Getting the GeoSTAR instrument concept ready for a space mission

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GeoSTAR timeline

• Concept: NMP/EO-3 (1998-1999)
• Proof-of-concept prototype: IIP-03 (2003-2006)
• PATH mission: NRC Decadal Survey (2007)
• Key technology: IIP-07 (2008-2011)
• Risk reduction: IIP-10 (2011-2014)
• Venture mission: 2012-2017?
• PATH mission: ~202X?
Why GEO Microwave Sounders?

- **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
Low-earth-orbiting MW sounder (AMSU)

The problem: Need large aperture

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
GeoSTAR Development History

NMP EO-3: STAR concept
GeoSTAR Development History

IIP-03: Proof of concept

Partnership with NOAA: Mission study

<table>
<thead>
<tr>
<th>Spatial resolution</th>
<th>Frequency band</th>
<th>50 GHz</th>
<th>89 GHz</th>
<th>118 GHz</th>
<th>183 GHz</th>
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<td>Antenna element spacing</td>
<td>2.1 cm</td>
<td>1.2 cm</td>
<td>0.9 cm</td>
<td>0.6 cm</td>
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STAR concept and key technologies

- Compact receivers
- Low-power MMICs
- LO phase switching system: Ultrastable operation
- Correlator: • Efficient • Redundant • OK for ASICs
- Feedhorns: Low mutual coupling
- Innovative array layout

Partnership with NOAA: Mission study

First images at 50 GHz by aperture synthesis

NOAA mission
GeoSTAR Development History
Calibration & performance assessment

- STAR sounder concept
- STAR concept and key technologies developed & tested
- Compact receivers
- Low-power MMICs
- Innovative array layout
- LO phase switching system: Ultrastable operation
- Correlator:
  - Efficient
  - Redundant
  - OK for ASICs
- Feedhorns:
  - Low mutual coupling
- First images at 50 GHz by aperture synthesis
- NOAA
Sidebar:

The High Altitude MMIC Sounding Radiometer (HAMSR) was developed under IIP-98, upgraded under AITT; now flying on Global Hawk.

Technology infusion: GeoSTAR receiver → HAMSR

Hurricane Earl, September 2, 2010

[Image of Hurricane Earl on September 2, 2010]
# GeoSTAR Development History

**Decadal survey: PATH mission**

**PATH applications**

| Weather forecasting                      | All-weather soundings, in cloudy and stormy scenes  
|                                          | Soundings @<50/25 km every 15-30 minutes (continuous)  
|                                          | Synoptic rapid-update soundings  
|                                          | Forecast error detection; 4DVAR applications  
| Hurricane & severe-storm diagnostics    | Location, intensity & vertical structure of deep convection  
|                                          | NRT atmospheric instability; tornado precursor detection  
|                                          | Intensification/weakening in NRT, frequently sampled  
|                                          | Measure all H₂O phases: vapor, liquid, ice, rain/snow  
|                                          | Operational analysis, forecast verification  
|                                          | Improved model microphysics  
| Rain                                     | Full hemisphere @ ≤ 25 km every 15 minutes  
|                                          | Directly measure storm and diurnal total rainfall: predict flooding events  
|                                          | Snowfall, light rain, intense convective precipitation  
| Tropospheric wind profiling             | 1000-300 mb; very high temp.res.; in & below clouds  
| Climate research                        | Air quality applications (pollution transport)  
|                                          | Stable & continuous MW observations  
|                                          | Long term trends in T & q and storm statistics  
|                                          | Fully resolved diurnal cycle  
|                                          | ENSO; monsoon; tropical moisture flow into the US  
|                                          | “Science continuity”: GeoSTAR ≈ AMSU  

![Near Field range](image1)

![JPL](image2)

![STAR concept and key technologies developed & tested](image3)

![First images at 50 GHz by aperture synthesis](image4)

![NOAA mission](image5)

![STAR sonnder concept](image6)

![PATH applications](image7)
GeoSTAR Development History

ASICS (small demo chips)

Correlator chip

ADC chip

Compact receivers

Low-power MMICs

LO phase switching system: Ultrastable operation

Correlator:
• Efficient
• Redundant
• OK for ASICs

Feedhorns:
Low mutual coupling

Innovative array layout

STAR concept and key technologies developed & tested

First images at 50 GHz by aperture synthesis NOAA mission

Raw synthesized image

Processed image

"Near Field range", JPL GeoST AR

Target Temperature controlled pads

Calibration, performance verification

Design innovations

Study

IIP-07: GeoSTAR/PATH risk reduction

IIP-07: NOAA co-funding

Application studies

STAR sounder concept

ASICs

Antenna design

183-GHz receiver (fab 50 samples)

New antenna design (demo)

Sharply bounded FOR

Large alias-free region

NEDT < 1/3 K

Array submodules (fab 3 samples)

ASICs (small demo chips)
GeoSTAR Development History

PATH risk reduction: IIP-10

Small mission of opportunity

Complete PATH mission

Cost-performance tradeoffs

Risk/cost buy-down

System TRL

Component TRL

Risk/cost buy-down

Concept

NMP

Proof of concept

IIP-03

Key technology

IIP-07

Realizability

IIP-10

Timeline

Summary

We are approaching readiness for space mission

• STAR concept demonstrated in IIP-03
• Key technologies developed in IIP-07
• Ready for PATH mission after IIP-10
  – Can start development ~2015 → launch ~2020

• Ready for Venture-class mission now
  – Objective: PATH science subset demonstrator
  – Instrument: “GeoSTAR-lite” – all key technologies @ TRL 6
    • Correlator baseline: FPGA (TRL 6) – meets minimum science requirements