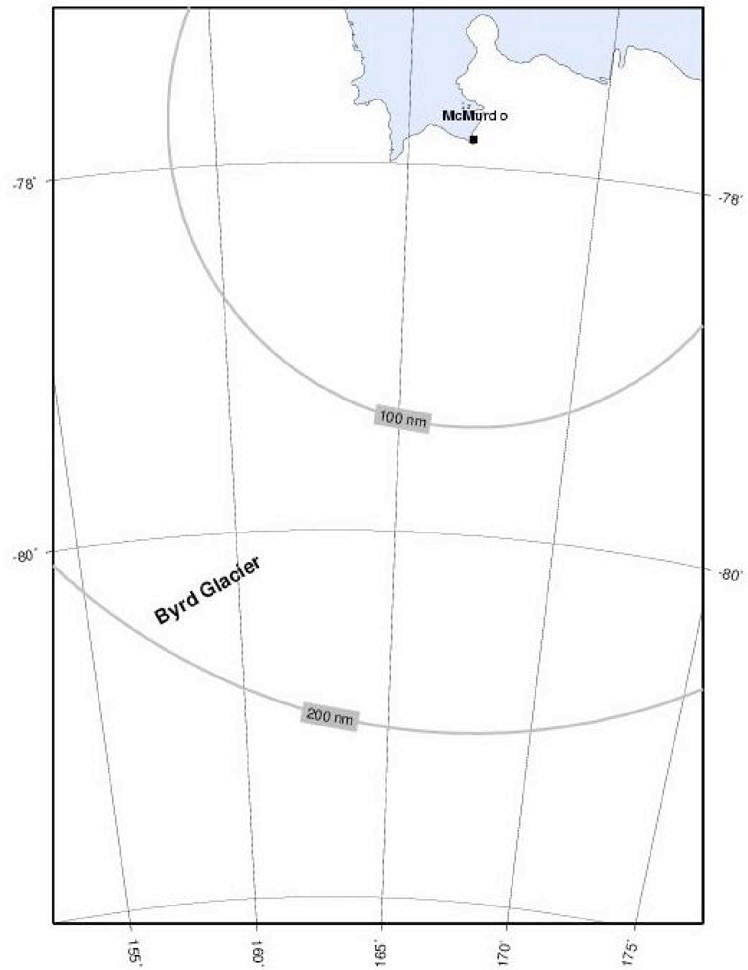
Jakobshavn Glacier, Greenland

- Fastest glacier in Greenland; among the largest
- Stable through early 90s, undergoing rapid change since 1997
- Short range to a good airport
- Easy logistics (as remote places go)



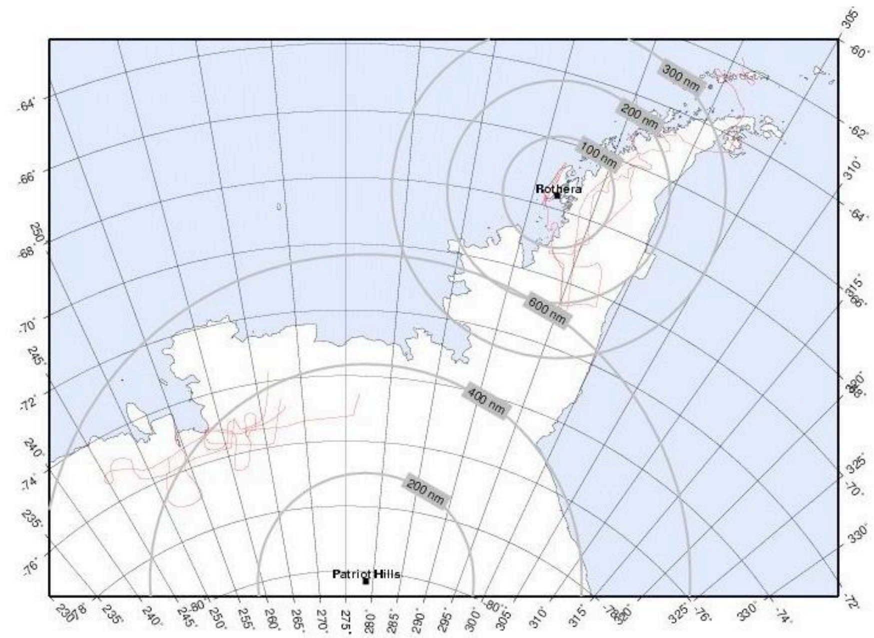
Byrd Glacier, Antarctica

- Large glacier, rough bed, drains EAIS
- Confined by the Ross Ice Shelf
- More challenging place to operate
  - Farther from airfield
  - Airfields are snow/ice
  - Very remote from US



Antarctic Peninsula, Pine Island Basin

- Collapsing Larsen Ice Shelf, importance of Pine Island Basin
- Large manned aircraft must “commute” from South America, P-3 still at max range
- Smaller aircraft range-limited from Rothera/Patriot Hills



Preliminary UAV Requirements for Scanning Lidar Missions

- 50 – 100 lbs payload
- Nadir optical port(s)
- Precise cross-track navigation (~10 m)
- Limited terrain-following capability
- Little or no science comms
- Range – minimum 400 nm, up to 4000 nm or more
- Snow/ice capable