

# Geosynchronous Technology Infusion Studies

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Abstract -- NASA and NOAA are now sponsoring Advanced Geosynchronous Studies (AGeoS), technology work that will lead to the next generation of space sensors located in geosynchronous orbit.

## INTRODUCTION

In the early 1990's, NASA commissioned a Geostationary Earth Observatory (GEO) team [1] to study the utility of environmental observations from geostationary orbit. This GEO study concluded that: "In many respects, the polar-orbiting instruments study the effects of processes, whereas the geostationary instruments can study the process itself."

Indeed, research in climate change consists of determining how the long-term changes affect short-term processes, and how those altered short-term processes, in turn, establish new long-term behavior. Because the diurnal cycle drives so many energetic short-term processes, it is necessary to directly measure rapidly changing components like winds, clouds, aerosols and precipitation on a global scale. While a polar-orbiting satellite can observe the entire globe at high resolution, it cannot resolve the diurnal cycle. While a geosynchronous satellite can resolve the diurnal cycle, it is limited about one-quarter of the earth's surface. Therefore, a combination of remote sensing data from both platforms yields a synergistic system for studying both the processes and the resulting changes in weather and climate.

For the last 25 years, National Oceanic and Atmospheric Administration (NOAA) has been flying Geosynchronous Operational Environmental Satellites (GOES) to observe weather. In the mid-1990's, a new generation GOES imager and infrared Sounder came on-line with accurate radiometric calibration and earth-location, with performance similar to the NOAA polar-orbiting instruments.

Up to the early 1980's, NASA's Operational Satellite Improvement Program (OSIP) orchestrated changes in the NOAA satellites [2]. Since that time, there is a next-generation National Polar-Orbiting Environmental Satellite System (NPOESS) being planned, but there is no corresponding effort to infuse advanced technology into the GOES program for improved weather and climate monitoring, or to coordinate the polar- and geosystems [3]. To deal with this issue, an AGeoS team has been formed to consider improvements in future GOES missions[4].

NASA's Mission to Planet Earth (MTPE) has developed a low earth orbit imager called the Moderate Resolution Imaging Spectrometer (MODIS) carrying 36 spectral channels from 0.4 to 13.3  $\mu\text{m}$  in wavelength [5]. MTPE will also fly, on the Earth Observing System (EOS) missions, microwave sensors that probe to lower levels of the atmosphere when clouds are present. With similar imaging and sounding data from geostationary orbit, numerical modelers would have access to the diurnal drivers of climate change.

In addition to imaging and sounding, AGeoS will consider requirements for a lightning mapper, more efficient ground distribution and autonomous spacecraft control systems, spaceborne architecture tradeoffs (i.e. constellation studies), and the science algorithms associated with all of these enhancements so they can be effectively used by the scientific community. To address all of these issues joint NASA/NOAA Management and Science Teams have been established to oversee the AGeoS effort. This report briefly describes the initial steps being taken to investigate the high priority geosynchronous measurement needs identified so far.

## IMAGER

Using current technology, it is possible to build a GOES imager agile enough to provide continental U.S. coverage synchronized to the national weather radars and also several full-disk images every hour. NASA-Goddard Space Flight Center has studied the Geosynchronous Advanced Technology Environmental System (GATES) [6] as one way to deliver full-disk images in all the MODIS spectral window channels.

The GATES imager study shows that recently developed technologies are sufficient to create a geosynchronous imaging system that will likely meet or exceed all known National Weather Service (NWS) next generation GOES imaging needs while simultaneously providing valuable climate imaging data. Some of the key technologies are photovoltaic long wave detectors, large focal plane arrays with high performance readout circuitry, wide field large aperture optics, stable and thermally conductive mirrors and composite structure, high-repeatability full spectrum calibration, reliable and low-vibration mechanical coolers, loop heat pipes, very high speed communication and processing systems, automated image registration and resampling algorithms, and highly autonomous operation.

Many of these technologies are, however, unproven in space to the degree required by GOES. Of chief concern

is the large degree of cost, schedule, and performance risk involved in integrating many new technologies into a precision sensing system. Demonstrating that these components will work together in a calibrated system and provide the required quality of science and weather data is critical for infusion into an operational program.

AGeoS is investigating the pros and cons of various geosynchronous imaging techniques through a series of trade studies that will be used to focus technology development and demonstration activities. A laboratory testbed will likely be developed that will integrate the technologies together as a first step in evaluating mutual compatibility. This testbed will also be valuable in developing streamlined performance verification techniques to reduce the cost and risk of flight instrument integration and test.

Certain system level technology issues such as proof of techniques to overcome the geosynchronous solar environment, and proof of sufficient performance and reliability to meet GOES operational needs must await actual demonstration in geosynchronous orbit to be truly resolved.

#### INFRARED SOUNDER

In 1996, the GATES-2 studies looked for a high spectral resolution infrared (IR) sounder design that could coordinate measurements with a microwave (MW) sounder from a single geosynchronous IR/MW platform. An MIT Lincoln Laboratory IR interferometer sounder concept uses a 65K 6 x 6 photovoltaic HgCdTe Focal Plane Array. For compatibility with the microwave sounder, the GATES-2 IR sounder concept used a 22 cm aperture with an internal nodding mirror. Nodding compensates for spacecraft scan motion that is being used to raster the infrared and microwave field-of-view over the earth disk.

AGeoS will be taking a broader look at geosynchronous infrared sounding techniques and will be initiating technology development and demonstration activities. Key technology issues will be the evaluation of various types of interferometers and spectrometers for their viability in geosynchronous earth sensing, the use of large focal plane arrays to increase ground coverage rate, evaluation of calibration requirements and techniques, and issues surrounding synchronized operation with a microwave sounder. The latest subsystem technologies will be evaluated, some of which are being developed for NASA's New Millennium Program (NMP). NASA's Strategic Enterprise for Atmospheric Science at Langley Research Center will play a major role in this study.

#### MICROWAVE SOUNDER

The GOES satellites currently have no microwave frequency sounder on board. Thus, current IR sounding techniques are limited by clouds. In NOAA's vision of the future, co-registered infrared and microwave sounders will do the temperature profiling and water vapor tracking required for predicting severe storm activity. The Geosynchronous Microwave Sounder Working Group (GMSWG) has proposed a microwave sounder [7].

The least mature of the technologies being considered in the next generation geostationary platforms are related to microwave sounding. Feasibility studies for performing microwave sounding from a geostationary orbit were performed in the 1970's [8]. The study found that placing a large aperture antenna to realize reasonable spatial resolution and developing reliable low noise receivers sensitive enough for sounding measurements were of greatest challenge. Today, these challenges still represent the barriers to realizing a geostationary microwave sounder.

The current strawman configuration being considered is derived from recommendations from the GMSWG. The design uses twelve channels centered about four frequencies at 118 GHz, 183.31 GHz, 380 GHz and 425 GHz. A two meter aperture provides a resolution of 20 km at the two highest frequencies, the maximum spatial resolution deemed useful by the GMSWG. Of particular challenge is obtaining 10 micron surface accuracy across the aperture to obtain better than 90% beam efficiency at the higher frequencies. Numerical modeling of the structural integrity of a composite antenna design is in progress. Determining the influences of thermal loading on aperture efficiency is of key consideration.

The highest priority technology need is to develop low noise receiver components at the submillimeter wave channels of 380 GHz and 425 GHz. The previous work in space science [9] plus additional development of planar diode mixer components at 557 GHz have established a good approach to this challenge. A research grant has been provided to the University of Virginia to build breadboard front end devices and matching circuits to demonstrate low noise performance at 380 and 425 GHz. Precision machining for integrated feedhorns and resonant cavities will be made repeatable using a new plastic molding process developed by the University of Virginia. Flying these technologies on an aircraft instrument will provide relevant data for assessing these new channels.

## LIGHTNING MAPPER

A low earth orbit lightning mapper, the Optical Transient Detector, is currently on orbit, and a similar instrument will be flying on board the Tropical Rainfall Measurement Mission (TRMM) scheduled for launch later this year. However, these measurements do not provide the capability to continuously monitor specific storms or storm systems. Clearly, geosynchronous orbit provides the best vantage point for continuous monitoring of regions of interest. Data from a geosynchronous lightning mapper will be especially useful in concert with other measurements of water in the atmosphere.

Modern solid state mosaic focal planes have enabled these scientific instruments to be low impact on system weight and volume budgets. The prime technology challenge for a geosynchronous lightning mapper will be the development of the real time event processor that can extract the momentary differences in intensity of a lightning event. The Marshall Space Flight Center will be leading this investigation [10].

## ADVANCED GROUND SYSTEMS

The infusion of advanced instruments into the GOES program will significantly increase the downlink data rate to a level that is beyond the capability of the current GOES ground station and data distribution system. This study will investigate new ground station and data distribution architectures for delivery of advanced data products to users.

The investigation of advanced ground systems must take into account synergism with the MTPE products acquired in low earth orbit. A subset of the climate data must be compatible with the daily data requirements used by the National Weather Service (NWS) forecast models. A technology demonstration mission would allow NWS data products to merge with minimal disruption to the operational system.

## GOES CONSTELLATION STUDIES

The GATES studies suggested that technology demonstrations should be accomplished with a series of small scale missions to minimize cost and risk. Perhaps this architecture is also best for the future fleet of operational satellites. Of prime concern for infusion of technology into the operational GOES program is how technology can be used to make the space segment as cost efficient and flexible as possible while providing improved and expanded measurements. This constellation study will investigate the issues and options surrounding large-satellite versus small-satellite versus hybrid architectures.

## SUMMARY

The AGeoS team has used the mutual interest of the NASA/MTPE and NOAA/GOES programs to define the objectives of a technology infusion study. With the point designs that came from early studies sponsored by NASA, more system and technology trades have been uncovered. AGeoS technology mile-stones include laboratory testbeds, aircraft instruments, and flight demonstrations achieved through a NASA pathfinder program such as the NMP or the Earth System Science Pathfinder (ESSP) program. Investigations infusing new technology and measurements into the GOES program will come through constellation and ground system studies.

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