The Airborne Glacier and Ice Surface Topography Interferometer (GLISTIN-A)

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Acknowledgements: Xiaoqing Wu, Jim Canniff, Maurio Grando, Lance Milligan, Hung Pham

6/20/2011
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PI: Delwyn Moller, Remote Sensing Solutions (RSS)

Objective
- Provide an ice surface topography, swath mapping sensor capable of operationally supporting NASA cryospheric science campaigns including potential IceBridge participation and ICESat-II augmentation - especially in coastal regions.
- Transition the Ka-band interferometer capability developed under the NASA International Polar Year (IPY) to a permanently available Ka-band UAVSAR configuration
- Improve IPY configuration to provide enhanced performance (e.g. ping-pong) and swath-mapping capability.
- Enable compact "plug and play" reconfiguration between L-band UAVSAR and Ka-band.

Approach
- Upgrade front-end-electronics for ping-pong operation
- Integrate a state-of-the-art solid-state-power-amplifier (SSPA) to contain all GLISTIN-A hardware on the panel assembly.
- Perform thermal analysis and modify the panel to accommodate the new hardware
- Verify upgrades with engineering checkout and calibration flights on the Gulfstream III
- Update the Ka-Band single-pass processor for the GLISTIN-A configuration including ping-pong mode

Key Milestones
- Complete transceiver design 11/10
- Complete thermal analysis 07/11
- Complete transceiver integration & test 01/12
- Complete Ka-Band pod integration & test 03/12
- Flight Readiness Review 04/12
- Complete calibration/Engineering flights 06/12
- Calibrated Data/Digital Elevation Models 09/12

Co-Is/Partners
James Carswell, RSS; Scott Hensley, Gregory Sadowy, Yunling Lou, Charles Fisher, Jet Propulsion Laboratory

Left: example height map over Greenland’s coast collected 5/1/2009. Color wrap is 800m and swath is 7.5km. GLISTIN-A will improve swath coverage to >10km.
Outline

• Summary of GLISTIN-A International Polar Year progress and findings
  o System performance/stability
• AITT system upgrades
  o performance implications
  o Block diagram and key design criteria
• Ka-band RF electronics accommodation
• Timeline
• Technology infusion and Related NASA and NASA ESTO programs
The image shows the topography over the West Coast of Greenland generated from a Ka-band single-pass interferometric radar flown on the NASA GIII as part of the NASA International Polar Year activities in May 2009.


<table>
<thead>
<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>Coverage</td>
<td>&gt;5km (10km goal)</td>
</tr>
<tr>
<td>Coastal Accuracy</td>
<td>50cm</td>
</tr>
<tr>
<td>Coastal Posting</td>
<td>30m x 30m</td>
</tr>
<tr>
<td>Ice Sheet Accuracy</td>
<td>10cm</td>
</tr>
<tr>
<td>Ice Sheet Posting</td>
<td>100m x 100m</td>
</tr>
</tbody>
</table>
Height precision ranges from 30cm near-range to 3m far-range for 3m horizontal posting. Therefore this is compatible with the science accuracy requirements in terms of system precision. (e.g. 3cm-30cm precision for 30m horizontal posting).
• The correspondence of frequency and magnitude of the observed multipath between antenna range measurements and data observations show good system stability for the phase-screen correction.

• Detailed processing has progressed – we generated a phase-screen correction that corrects simultaneously for the interacting multipath and residual baseline systematic artifacts.
Phase Drift Observed in Long Data Line

Along-track 220 km

(far range) Absolute phase (near range)
Ka-band and Lidar Data Comparison

• Ka-band single pass interferometric data was collected at Greenland’s Summit in Greenland along with ATM lidar data.
• Lidar tracks are shown overlaid on two passes of Ka-band elevation. Approximately 10,000 lidar points are contained in each scene.
• Initial observations show mean difference of 34cm (σ~1m). Further refinement and additional observations will better bound this.
• Predicted penetration is in the range of 10-30 cm.
Some recent high-relief images

- 80m color wrap for height
- Images ~7km range x 12km long
AITT GLISTIN-A Upgrades
### AITT Upgrades

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>IPY</th>
<th>GLISTIN-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak transmit power (at antenna)</td>
<td>W</td>
<td>40 (TWTA)</td>
<td>40 (SSPA)</td>
</tr>
<tr>
<td>Receive Losses</td>
<td>dB</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Ping-pong</td>
<td></td>
<td>No</td>
<td>yes</td>
</tr>
<tr>
<td>Nominal flight altitude (AGL)</td>
<td>km</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Nominal Swath</td>
<td>km</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Height precision (30x30m posting)</td>
<td>m</td>
<td>15°</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31°</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50°</td>
<td>0.50</td>
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<td></td>
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<td>0.10</td>
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<td></td>
<td>0.11</td>
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<tr>
<td></td>
<td></td>
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<td>0.49</td>
</tr>
</tbody>
</table>

- New RF front-end to include ping-pong
  - Minimum 80dB isolation
  - Cal-loop integrated with UAVSAR
- SSPA for solid-state self-contained configuration
  - Transmit power equivalent but reduced receive losses
• > 80dB cross-channel isolation requirement
• Cal-loop SNR > 40dB
Calibration Loop

- Loopback Calibration is used to measure TX/RX gain and phase products.
- Differential gain and phase of upper and lower receivers is used to remove drifts.
- Calibrations are controlled and recorded in exactly the same way as during UAVSAR L-band data collections.
- No hardware or software changes required.

**Diagram:**
- ADC1, ADC2, AWG, RFES Switch Network, RX Cal, RX Cal, TX Cal, RFES Cal, GLISTIN-A Ka-Band Front End, L-band Active Phased Array Antenna, TR Module.
Electronics Layout

- No major modifications to the antenna panel.
  - SSPA will fit if heat can be removed from the sides instead of the top.
- GLISTIN-A antenna uses the same connector bulkheads and has the same pod mechanical interfaces as UAVSAR

- Thermal analysis verified SSPA will stay close to 25°C with natural convection only. Pod ducting will be plugged for flight operations
Implementation Timeline

- RF subassemblies nearly complete with the exception of the SSPA
- Accommodation and initial layout complete
- Preliminary thermal analysis complete, detailed underway for thermal control and electronics packaging design
- System I&T late this calendar year
- GIII install and engineering checkout Spring 2012 but interdependent with UAVSAR resource availability
GLISTIN-A Technology Heritage and Infusion

**HiWRAP: IIP & NASA SBIR**
Multichannel, high-throughput digital system compatible with unpressurized unattended operation

**GLISTIN-A: IPY & AITT**
First demonstration of mm-wave SAR interferometry
- technology development & technique demonstration
- Processor development is direct heritage for KaSPAR/AirSWOT

**D3R GPM cal/val sensor: SBIR**
High power Ka-band solid-state power amplifier will be utilized for GLISTIN-A and AirSWOT

**AirSWOT SWOT cal/val sensor: ESTO & NASA SBIR**
Compact integrated assembly compatible across platforms (e.g. NASA King Air, Ikhana, Global Hawk, DC8).
Backups
Phase drift as a function of along track estimated from comparison with ATM height
Globalhawk Considerations

• GLISTIN-A will be interchangeable with UAVSAR w/ no mods to UAVSAR or GH.

• Mass and CG
  – Mass of GLISTIN-A antenna will be considerably less than UAVSAR.
  – Account for difference either by ballast on antenna or ballast on GH.
  – CG on antenna can be matched by adding ballast on the antenna.

• GLISTIN-A already meets same environment requirements for temperature, vibration, load factors, etc. as UAVSAR.

• Flight altitudes of GLISTIN-A compatible with GH
  – Includes RF Breakdown analysis
Pod Accommodation and Interfaces

- GLISTIN-A antenna will use the same connector bulkheads design as UAVSAR.
- Mechanical interface to pod remains the same, as does radome interface.
- No modifications to the pod are needed.
- Thermal analysis verified SSPA will stay close to 25°C with natural convection only. Pod ducting will be plugged for flight operations.
  - UAVSAR AC unit will be used for cooling during ground tests
- Survival heaters used to maintain operating temp on all electronics.
SSPA Cooling/Thermal Analysis

- SSPA creates the majority of heat for the entire system conservatively estimated at ~65 W.
  - Assumes 5% duty cycle, poor efficiency (8%) and 40W non-transmit power draw
- Thermal analysis verified SSPA will stay close to 25°C with natural convection only. Pod ducting will be plugged for flight operations.
  - UAVSAR AC unit will be used for cooling during ground tests
- Analysis is conservative but will be refined; design can accommodate changes to improve cooling.
- Survival heaters used to maintain operating temp on all electronics.
Quick Look Intensity Processing: May 6 and May 12 – Jakobsholm Pass

- Left shows Google Earth view zoomed out to show surrounding region. Quick look processing image is also shown in Google Earth.
- Right images are zoomed in to shown more details in the quick look processing (intensity only) of Jakobsholm pass. They have been imported into Google Earth.
- From the 6th to the 12th (toggle between) the ice sheet retreats ~ 1 km.
The correspondence of frequency and magnitude of the observed multipath between antenna range measurements and data observations suggests good system stability for the phase-screen correction. Below shows the multipath from several data takes over different days after correcting for a drift term.