# What a 'Web Sensor' can do for 'Sensor Webs'

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**Organization of Primary Author: Goddard Space Flight Center**
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# Introduction to ERIN-WSS

- The 2005 AIST Program awarded funding for the development of a Expandable Reconfigureable Instrument Node (ERIN) to demonstrate a Web Sensor Strand(WSS)
- Various ESTO and Goddard Research and Development efforts have been leveraged to maximize the Return on Investment of ERIN-WSS.
  - L-Band Imaging Scatterometer (similar analog front end)
  - Nanosat Antenna (also Aerotenna "in wing" design)
  - Concurrent efforts on Digital Beamforming Synthetic Aperture Radar, and Rad-hard Space Cube (same FPGA)

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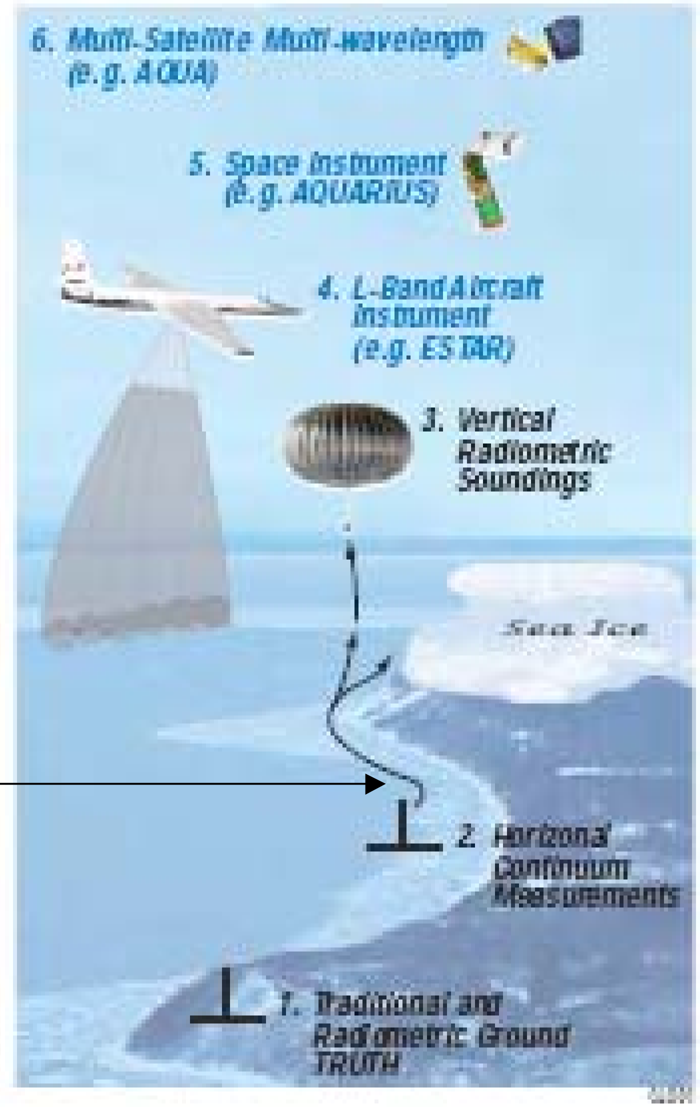
# Objective of Talk

- What CAN a 'Web Sensor' do for 'Sensor Webs'?
  - Stitch together ground truth in a local continuum
  - Provide a unique and useful viewing angle to optimize microwave polarimetry
  - Calibrate passive measurements taken from higher altitudes lower resolution
  - Infer from climatic records, and unique web sensor data, predictions for Synthetic Aperture Radars such as those being proposed for SMAP, DESDynI, and SCLP . Validate by Web Sensor Strand (WSS) co-registration prior to launch

# The Slow and Low Continuum of Remote Sensing Measurements

- The Web Sensor (slow and low) niche will build validity in new high resolution measurements from the bottom up
- With synchronous operation and precise position and beam pointing information we will help calibrate the global data set via sensor webs

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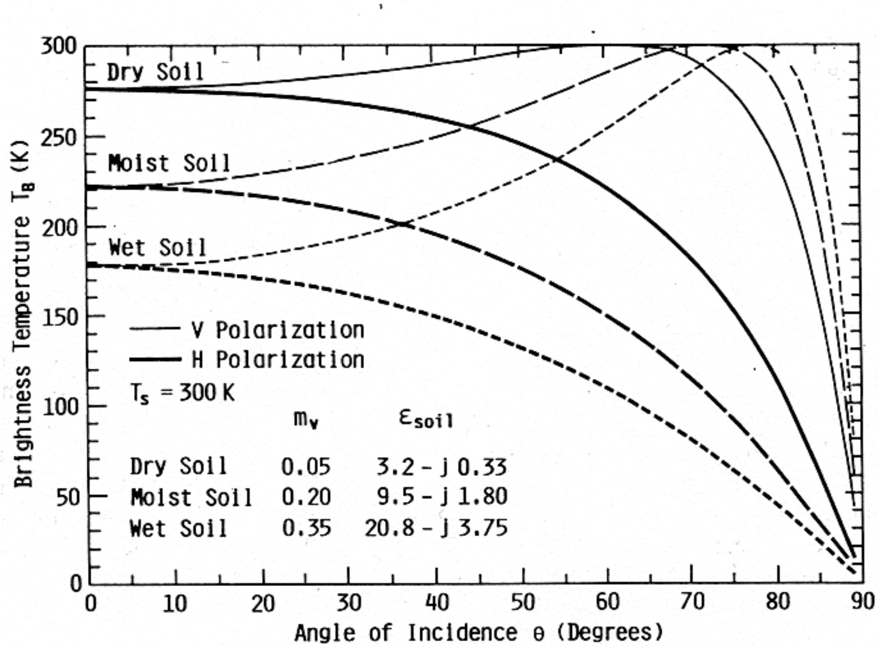
# Earth Science Measurement Needs

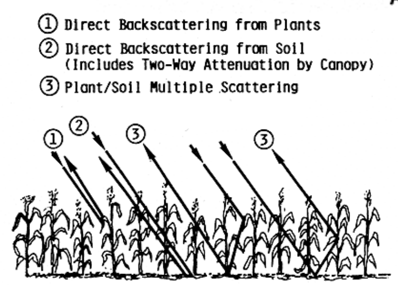
## Soil Moisture

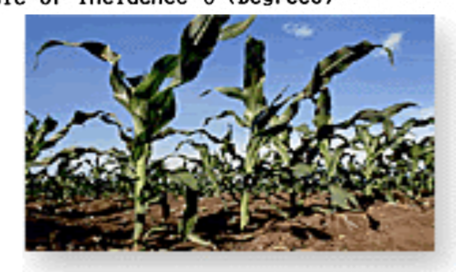
- Important for:

  *climate and weather forecasting*

- Measurement must include:
  - root-zone penetration depth (L-band),
  - variability in L-band $T_b$ with soil water content,
  - variability of L-band backscatter polarization with vegetation cover



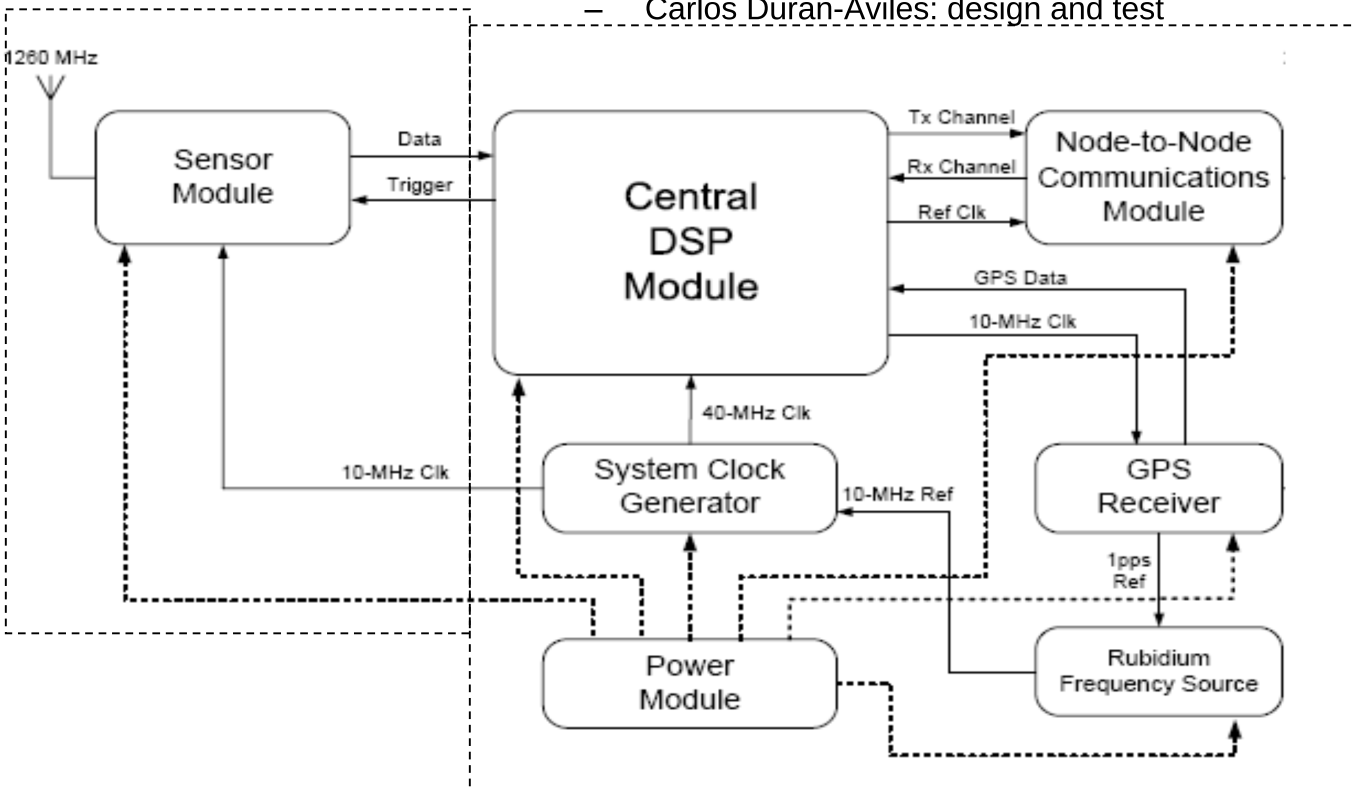



# The Expandable Reconfigurable Instrument Node (ERIN) Supernode or Road Warrior(RW)

- RW-Analog (RW-A)
  - Jared Lucey, Pete Young

- RW-Digital (RW-D)
  - Phyllis Hestnes, Damon Bradley, Kenda Newton: design
  - Carlos Duran-Aviles: design and test



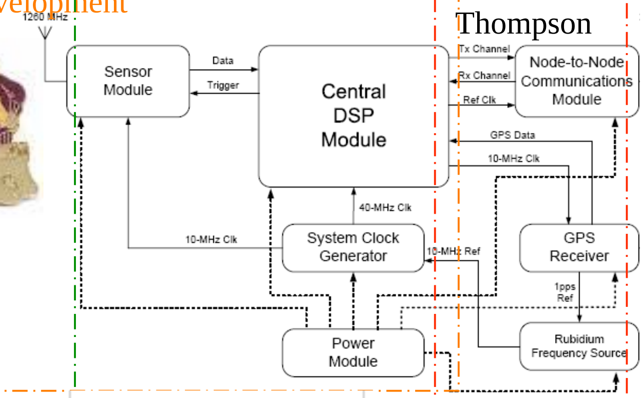
# Summer 2008
# Web Sensor Strand Team

Deshpande/
Piet
System Analysis and Test

GEORGETOWN UNIVERSITY

Hilliard/ Kablan - Mallik
H/W System Development

Greg
Heckler/
Willie
Thompson

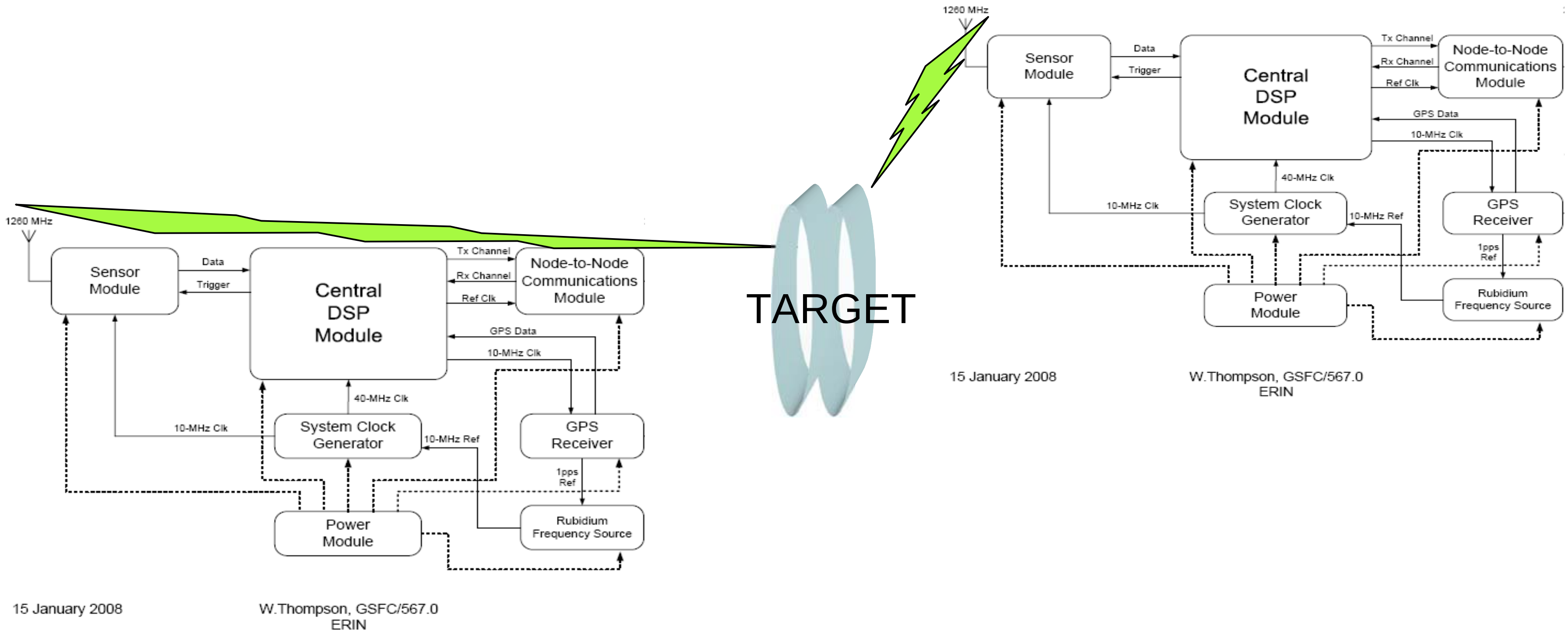



Linares /
Vega
Nassar

Hestnes/
Buenfil

Image Processing/
Graphical User
Interface

Refine and Adapt Analytical Model




# Systems Analysis Models

- Closed circuit test along a cable with known properties
- Anechoic chamber test with minimal noise and calibration targets with known properties
- Outdoor monostatic field test introducing natural noise and targets with predictable properties
- Outdoor bistatic field test also with natural noise and predictable targets

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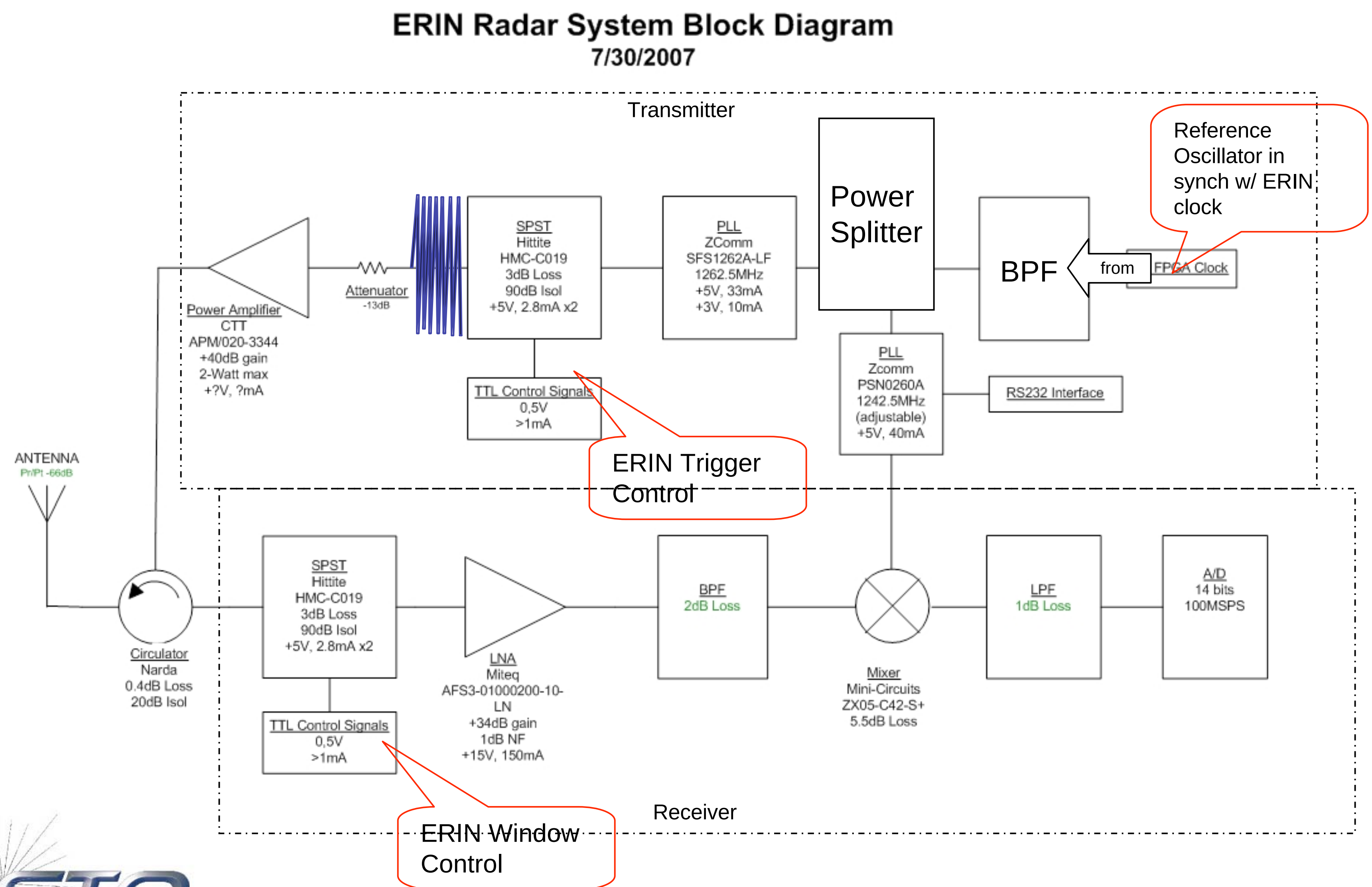
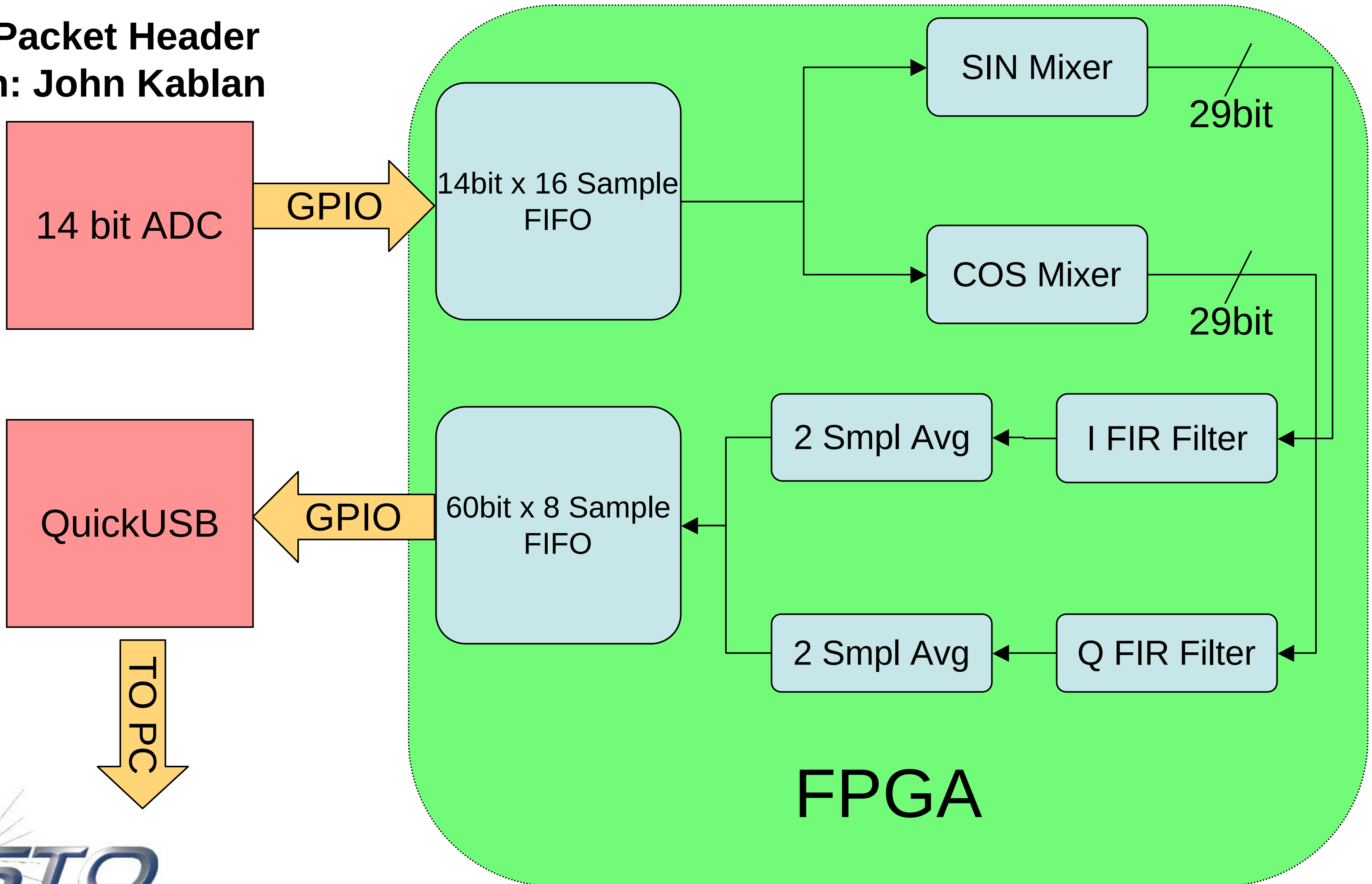
# ERIN Radar Block Diagram



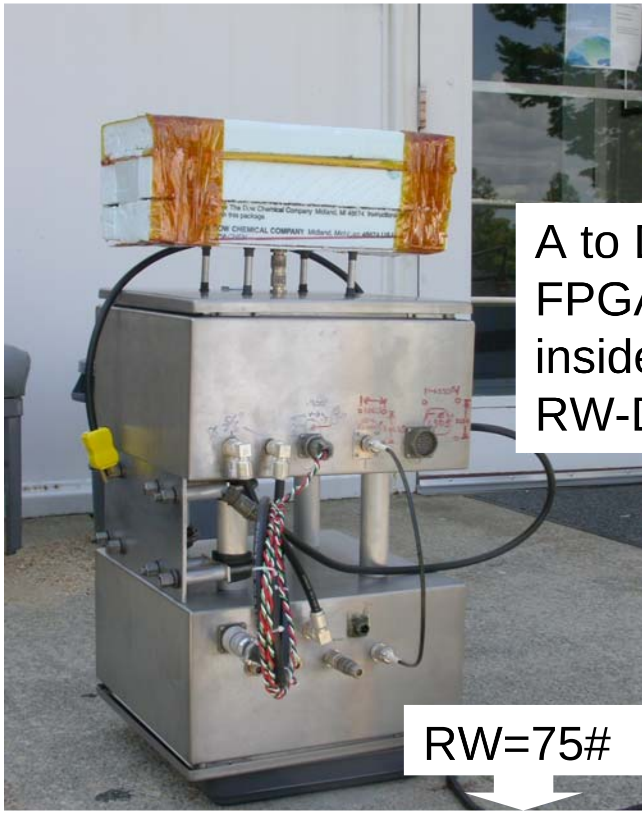
# Digital Signal Processor Block Diagram

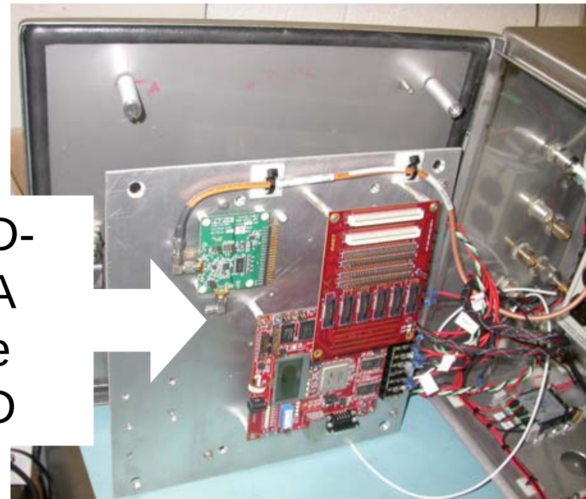
Radar Packet Data Handling
Design: Udayan Mallik

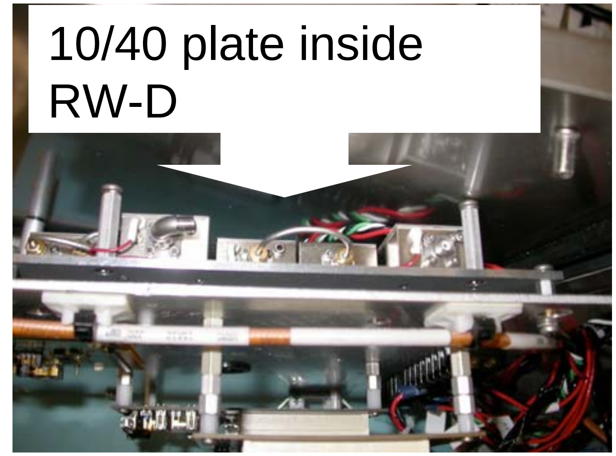
**Task- Packet Header**
**Design: John Kablan**



# ERIN Radar/FPGA aka “The Road Warrior”(RW) -Status

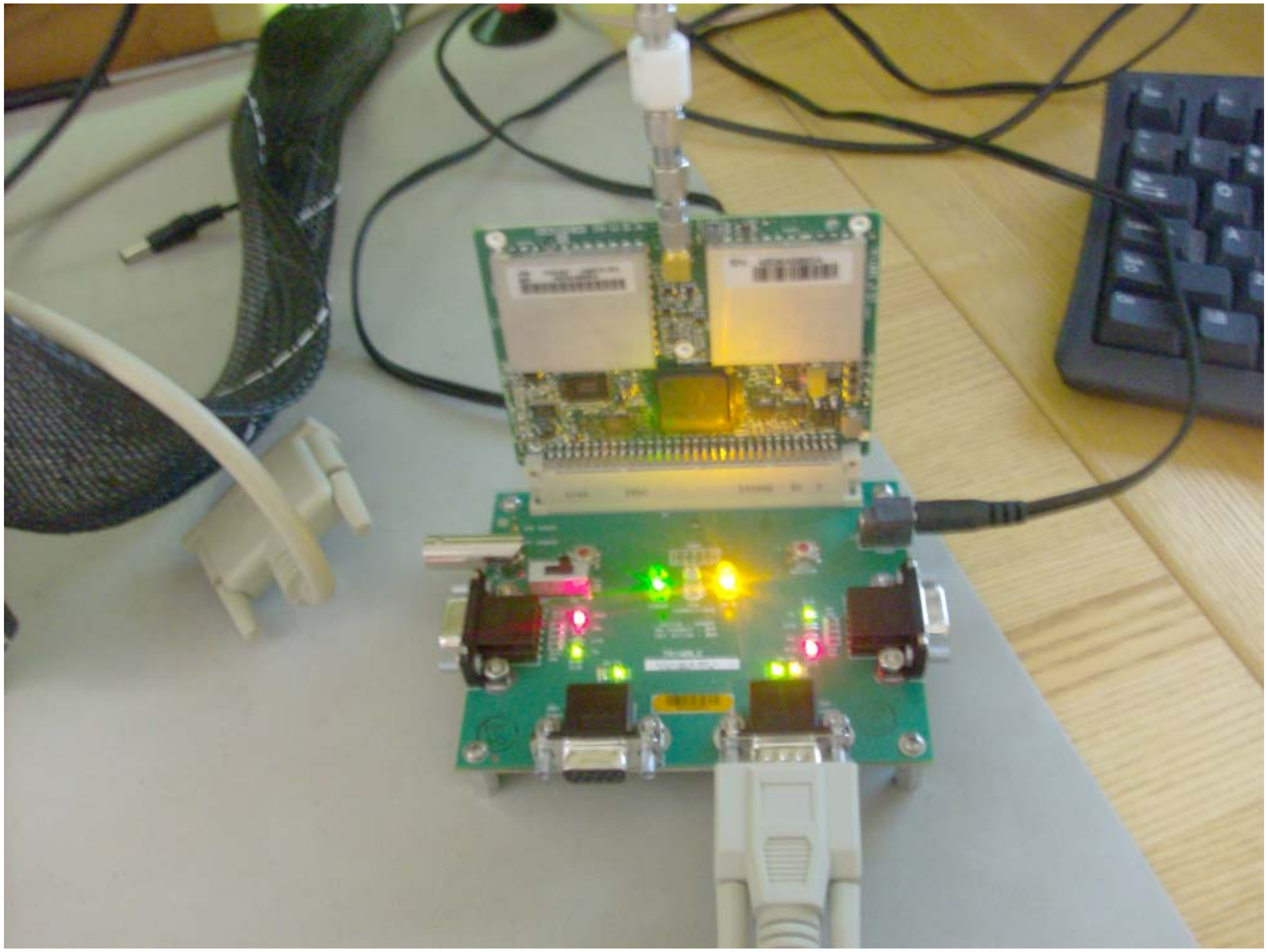


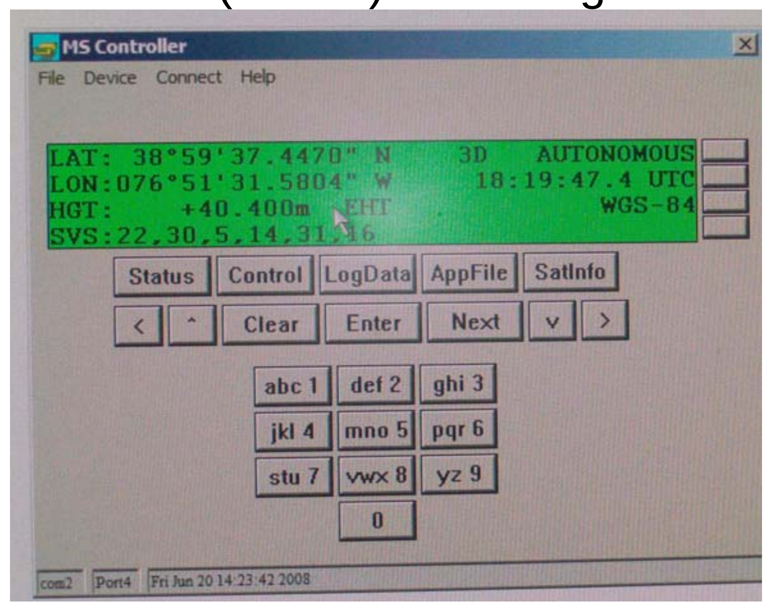

- The road warrior is headed for a June 2008 monostatic test in the Goddard anechoic chamber

Trimble- BD950 operating
- w/ Building 8 Base Station can achieve
Differential GPS Positions within 1cm



# More “Strand Team” Achievements

- BD950 successfully captured six satellites to calculate its latitude and longitude position
- BD950 successfully output a one pulse per second (1 PPS) strobe signal
- Results obtained by
  - **Nefertiti Nassar**
  - **Mentor: PI Irving Linares**
  - Task: Test ERIN GPS interfaces

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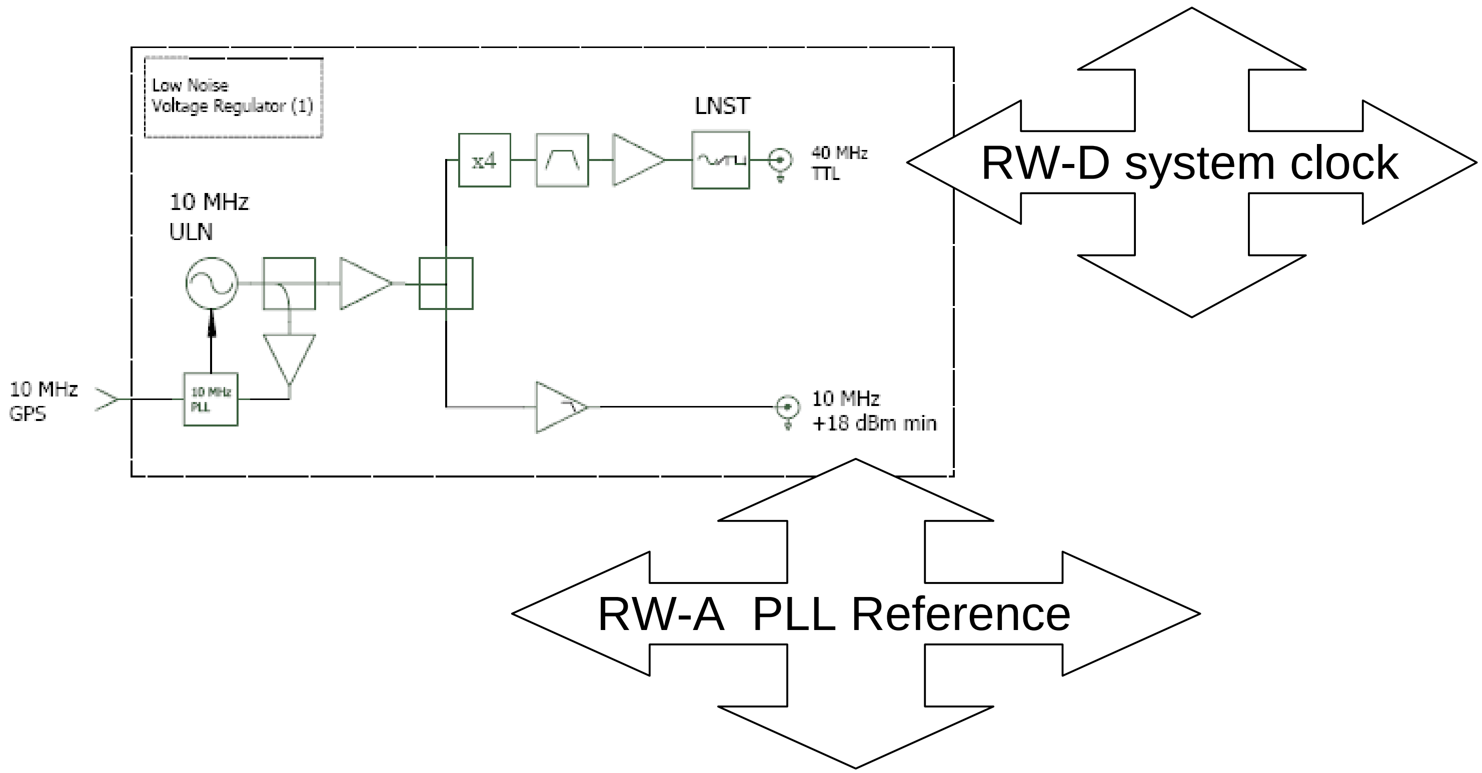
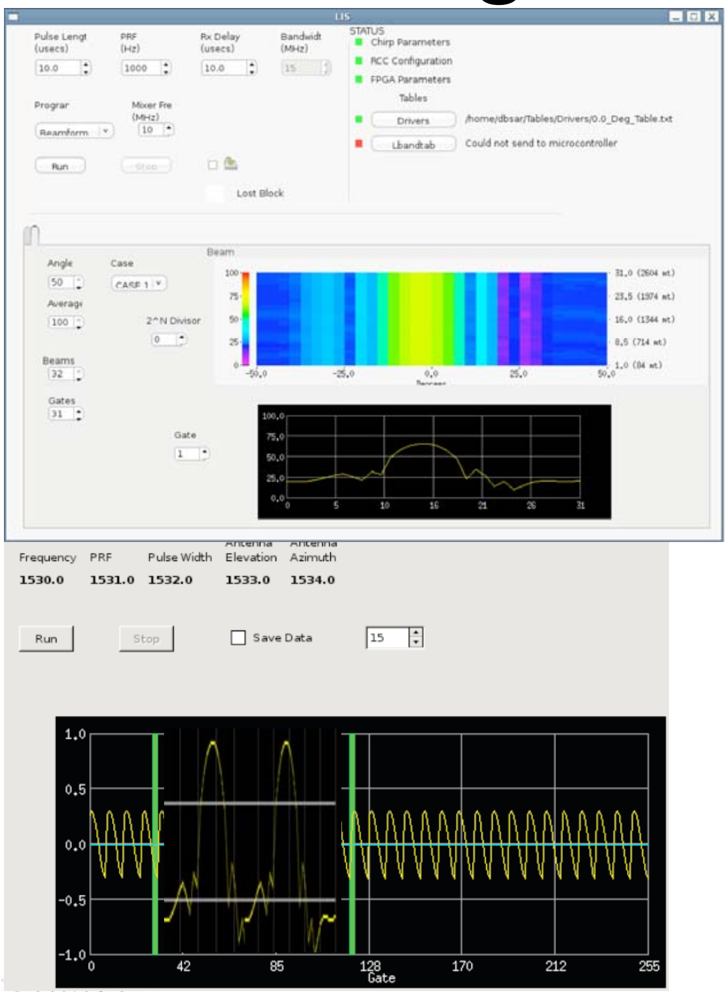
# Synchronous radar and digital clocks: Current work on RW/ Development System



# Graphical User Interface leverages off Digital Beamforming SAR




Graphical User Interface (GUI)

- Need one radar channel display for tower GUI:
  - include expected <u>2 way return time on horizontal scale</u> (~100 ns)
  - include <u>receiver dynamic range on vertical scale</u> (logarithmic (dB) representation that shows noise floor at bottom)
    - normal receive dynamic range
    - scaling from transmit dynamic range (~66dB up from expected return)
  - build with <u>pointers</u> to ephemeris generated expected returns:
    - yo-yo (monostatic)
    - Bounce pass (bistatic)
  - build with <u>window</u> around yo-yo and bounce pass representing opening return pulse gate and closing return pulse gate (10 ns increments of gate selectability)
  - window should return clutter outside it (before or after in time) to the noise floor (i.e. show that ERIN is gating it out)
- Need <u>playback</u> two radar channel display for tower node AND boom truck node simultaneously
  - purpose: analysis of simultaneity of transmit pulses
  - verification of web sensor strand methods/ validation of two-node data

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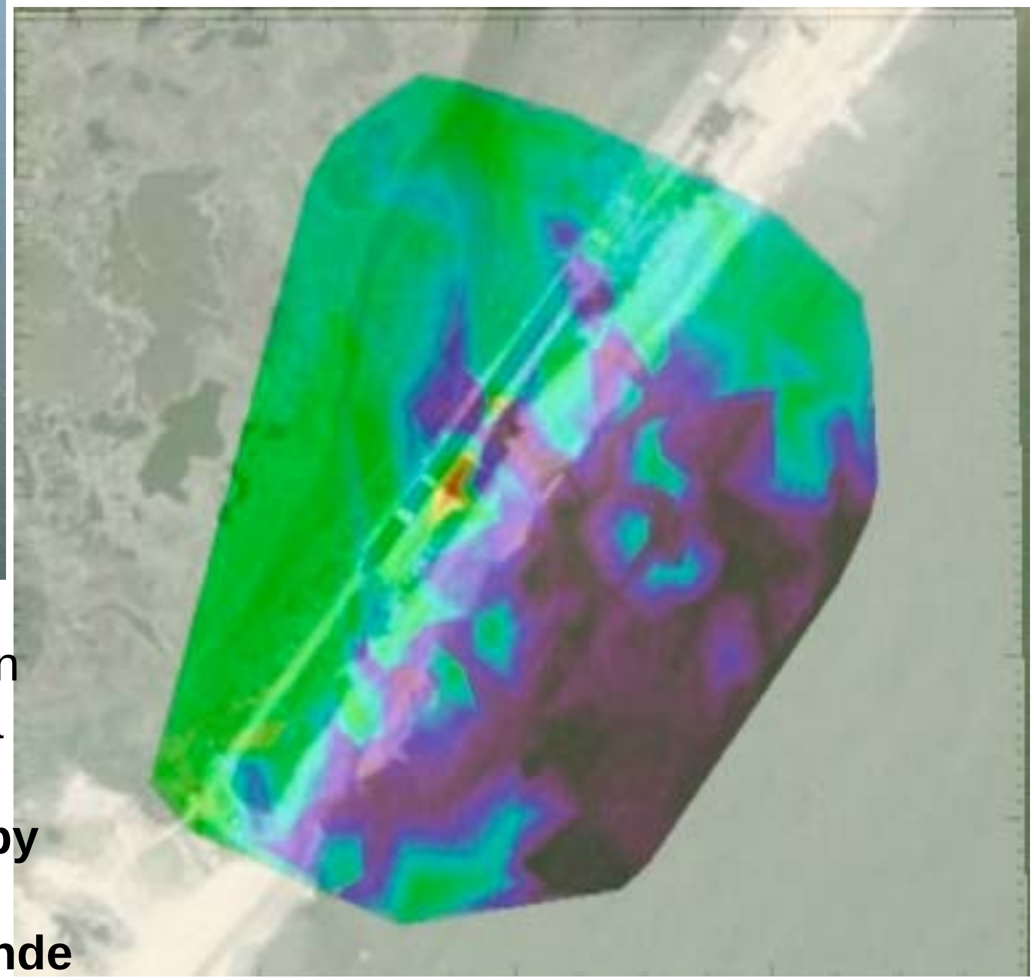
Results obtained by
Oscar Perez Cruz and Bill Van Biesen
Mentored by Larry Hilliard and Kenda Newton

**<u>Brightness Temperature Map</u> by David Piet**

**Mentor: Co-I Manohar Deshpande**

Task: Analyze and Test ERIN Measurement Models



June 18th, 2007 flight of L-Band radiometer

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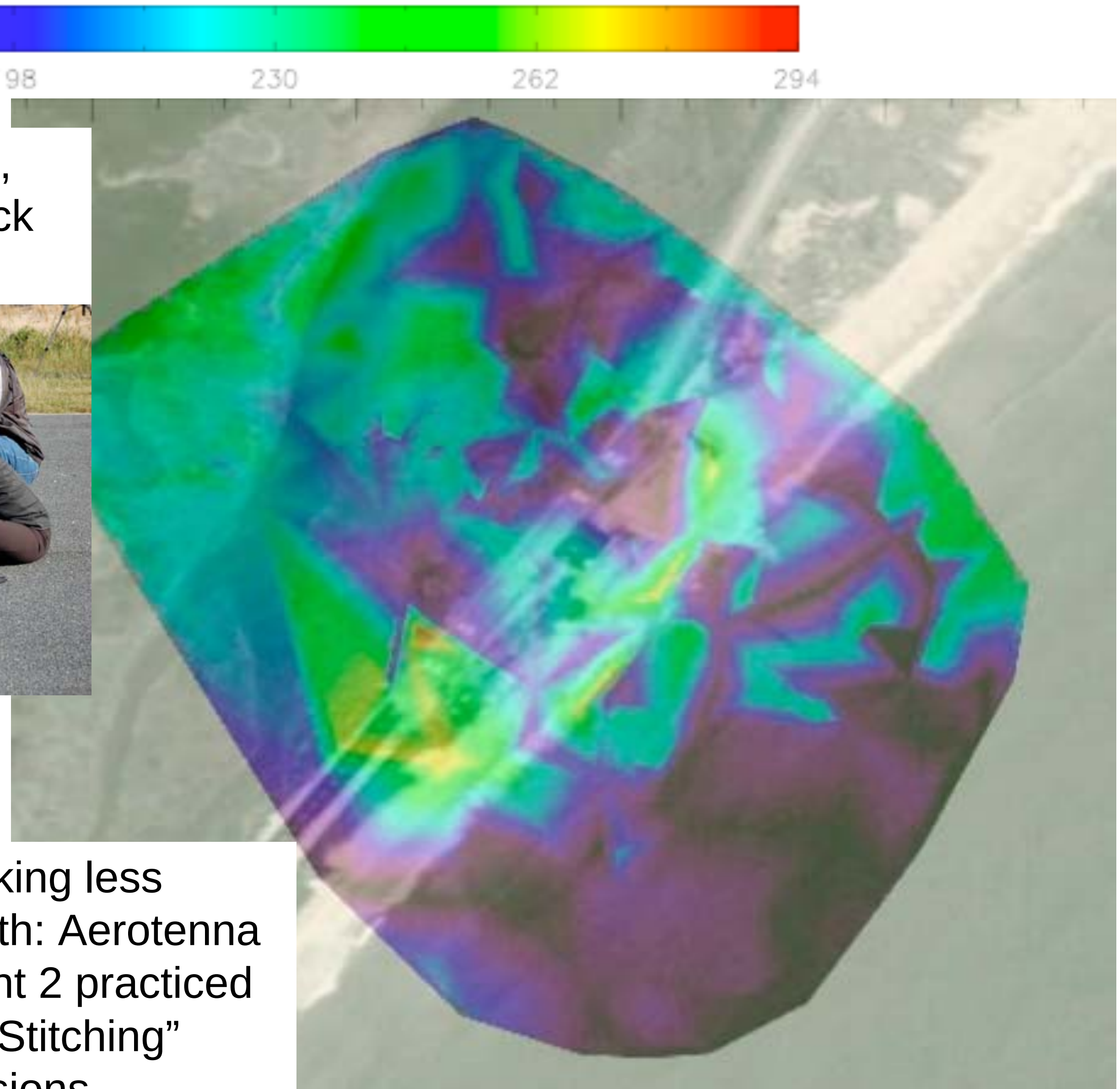


Jared Lucey , Kenda Newton, and Larry Hilliard brought back passive data from Wallops

Looking less South: Aerotenna Flight 2 practiced for “Stitching” Missions

# October 29th, 2007 Flight of L-Band Radiometer

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# Co-Registered Land Ocean measurements for Total Hydrology (CLOTH)

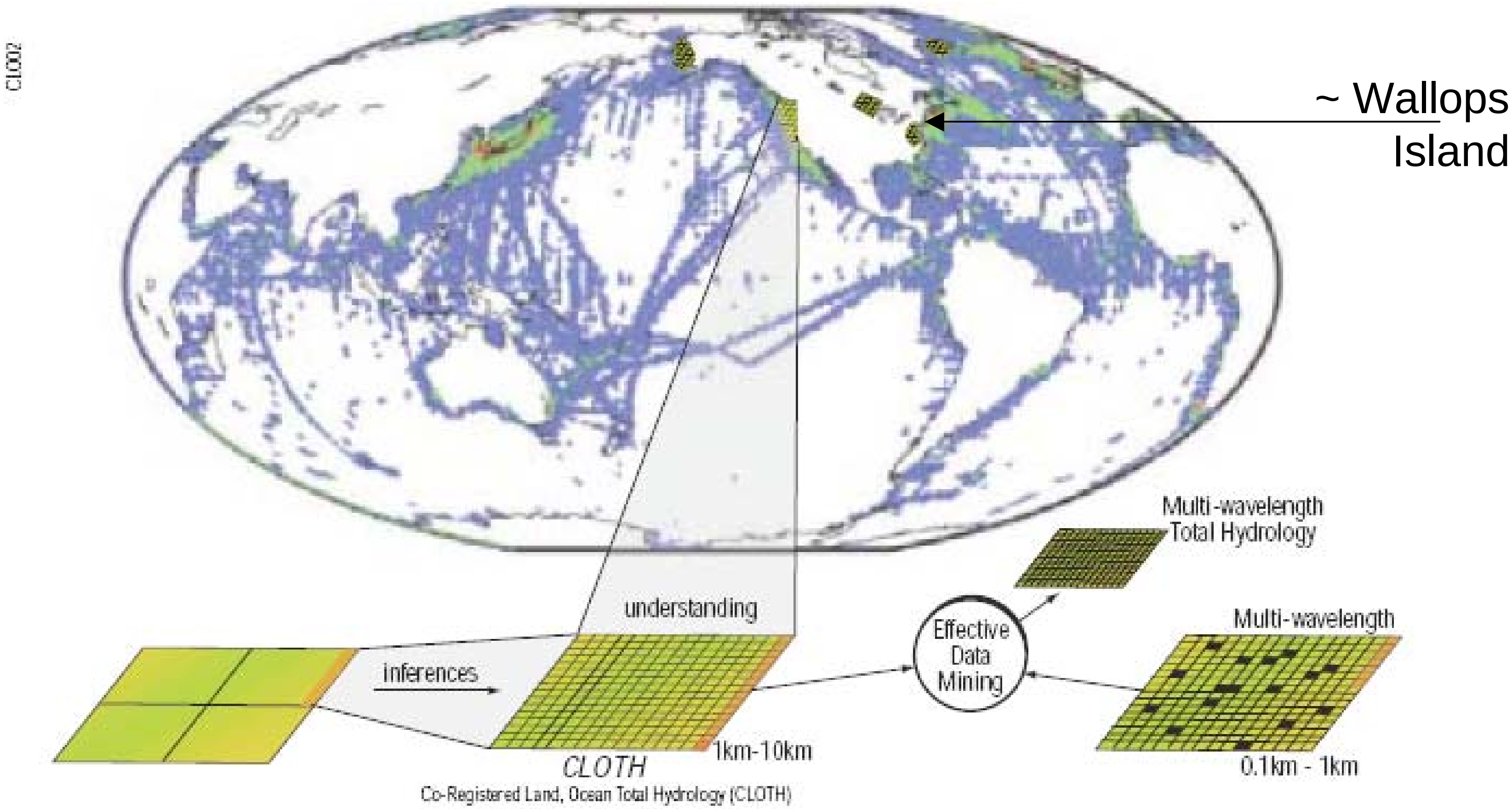


**Figure 2.** CLOTH–Using L-Band Measurements to Mine Data. [*Reference—100 years of Sea Surface Salinity (SSS) ground validation data–courtesy of ESSP Aquarius Project.*]

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# Next steps

- Monostatic Radar
- Bistatic Radar
  - w/ GPS Tags
  - w/IMU Tags
  - w/ DGPS
- Synchronous Bistatic Radar

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# Future Work(beyond AIST) and applications

- Interleaved Active Passive
- SMAP calibration
- Coastal Studies
- Snow – SCLP Use Case – SLUSH
- Sea Ice and Glaciers – DESDynI – STITCH

# Summary

- Slow and Low Niche for ERIN Concept in earth science hydrology
- Technology payoff in miniaturized versions
- Further technology payoff in "rad-hard versions w/o GPS available" requirement

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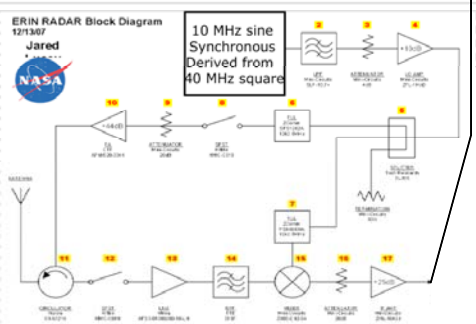
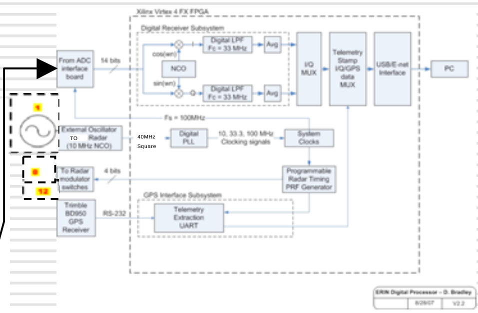
# Expandable Reconfigureable Instrument Node

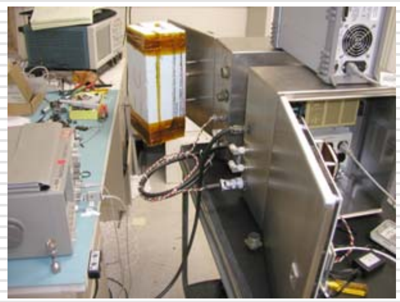
# and the Web Sensor Strand

ERIN: At the center of the node, ERIN synchronizes & modulates pulses, captures returns, closes out radar clutter, tags data with time, position and bearing of the beam



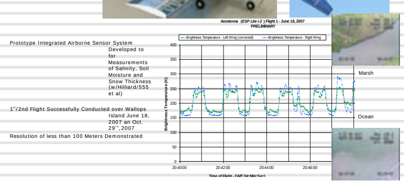




This fast radar enables the platform to be close to the ground by "gating out" clutter from unintended returns



The "Road Warrior": These two stainless steel boxes take the ERIN Control System and the radar development hardware to a relevant environment. There the synchronous strand can be demonstrated.

MultiProbe Use Case: L-Band Radiometer demonstrated on 12lb. UAV w/Radar … coming soon to Measure Fresh and Saltwater content of coastal areas (SMAP)

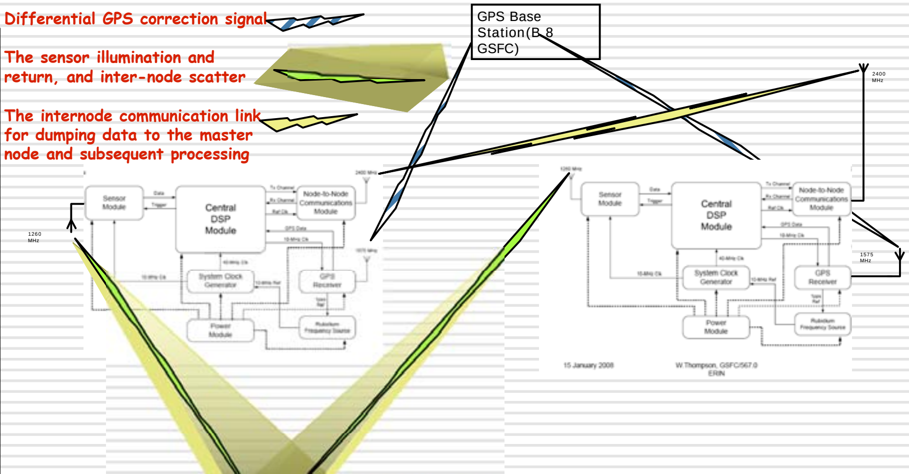


The "Web Sensor" Legend

Differential GPS correction signal

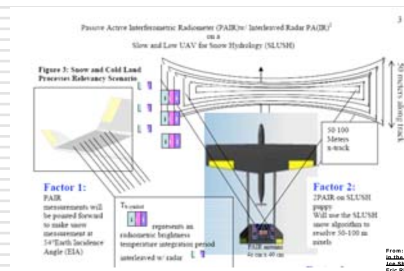
The sensor illumination and return, and inter-node scatter

The internode communication link for dumping data to the master node and subsequent processing




The "Strand": These two overlapping spots when synchronously illuminated by both nodes at 1.26 GHz, can be synthesized with other "shots" to form a huge array by their movement around the target (water, snow, sea ice)

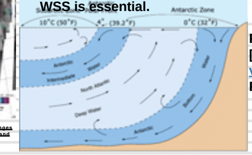
SLUSH Use Case: Passive Active Interferometric Radiometer w/Interleaved Radar PA(IR)² to Measure Snow Water Equivalent under canopy

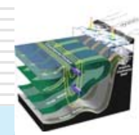


STITCH Use Case: PA(IR)² to measure Sea Ice retreat and density(Age). Sea-level rise @ headwaters

From: Science 17 February 2006: Changes in the Velocity Structure of the Greenland Ice Sheet
Eric Rignot-JPL and Pannir Kanagaratnam-CReSIS

The Ocean's deepest coldest water, comes from 2 parts of the earth. Coverable by a small platform DB-SAR/Aquarius like instrument flying low and slow. ERIN-WSS is essential.





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Related to Rignot charts


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The 2008 ESTO AIST-05 Sensor Web PI Meeting – Orlando, FL
April 2-3, 2008


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