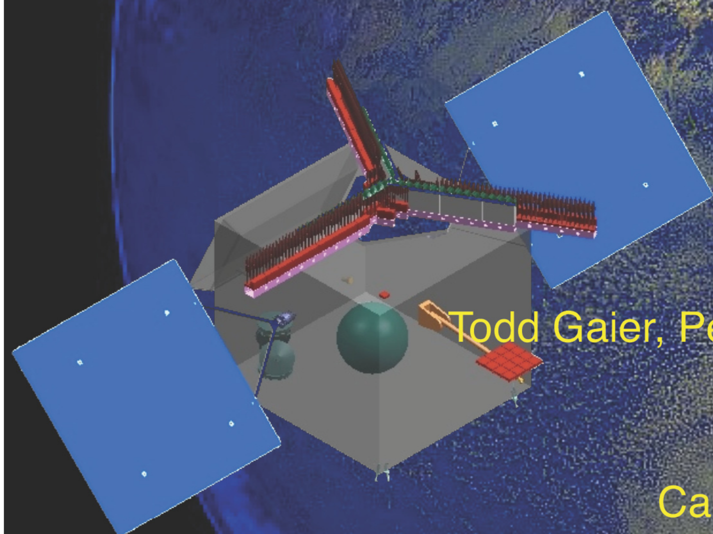
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

GeoSTAR

and the geosynchronous microwave sounder mission



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Why GEO Microwave Sounders?

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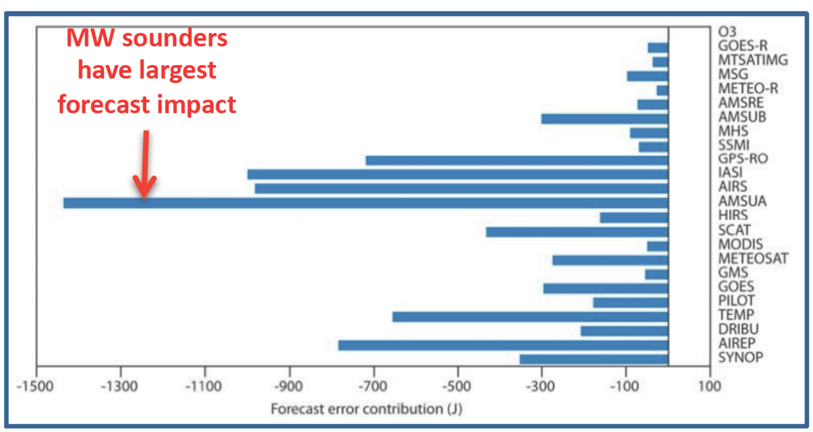
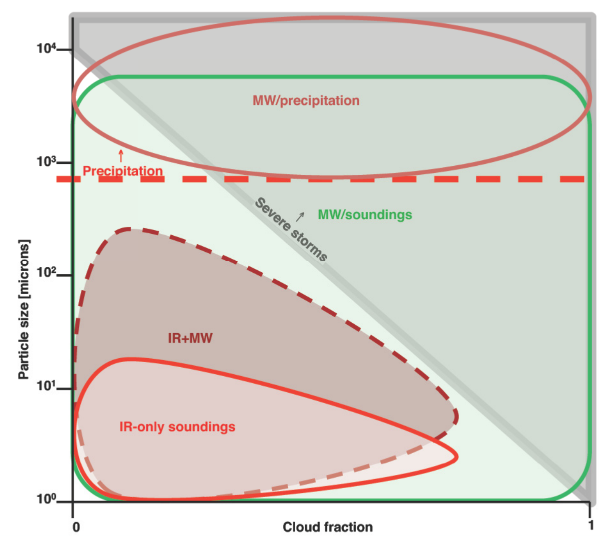
- **GEO sensors achieve high temporal resolution**
  - LEO: Global coverage, but poor temporal resolution; high spatial res. is easy
  - GEO: High temporal resolution and coverage, but only hemispheric non-polar coverage
  - Requires equivalent measurement capabilities as now in LEO: IR & MW sounders
- **MW sounders measure quantities IR sounders cannot**
  - Meteorologically "interesting" scenes: Full cloud cover; Severe storms & hurricanes
  - Cloud liquid water distribution
  - Precipitation & convection
- **MW sounders complement IR sounders**
  - Complement primary IR sounder with matching MW sounder
  - Microwave provides cloud/"cloud-clearing" information
- **A MW sounder is one of the most desired GEO payloads**
  - High on the list of unmet capabilities
  - Largest number of high-value applications

MW sounders are key sensors for NWP



MW sounders are excellent storm sensors



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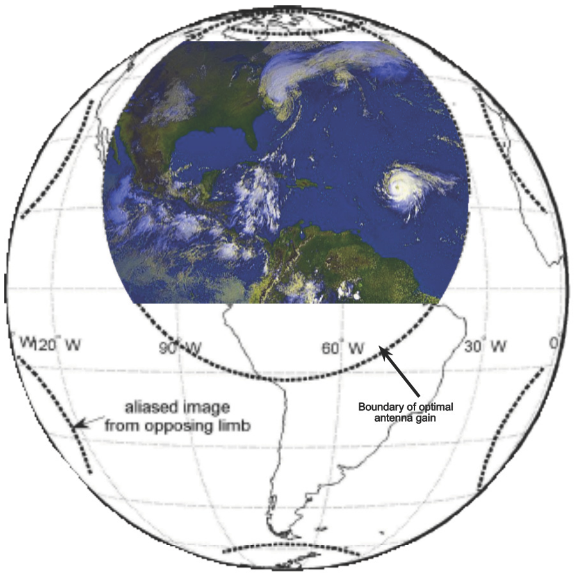
GEO/MW applications



Hurricanes - Severe storms - Moisture flow - Hydrologic cycle - Climate

Weather forecasting -Improve regional forecasts; severe storms

- All-weather soundings, including cloudy and stormy scenes
- Full hemispheric soundings @<50/25 km every ~ 15-30 minutes (continuous)
- "Synoptic" rapid-update soundings => Forecast error detection; 4DVAR applications

Severe-storm diagnostics -Quintessential hurricane sensor

- Scattering signal from convection easily measurable
- Measure *location*, *intensity* & vertical *structure* (incl. *shear*) of deep convection
- Detect *intensification/weakening* in real time, frequently sampled (< 15 minutes)
- Measure all three phases of water: vapor, liquid, ice - including rain/snow
- Use for operational analysis & in research to improve microphysics of models

Rain -Complements current capabilities

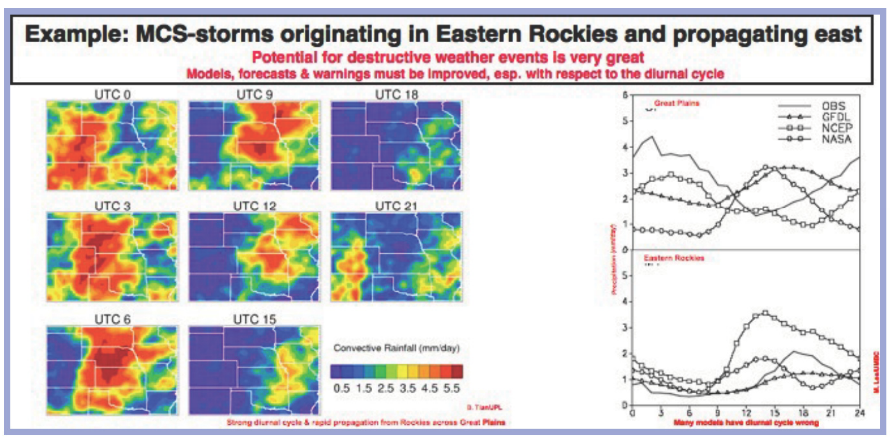
- Full hemisphere @ $\leq$ 25 km every 15 minutes (continuous) - both can be improved
- Directly measure storm and diurnal *total rainfall*: predict flooding events
- Measure *snowfall*, light rain, intense convective precipitation

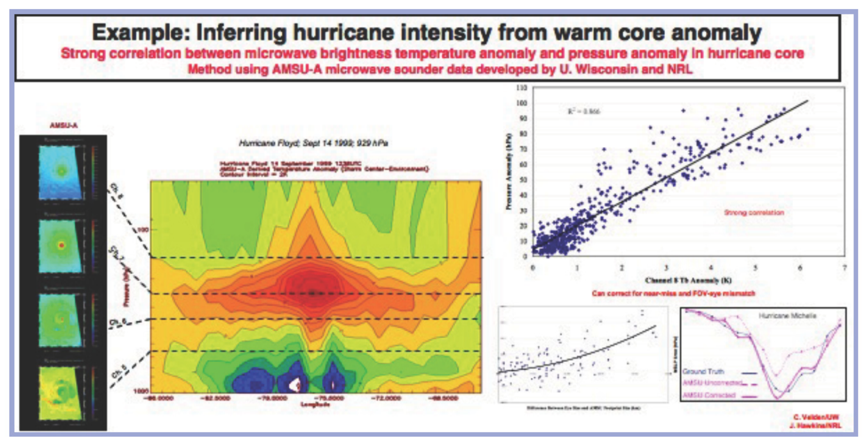
Tropospheric wind profiling -NWP, transport applications

- Surface to 300 mb; very high temp.res.; in & below clouds
- Major forecast impact expected (OSSE planned) - particularly for hurricanes
- Air quality applications (pollution transport)

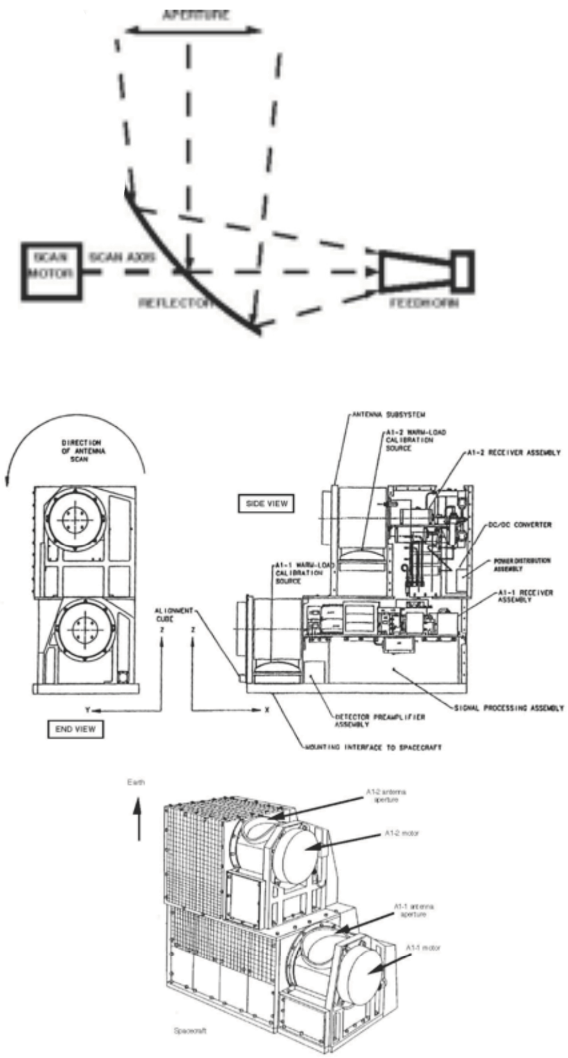
Climate research -Hydrology cycle, climate variability

- Stable & continuous MW observations => Long term trends in T & q and storm stats
- Fully resolved diurnal cycle: water vapor, clouds, convection
- ENSO observer: Continuous observations from "warm pool" to Pacific coast under all conditions
- "Science continuity": PATH $\approx$ AMSU (currently operating LEO sounders)





The problem: Need large aperture



Low-earth-orbiting MW sounder (AMSU)

The antenna is the key…

- Antenna size is determined by distance and "spatial resolution"
- AMSU antenna is 15 cm dia. ⇒ 50-km resolution from 850 km
- GEO orbit is ~36000 km ≈ 42 x 850 km
- AMSU-antenna must then be 42 x 15 cm to give 50-km res. from GEO
- This is 6.5 meters! Not feasible!
  This can be reduced somewhat by degrading the antenna efficiency - but still impractical
- Solution: *Synthesize* large antenna ⇒ GeoSTAR

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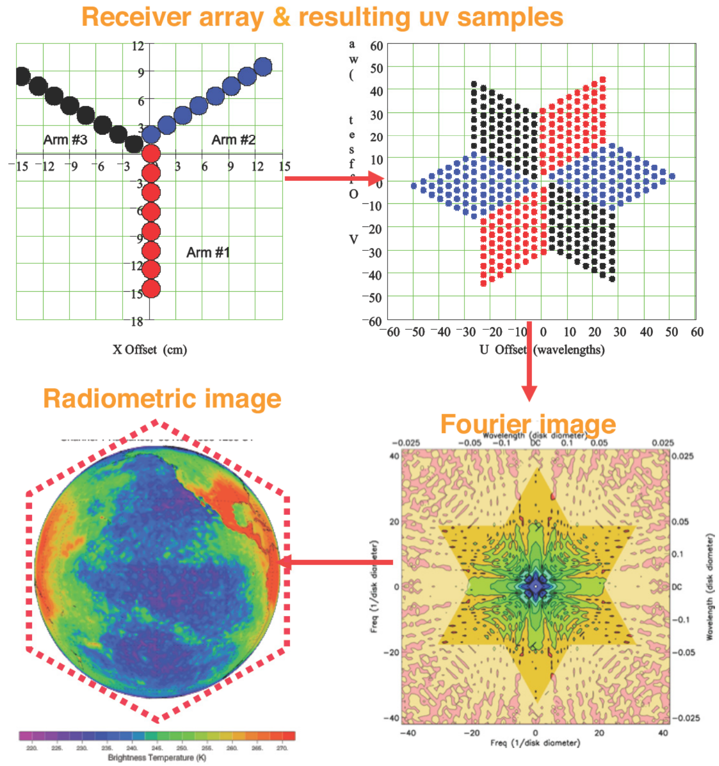
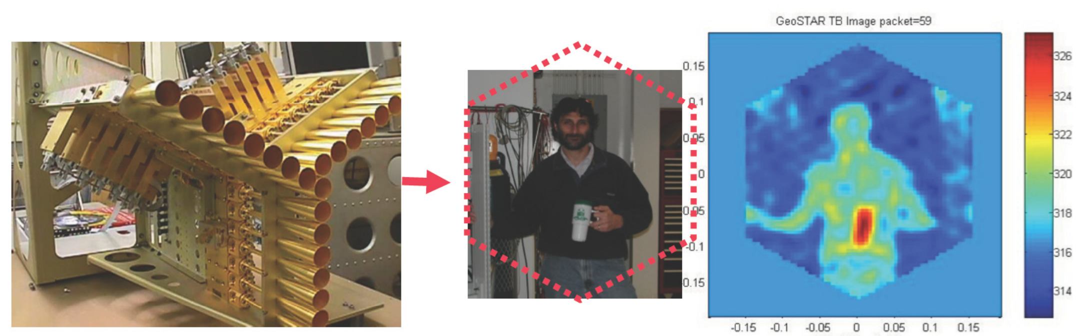
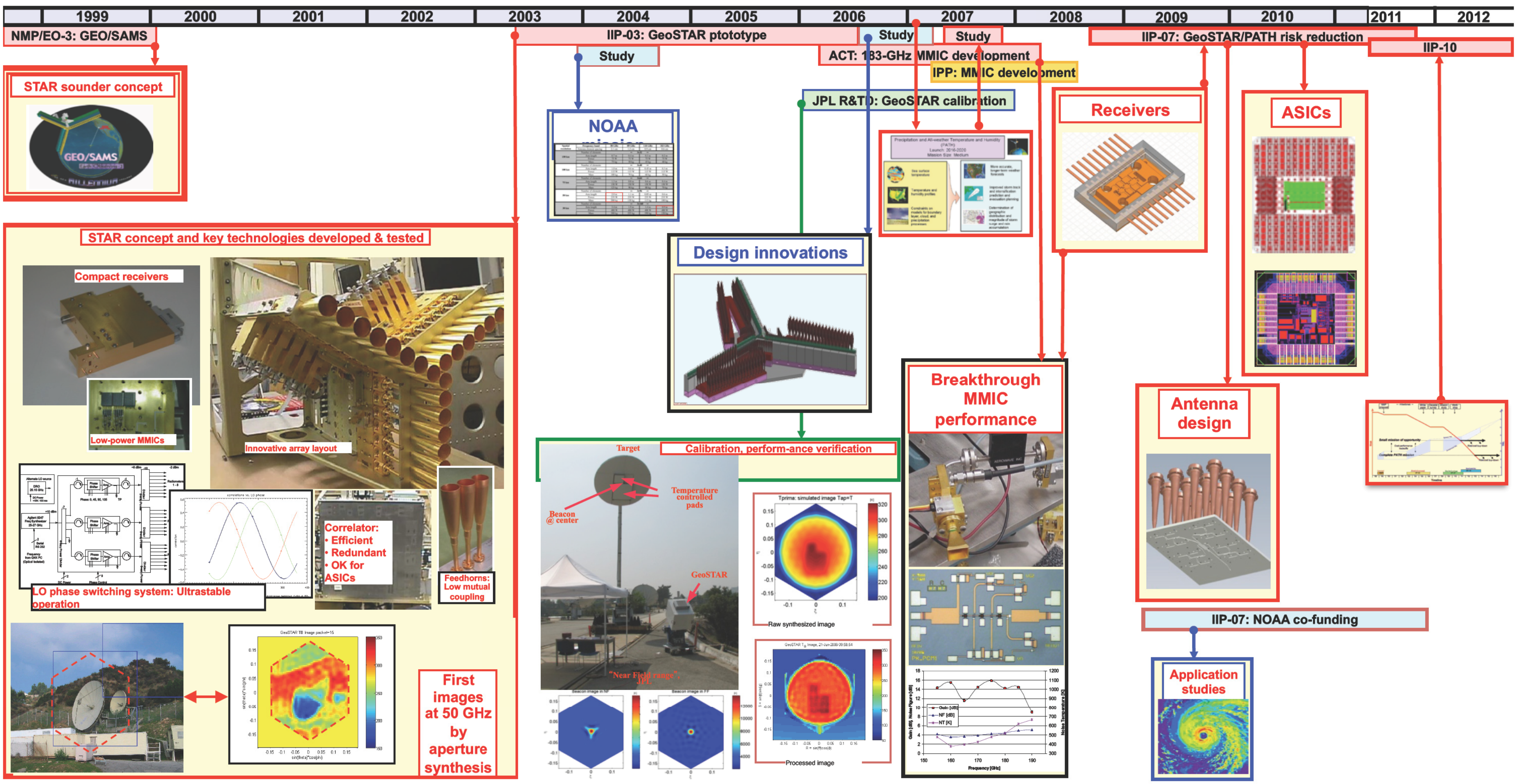
The solution: GeoSTAR

- Problem: How to develop a microwave sounder for geostationary orbit?
  - Need: Time-continuous all-weather observations of the atmosphere
  - Challenge: Achieve adequate spatial resolution from 37,000 km
- Solution: Aperture-synthesis concept
  - Can make a very large aperture w/out large parabolic dish antenna
  - Sparse array employed to synthesize large aperture
  - Spatial interferometry -> Fourier transform of Tb field
  - Inverse Fourier transform on ground -> Tb field
  - Bonus: No moving parts, simultaneous 2-D "synoptic" imaging
- Design: Sparse array - GeoSTAR
  - Optimal: Y-configuration; 3 "sticks"; 100-200 elements each
  - Each element = I/Q receiver, ~4λ wide (6 mm @ 183 GHz!)
  - Example: 100/arm ⇒ Pixel = 50 km at nadir ≈ LEO sounders
  - One "Y"-array per sounding band, interleaved
- Proof of concept
  - Ground-based prototype under NASA/ESTO/IIP, 2003-2006
  - Performance is excellent & as predicted => Proof of concept
- Risk reduction for space mission
  - Further technology development under IIP, 2008-2010
  - Mission design studies
- "PATH" decadal-survey mission
  - Precipitation and All-weather Temperature and Humidity
- "GeoStorm" Venture mission
  - GeoSTAR-lite
  - Hosted payload under Ventures EV-I
  - Multi-national collaboration
  - Ready to start in 2012
  - Launch ~2017-18





GeoSTAR Development History



Total investments in GeoSTAR concept & technology now approaching $15M

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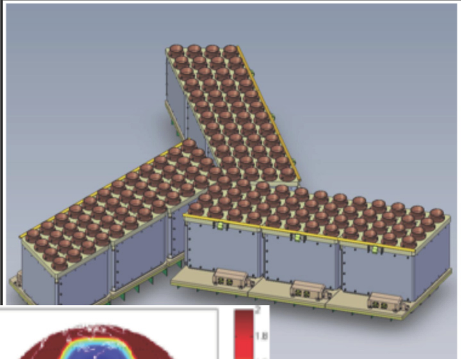
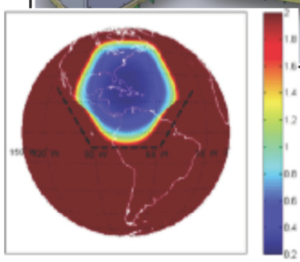
Recent GeoSTAR developments

New antenna design (demo)



- Develop 50 low-noise 183-GHz receivers
- Develop 3 2x8-element receiver sub-array modules
- Develop low-power Application-Specific Integrated Circuit (ASIC) correlator chips
- Develop low-mass/power signal distribution system
- Develop functional 183-GHz 2D STAR prototype

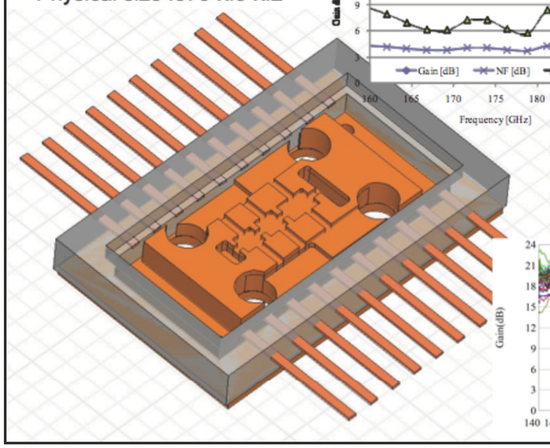


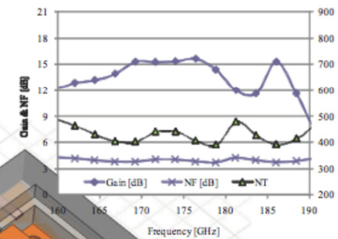
⇐ Sharply bounded FOR

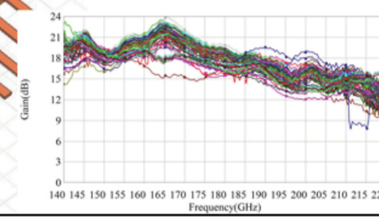
Large alias-free region
NEDT < 1/3 K

183-GHz receiver (fab 50 samples)

- Conversion gain 10 dB
- Power consumption <60mW
- Mass <3g
- Physical size .375"x.3"x.2"



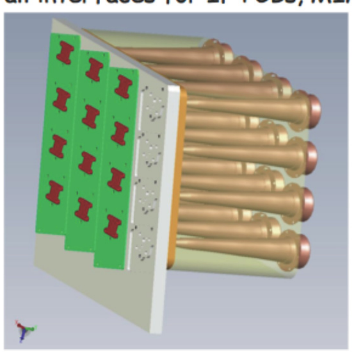


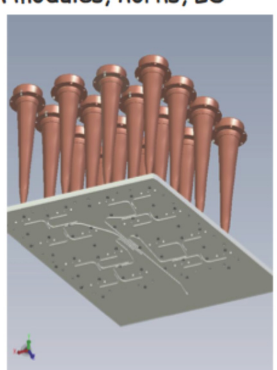


Array submodules (fab 3 samples)

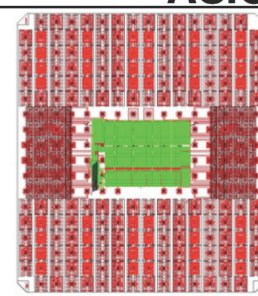
Manifold is structural basis of GeoSTAR sub-array which integrates:

- WR10 Local Oscillator distribution
- WR5 "twists" (+/- 60 degree and 0; unique to ea array)
- WR5 circular transitions
- all interfaces for IF PCBs, MIMRAM modules, horns, LO

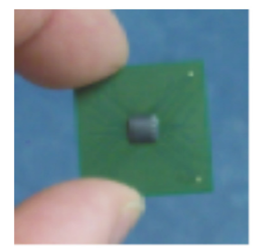


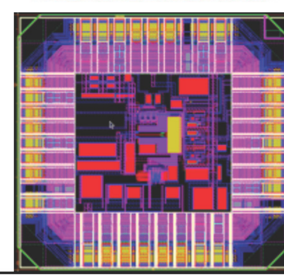


ASICs (small demo chips)

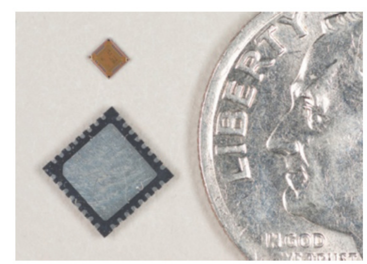


Correlator chip





ADC chip



The "GeoStorm" mission

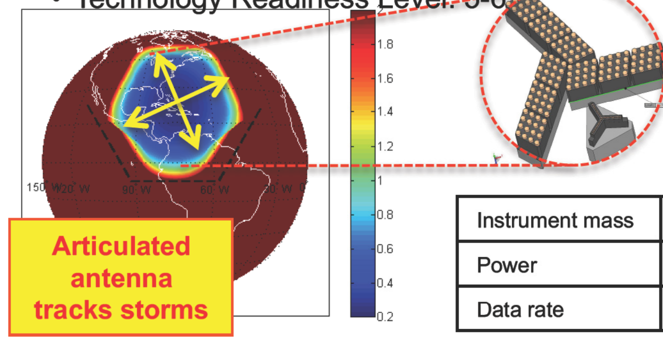
A GEOSTATIONARY MICROWAVE SOUNDER MISSION FOCUSED ON THE EVOLUTION OF STORMS

Science: Life-cycle storm physics

- *Address critical aspects of hurricane and severe storm behavior that are not revealed by existing observing systems*
- PI: Bjorn Lambrigtsen, JPL
- Science Team: Universities, NASA, NOAA, Sweden, Italy
- Relevance:
  - Complements next-gen GEO IR-systems
  - Ports AMSU (POES/Metop) capabilities to GEO
  - Large operational & research user community
  - Addresses theme of multi-national concern: **severe storms in a warming climate**
  - Cloud-penetrating storm life-cycle observations will significantly advance our capabilities and ability to make progress
  - Understanding dynamic moisture-cloud-precipitation processes is high priority in Energy and Water cycle climate science

Instrument: GeoSTAR-lite

- *Microwave sounder; Y-shaped steerable antenna, large synthesized aperture.* Sensitivity: < 0.5 K. Measure T-profile and q-profile
- Technology Readiness Level: 5-6



Instrument mass	~ 100 kg
Power	~ 150 W
Data rate	< 100 kbps

Partnerships: US + Sweden + Italy + ??†

Sweden: contributing instrument subsystem
- Interest: Technology, relevant to European GEO/MW STAR

Italy (ASI): contributing instrument subsystem
- Interest: Technology & storm science

Additional international partnerships being explored
- Discussions with ESA/ESTEC under way
  - Possible synergy with European GEO/MW STAR design
- Collaboration with Eumetsat being explored

Benefits to partners:
- Complements partner's other satellite systems
- Prototyping of future systems, demo new capabilities
- Provides ability to target science of particular interest
- Access to cutting-edge observational data
- Jointly leverage technology strengths in US and Europe

† Definitive commitments by potential partners pending

Programmatics: NASA Venture EV-I

ROM instrument cost: ~ $120M
- NASA: $90M
- Est. value of partner contributions: $30M†

Launch readiness date: 2016-17
- Hosted on GEO partner mission – *looking for opportunities*

Implementation:
- System design & assembly: JPL
- Select subsystems provided by partners
- Data system & science: JPL + NOAA + partners
- Option: Add partner-specific features (e.g., ESA rotating array)

Opportunities:
- Strengthen mission with science & technology collaboration
- Pathfinder for future GOES, Meteosat and similar missions
- Enhanced mission through partnership contributions

† Based on informal discussions

GeoStorm objectives

A COMPREHENSIVE STUDY OF THE EVOLUTION OF THE THERMODYNAMICS AND STRUCTURE OF STORMS

Pressing storm issues:

- Frequency and intensity of severe storms may be increasing as the climate changes
- Current models do not represent storm dynamics, microphysics & diurnal cycle well enough
- Current observing systems do not adequately capture rapidly forming/changing storms

Overarching science goals:

- GeoStorm will answer key questions about storm evolution, filling an observing gap of long standing. The required technology is now ready
- GeoStorm will, for the first time, provide *time-continuous cloud-penetrating life cycle* observations of tropical cyclones and severe storms
- This will enable major progress in the understanding of storm processes and their time dependence, leading to improved model performance at all time scales

Science questions:

- How does the evolution of tropical cyclones and severe storms depend on changing environmental conditions, and what are the feedbacks involved?
- Which environmental factors in a changing climate might cause more frequent or more intense storms, and how can these relationships be observed and characterized?
- What conditions lead to rapid intensity changes in severe storms, and how can we use frequent observations to improve model representation of highly dynamic storm processes?
- What processes control cloud formation, convection and precipitation from hourly to monthly time scales, and what is their their role in weather and climate processes?

GeoStorm data products

GeoStorm will make similar measurements from GEO as AMSU currently does from LEO, but every 30 minutes vs. 2 times per day

High-intensity events can be sampled in 5 minutes or less

Baseline products:

Parameter	Horizontal	Vertical	Temporal	Accuracy	Thermodyn	Microphys	Dynamics
Temperature	< 50 km	2 km	< 30 min	1.5 K	√		
Water vapor	25 km	2 km	< 30 min	25%	√		
Stability index	< 50 km	N/A	< 30 min	N/A	√		
LWC	25 km	N/A	< 30 min	20%	√		
Rain rate	25 km	N/A	< 30 min	2 mm/hr	√	√	
Reflectivity	25/50 km	1-2 km	< 30 min	3-6 dBZ		√	
IWC	25 km	N/A	< 30 min	30%	√	√	
Wind vector	25 km	2 km	< 45 min	TBD			√

Note: Added-cost enhancements can improve spatial resolution and/or reduce cycle time

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Summary and the path forward

The time has come for a geostationary microwave sounder
- US and Europe have made great strides in developing the required technology
- Technology is sufficiently mature that a space mission can be initiated now
- The value of a GEO/MW sounder is indisputable
- The potential synergy with a GEO/IR sounder is great and timely

The NASA Venture program is a promising vehicle
- EV-I opportunities every year
- Designed to invite collaborations
- Intended for low-cost hosted-payload opportunities

What's next
- Develop broad partnership with ESA/ESTEC
- Obtain Eumetsat backing and sponsorship
- Find committed access to space (hosting mission)
- Submit collaborative proposal early 2012. Win!

We invite you to partner with us on a great step forward in remote sensing and storm science

Why partner?
- Showcase US and European technology & capabilities
- Participate in making a great stride forward in remote sensing
- Demonstrate new low-cost "hosted-payload" paradigm
- Advance science important to" environmental security"

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