# Chapter 1. Remote Sensing and Estimation

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## 1.1 Geostationary Microwave Sounder Study

### Sponsor

MIT Lincoln Laboratory
Agreement CX-19383

### Project Staff

Dr. Philip W. Rosenkranz, John W. Barrett

This project provided supporting studies of candidate sounder designs to the Geosynchronous Microwave Sounder Working Group (GMSWG), which is composed of government and university personnel. GMSWG was formed at the behest of NOAA for the purpose of identifying requirements, determining technology readiness, and making recommendations for a microwave sounder to be added to the Geostationary Operational Environmental Satellite (GOES) program.

GMSWG, chaired by Professor Staelin, developed a reference sounder design that includes a 2-m diameter antenna and four frequency bands, with oxygen lines at 119 and 425 GHz and the water lines at 183 and 380 GHz. Simulations of temperature and humidity retrievals from this instrument predict accuracies comparable to low-earth-orbit sounders, except that the 425 and 380 GHz bands are limited by continuum water-vapor absorption to parts of the atmosphere with water-vapor overburden less than 0.3-0.6 kg/m$^2$. The 119- and 183-GHz bands, in contrast, allow sounding down to the surface. Subsatellite horizontal spatial resolution would be ~20 km for the 380-425 GHz bands, however, compared with ~66 km at 119 GHz. These recommendations were distributed in the form of a Lincoln Laboratory report.

## 1.2 Algorithms for Operational Meteorological Satellite Instruments

### Sponsor

MIT Lincoln Laboratory
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### Project Staff

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This project provided scientific support to the National Oceanic and Atmospheric Administration (NOAA) for the Advanced Microwave Sounding Units A and B (AMSU-A, AMSU-B), which were launched on the NOAA-15 polar-orbiting weather satellite in 1998, and also for improved instruments. In the area of atmospheric-gas transmittance, models for the microwave continuum absorption by water vapor were reviewed, and a best-fit composite model was identified.

### 1.2.1 Journal Article

Rosenkranz, P.W. "Water Vapor Microwave Continuum Absorption: A Comparison of Measurements and Models." *Radio Sci.* 33(4): 919-28 (1998).

## 1.3 Development and Operation of an NPOESS Aircraft Sounder Testbed Passive Microwave Sensor

**Sponsor**

MIT Lincoln Laboratory
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**Project Staff**

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The NPOESS Aircraft Sounder Testbed (NAST) is a cooperative effort by MIT Lincoln Laboratory, RLE, and the University of Wisconsin in which an infrared interferometer sounder built by Lincoln Laboratory and a co-located microwave sounder built by RLE are flown on the NASA ER-2 aircraft, for the purpose of answering technical questions related to the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The microwave sounder is an improved version of the Microwave Temperature Sounder which was flown previously by RLE. The NAST-MTS has eight channels between 50 and 56 GHz and nine channels near 119 GHz. It is fully scanning and has a three-point calibration system (two blackbody targets and a zenith view) for accurate calibration.

This year, we participated in the TEFLUN and CAMEX-3 experiments organized by NASA. The ER2 flew over test sites in Texas, Florida, and the Bahamas and over hurricanes Bonnie, Earl, and Georges. Aside from a few problems, NAST-MTS produced generally good data, which will be used to investigate the effects of precipitation, surface emissivity, and other phenomena.

## 1.4 Earth Observing System: Advanced Microwave Sounding Unit

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**Project Staff**

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The Advanced Microwave Sounding Unit (AMSU) and the Humidity Sounder Brazil (HSB) will provide data together with the Atmospheric Infrared Sounder (AIRS), which will be a facility instrument on the PM-1 platform of NASA's Earth Observing System (EOS). This platform will circle Earth in a 800-km polar orbit. AMSU will image the Earth in a wide swath with 50-km resolution at nadir at 15 frequencies ranging from 23.8 to 89 GHz. HSB will image the same swath with 15-km resolution at nadir at 4 frequencies sensitive to the water vapor resonance near 183 GHz.

One key role of AMSU and HSB is to facilitate removal of cloud and surface effects impacting the high-spectral-resolution AIRS infrared data. This year high priority was placed on developing methods for detecting and reducing the surface and cloud effects in the microwave data itself before it is used in combination with AIRS data.

Several approaches to detecting and correcting for precipitation might be used for processing AMSU/HSB data. Testing these methods requires accurate ground truth data. Considerable effort was therefore devoted to obtaining data from the NPOESS Aircraft Sounder Testbed Microwave Temperature Sounder (NAST-MTS), which flew ten missions over precipitation and hurricanes during August and September, 1998. NAST-MTS has eight channels located across each of the 54- and 118-GHz spectral bands of oxygen. This aircraft instrument flies near 20-km altitude and scans laterally ±65° from nadir with 7.5° beamwidth. This data revealed the inadequacies of single-point spectral detection of 54-GHz perturbations due to precipitation; combined 54- and 118-GHz spectral data was used for comparison in these tests.

### 1.4.1 Meeting Paper

Chen, F.W., J.W. Barrett, W.J. Blackwell, P.W. Rosenkranz, M.J. Schwartz, and D.H. Staelin. "Millimeter-Wave Spectral Observations of Clouds and Precipitation from Aircraft and Spacecraft." National Radio Science Meeting, Boulder, Colorado, January 4-8, 1999.

## 1.5 Passive Microwave Spectral Imaging of Atmospheric Structure

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A new method was developed for detecting precipitation; it uses the 183-GHz spectral response to clouds and precipitation. This approach was tested using AMSU-A and AMSU-B data from the NOAA-15 operational meteorological satellite launched in May, 1998. AMSU-B is similar to HSB, but also has an additional channel near 89 GHz. This approach appears more promising, particularly when combined with spatial operators.

Preliminary tests of the ability of 183-GHz spectral data to estimate precipitation were made using two orbital passes of AMSU over the eastern United States, one over hurricane Georges on September 30, and the other over a strong frontal passage on October 7, 1998. Images of the retrieved precipitation rates agree well with precipitation data obtained using the NOAA NEXRAD radar data smoothed to 15-km resolution. It was found that 2.3% of the total AMSU-estimated rain was missed by NEXRAD, and 11.8% of the NEXRAD-estimated rain was missed by AMSU. In addition, the precipitation-rate-weighted RMS differences in regional rain rates were 2.2 dB, based on 18 cell-centered precipitation regions randomly selected from such regions observed on the two test days. Typical diameters for these regions were 15-150 km.

The precipitation estimator was based on a concatenation of two simple neural networks. The first neural network operated on the instrument scan angle and the spot radiances observed at 183±1 GHz and 183±7 to produce a NEXRAD-trained estimate of precipitation rate at a single point. After precipitation regions were defined centered on each strong convective cell, the total areas of these precipitating regions together with their total AMSU-estimated precipitation rates were input to a second neural net and again trained against NEXRAD regional rain-rate estimates. The 18 precipitation regions used to train the second neural network were different from the regions used to evaluate it. This modest 2.2-dB discrepancy in rain rates is comparable to the expected accuracy of NEXRAD alone. Furthermore, the AMSU 183-GHz data is plagued by interference radiated by transmitters on the satellite itself, rendering the observations less accurate than they ultimately could be. Similar tests of precipitation-measuring accuracy are planned for the NAST-MTS data, also in combination with NEXRAD.

## 1.6 Reduction of Variation

**Sponsor**

MIT Leaders for Manufacturing Program

**Project Staff**

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Reduction of process and product variation can be facilitated by statistical analysis of manufacturing data. The non-Gaussian non-stationary character of data-rich manufacturing processes poses special challenges to efforts seeking to extract maximum information about the nature and origins of variations.

Two manufacturing data sets of particular interest have involved a major paper manufacturing plant in the midwest, for which thousands of variables have been monitored at least hourly for one year. Another process involves a biological product produced continuously by living organisms. Preliminary analyses have been performed for dimensional data from an automobile assembly operation and for vibrational data from engines experiencing various defects. Generic methods are being developed for characterizing these processes and identifying anomalies.

Support was also provided for extension and application of techniques for designed experiments as applied to improvement of an acetate film base manufacturing system using a 32-part factorial experiment conducted by Charlene Johnson.[1]

### 1.6.1 Thesis

Johnson, C. *Dramatic Improvement of a Mature Process: Proactive Process Improvement*. S.M. thesis. Sloan School of Management and the Department of Electrical Engineering and Computer Science, MIT, 1998.

1 C. Johnson, *Dramatic Improvement of a Mature Process: Proactive Process Improvement*, S.M. thesis, Sloan School of Management and the Department of Electrical Engineering and Computer Science, MIT, 1998.