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COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
TO OBSERVE AND PREDICT;
HOW NOAA PROCURES DATA FOR WEATHER FORECASTING
MARCH 28, 2012

Thank you, Mr. Chairman and committee members, for inviting me to speak today.

Once upon a time in America, we were leaders in space. The United States won the race to the moon and invented many things we take for granted that have a space connection. The US invented the weather satellite, the communication satellite, GPS and from the 1960's to present day, the majority of earth observation satellites have been flown by the US. But things are changing. Our research satellite programs are almost universally over-budget and behind schedule. Our infrastructure and operational weather satellites are aging and the next generation programs in all areas have been dramatically cut back to the point that even our current capability to adequately monitor and predict severe weather over the United States is threatened to the point that we must rely on satellite missions flown by Europe and China to meet our basic weather observation requirements. We once flew a constellation of Polar Orbiting weather satellites in 3 separate orbit planes to provide comprehensive global coverage. In the JPSS era, we will fly only one, reducing coverage by 2/3^{rds}.

Moreover, we now critically rely on Eumetsat's METOP program for critical observations that predict weather over the United States. In the near future, we may have to rely on China's FY-3 Series of LEO orbiters to provide data in orbits currently flown by DMSP. Today, we still operate a robust fleet of Geostationary GOES weather satellites. We have been so generous with our GOES satellites, that we routinely reposition them for use by other countries (though still to our benefit). We have always maintained a spare GOES satellite in-orbit ready to take over for the operational East or West GOES in the case of a premature failure. This capability is now in immediate jeopardy. As the GAO has been warning about for years, there is a looming gap in the GOES fleet, which in addition to the reduced polar coverage puts the entire US space-based operational weather capability at risk. Prior to GOES-R launch, the US will be at risk of having only a single operational GOES spacecraft; after GOES-R launch there will be no spare spacecraft on orbit until GOES-S. A launch or premature orbit failure of GOES 15, GOES-R or GOES-S could lead to significant coverage gap beginning as soon as 2015 and lasting for several years.

But America remains a resourceful country, an entrepreneurial country. The Communication Satellite sector, once an exclusive sovereign government domain, is now in the vast majority of cases *commercial.* Over 250 commercial communication satellites are in operation today. Many of these sell critical communication bandwidth to our government at a fraction of the cost of a dedicated government operated system. GeoEye and DigitialGlobe have revolutionized and transformed the way high resolution imagery is collected and distributed with a capability that once was only obtainable at costs orders of magnitude higher and with significant risk to the government customer.

In the same way, I am convinced we can remedy the potential gap in our weather observation system and restore critical new observations that have been de-manifested from our future programs. When the GOES-R program was authorized, it was originally slated to carry both an advanced Imager and an advanced Sounder. The roles of the two instruments are complementary, with the Imager most sensitive to clouds and surface regions and the sounder most sensitive to water vapor and able to determine high resolution vertical profiles of the atmosphere and 3-D wind profiles continuously. In the words of a former GOES-R deputy program manager, “The Imager tells you what the weather is NOW and the Sounder tells you what the weather will be 6 hours from now.” NOAA’s own cost benefit analysis has shown that the benefit from each sensor is about 50% of the total program value.

When the Advanced Sounder (HES) was canceled on GOES-R, this benefit was lost while the total program cost has increased above the original authorization. There have been efforts to restore a “legacy sounding” capability using the Advanced Imager (ABI) alone, but even the GOES-R lead scientists conclude that this capability is not as good as the current sounder and cannot meet any of the Advanced Sounder requirements. This shortfall has been recognized by many groups in the US and internationally who have consistently advocated for a restoration of this capability.

Given the current fiscal environment, but also because of the precedent of successful commercial alternatives in other areas, GeoMetWatch (GMW) has made efforts to license and fly a commercial Advanced Sounder. GeoMetWatch applied for and was granted a commercial remote sensing license to operate up to Six Geostationary Hyperspectral Imaging Sounders in 2010. This license was issued by the US Department of Commerce and signed by the Assistant Administrator of NOAA/NESDIS. The planned capability of the GeoMetWatch sounder equals or exceeds the sounding requirements of the original HES mission, and if flown over the US would restore the full benefits of the GOES-R mission. A GeoMetWatch mission can provide redundancy and risk mitigation for a premature failure of any future GOES. A GeoMetWatch Sounder over the US also provides continuous coverage for severe weather forecasting and hurricane track and intensification. This continuous coverage over the US provides from 24 – 1300 times more sounder coverage of a given region than NPP or JPSS.

GeoMetWatch anticipates its first launch in late 2015 / early 2016 to cover the Asia Pacific region. We selected this location because of the customer commitments we have received to purchase the data when available.

And with commitment (even conditional) to purchase data in the US Sector, GMW can have a satellite ready in the 2015/2016 timeframe.

Why GEO Hyperspectral Sounding?

The benefits of Geostationary Weather observation are well documented. The primary benefit of a geostationary system (vs. a Polar orbiting Leo system) is the persistent and continual observation capability of a Geo System. This is especially significant for severe weather. A Geostationary system over the United Stated can continually observe evolving severe weather with NO gaps in coverage. In the case of a Geo Hyperspectral Sounder, continuous observations of the entire 3-D structure of the atmosphere BEFORE, during and after severe weather systems form is possible. The types of observations that a hyperspectral sounder can do are unique in that the conditions that can form future severe weather are possible to observe HOURS before any other technology, including Radar.

A GEO system has the additional advantage over a hyper spectral sounder in LEO orbit, in that the coverage is continuous. For example: If we examine a Midwest region of the United States, say Missouri, a GEO System can observe a region's full 3-D atmospheric structure each hour or half hour at 4km ground resolution. If severe weather emerges, then individual regions of 1000km x 1000km can be monitored every 1-5 minutes. Rapidly evolving weather can be monitored in a 512km x 512km region every 12 seconds. In contrast, a LEO System will take a snapshot of the 3-D structure of the atmosphere each time it flies over. In the case of a JPSS-like satellite, the revisit time for a single geographic location, such as our Midwest example, is only about once every 6 hours or less. This means that reliance on a LEO only system can lead to significant gaps in coverage and ability to warn for emerging severe weather. Additionally, the current JPSS/NPP sounder only makes observations with a 10-12km ground resolution.

In the case of our Midwest example, a GEO system can make as many as 6, 12, 72, 600, 1300 observations for every single LEO system observation. This can have tremendous impact on the ability to forecast and provide warnings for severe weather.

Additionally, because of the persistent nature of the GEO system, better and enhanced observations can be made like 3-D winds and improved vertical atmosphere profiles in cloudy regions.

For aviation applications, the ability to make more observations in regions of severe weather, enable more efficient and safer routing of air traffic through these regions, result in more efficient routing, fuel savings and minimization of passenger delays. Indeed these are key aspects of the NextGen FAA's 4-D weather cube initiative. Without a GEO Hyper spectral Sounder, there will be no capability to fully populate a CONUS and GLOBAL 4-D weather cube, except to use simulated data.

Why Commercial?

Commercial remote sensing has been part of US Space Policy for decades. In the case of the Commercial Hyper spectral Sounder, our company explicitly applied for and received a remote sensing license from the Department of Commerce after the HES mission was canceled from GOES-R. Our system is licensed to supply global observations of GEO Hyper spectral Sounding and Imaging products. These observations (which produce gridded high horizontal and vertical resolution atmospheric profiles) remain an ongoing requirement of the National Weather Service (NWS) and are critical inputs into the NextGen FAA and Warn on Forecast programs.

There is precedent for the NWS to purchase commercial data. National Lightning Detection Network (NLDN) data is purchased now on a commercial data-buy basis and is a component of the national capability to forecast and provide warnings for severe weather. Other data types are also purchased now, such as *in situ* weather data from commercial aircraft and other sources.

Additionally, a commercial system provides a means for a significant number of high-paying technical jobs that would not otherwise exist and a global commercial system represents a significant economic export, with resulting revenue and tax returns having direct economic benefit in the United States.

Background (NOAA Satellite Program and Geo Advanced Sounding)

Historically, NOAA has developed, procured and operated a fleet of Geosynchronous/Geostationary (GEO) and Polar Low Earth Orbit (LEO) spacecraft for purposes of providing space-based weather observations. These observations provide essential data to the NWS and other agencies that enable severe weather forecasting, hurricane tracking, intensification and landfall prediction, short, medium and long-range numerical weather prediction (NWP), now-casting and forecasts for aviation weather. These data also contribute to global monitoring of pollution, climate change and earth science.

The requirements of these systems have historically been developed and vetted through academic and research entities both in the United States and Internationally. Coordinating bodies such as the World Meteorological Organization (WMO), GCOS, GSICS, ITOVS as well as national organizations like the National Academy of Sciences (NAS), American Meteorological Society (AMS), National Weather Association (NWA) and others attempt to coordinate the utilization of current and future systems to maximize the ability of these systems to improve global weather forecasting. All of the agencies listed above have explicitly endorsed or recommended Hyperspectral Geostationary Sounding as a technology to dramatically improve global weather forecast capability. The reason this capability is so important is that it is the only technology capable of providing high vertical resolution atmospheric profiles with both high spatial and high time resolution. A single or even several LEO weather satellites, such as NPP and JPSS, cannot meet either of these requirements.

This was the rationale for the specification of an Advanced GEO Sounder in the original authorization of the GOES-R mission. This requirement for high vertical resolution atmospheric profiles was to be provided by the Hyperspectral Environmental Suite (HES), which was demanifested from GOES-R in 2006 and from all future missions in the GOES-R series in 2011. Both NOAA and 3rd Party Cost-benefit studies indicated that half or more of the total benefit of the GOES-R mission is derived from the HES sounding mission. This has been noted several times by the GAO in official reports in 2007, 2008, 2009, 2010 and 2011.

The cancelation of HES and the continual requirement by the NWS for high vertical resolution atmospheric profiles was the original impetus for the founding of GeoMetWatch.

Background (Commercial Remote Sensing)

The US Commercial Remote Sensing Act 2003 provides for the licensing of commercial remote sensing systems. An advantage of this act is that Foreign Sales are allowed with few restrictions (there are no ITAR issues for data). This allows American companies to compete with technology that is restricted for export. Most commercial licensee's sell services using a Fee-for-Service Data model. GeoEye and DigitalGlobe currently do this for Space-Based Imagery. GeoMetWatch will do this for licensed weather data products. The act also offers some beneficial implicit and explicit protections.

It is also consistent with the US Space Policy's intent to promote commercial options which meet Operational and Observation requirements to the maximum extent. Other advantages and benefits include:

- Meets government requirements with commercial solutions
- Grows Domestic Earth Observation Capability

- Strong International Demand for Data
- ITAR Neutral Business Model
- Lower Cost and Risk
- High Value US Jobs and International Exports

Commercialization of Weather Satellite Functions

The 1992 Land Remote Sensing Policy Act prohibits the Department of Commerce from commercializing weather satellite systems. Section 5671 of the bill states:

> *"Neither the President nor any other official of the Government shall make any effort to lease, sell, or transfer to the private sector, or commercialize, any portion of the weather satellite systems operated by the Department of Commerce or any successor agency."*

Recently, many commercial space companies have presented different ideas and concepts for providing environmental data to meet US government requirements. Some of these concepts include hosting Government Furnished Equipment (GFE), such as environmental instruments or sensors on commercial satellites, as well as selling commercial environmental data to the US government requirements.

One of the first tasks that we performed in exploring the license requirements for our system was to seek clarification of the 1992 law. Specifically, we asked NOAA General Counsel if and under what conditions licensing of a weather system was possible. Additionally, we had many discussions with the NOAA Commercial Remote Sensing Group, the entity responsible for the issuing of commercial remote sensing licenses.

What we were told is that the intent and the wording of the law explicitly prohibit the commercialization of any portion of the existing or future government-owned or government-operated weather satellite systems.

The intent was to prohibit transfer to the private sector the infrastructure that had been paid for and operated by the US Government, via lease, sale or transfer. Furthermore, a capability which is part of an ongoing Program of Record would be prohibited from receiving a license.

Thus, any *government system* -- currently funded and/or under development for future operational use -- cannot be licensed under the Commercial Remote Sensing Act.

This would mean that most of the commercial options that could make use of GFE (Government Furnished Equipment) equipment or allow for an operational gap-filler satellite on a commercial basis and that benefit from the use of the government-funded JPSS or POES ground systems are, by definition, not subject to commercial licensing.

What CAN be licensed, however, are capabilities or functions that meet a stated government requirement AND for which NOAA has specifically and unequivocally has stated that they would not fly as a program of record. The best example of this capability is the GEO Hyperspectral Sounder, which was originally part of the HES mission on GOES-R and was canceled in 2006 and officially removed from all satellites in the GOES-R series in 2011 (see Mary Kicza testimony to the National Academy Panel Review, April 2011).

These criteria having been met; a private company (GeoMetWatch) applied for and was granted by the Department of Commerce a commercial license to fly the GEO Hyperspectral Sounder in October of 2010.

The issuance of this license by the Department of Commerce reflects the Administration's commercial space policy that encourages the development of innovative, sustainable and affordable options to meet critical mission requirements that government otherwise cannot achieve.

The protections offered in the Commercial Remote Sensing Act incentivize private industry to invest and offer these services to both government and private customers. These protections state that a licensed system, that meets government requirements, should be preferentially procured by the US Government and, further, that the US Government will not compete against this licensed capability.

There is abundant precedence for this commercialization model of the US Government contracting with the private sector to meet critical program requirements. Both GEOEYE and DigitialGlobe are excellent examples. The reason the NextView program exists is because both of these companies have demonstrated a licensed capability to meet US Government space-based imaging requirements and because of this, the US Government cannot develop systems that directly infringe on this licensed capability (i.e. NRO BASIC program, canceled in part due to this issue).

Specific Questions from the Invitation letter:

1. **Describe the types of data available from commercial sources.**

The licensed capability of the GeoMetWatch system will provide calibrated and geolocated (Level 1b data in NASA/NOAA nomenclature) Top of Atmosphere (TOA) radiances which are specified to exceed the original HES and NASA GIFTS sensor requirements and to meet or exceed the Eumetsat MTG Sounding requirement. By incorporating both the technology and algorithm requirements of

the original mission, GMW can offer data that will meet all observational requirements for the original HES sounding mission, with the added capability of being able to serve as a backup or primary GEO imaging system. This imaging capability does not meet the full Advanced Imaging capability of the GOES-R mission, but it exceeds the imaging capability of the current GOES Imagers.
For customers who desire advanced data products, such as gridded vertical profiles of atmospheric parameters, 3-D Water vapor winds, aviation products and other specified derived products, GMW will provide these additional products in near real time.

The GeoMetWatch system will be a global system of 5 or 6 sounders and all of the data will be available to GMW subscribers. The availability of data, not just over the US, but from around the world will enable improved long range weather forecasts and mitigate any future loss of data from either US Government LEO or GEO missions.

2. How can this data supplement Government owned data?

Since Hyperspectral Sounding Data was part of the original mission spec for GOES-R, addition of this data will help restore the full mission capability originally authorized for this program. In addition, since the GMW system is flown on separate commercial spacecraft, there is significant risk mitigation for a GOES-R launch delay or failure. The GMW Sounder also provides the ability to provide emergency Imaging capability in the case of a premature loss of the GOES-R Imager. As noted above, the global imaging and sounding data available from the GeoMetWatch system will also supplement the data coming from the existing fleet of LEO (POES, DMSP, NPP and JPSS) and provide alternative Imaging and sounding data at non-polar latitudes globally in the event of a Gap or premature failure of these missions.

In addition, because of the importance of global, gridded high vertical resolution atmosphere profiles in other US Government programs, such as in the FAA's NextGen 4-D data cube and NWS Warn on Forecast initiative, GMW is the only capability to provide directly observed data (vs. synthetic data) that meet the resolution and timing requirements. Availability of this data will dramatically improve the ability to accurately compute and provide the decision aid data products needed for these programs.

Another benefit of Geostationary Hyperspectral Sounding is to complement existing and future NASA and other agencies' Earth Observation Missions. Over half of the NASA Decadal Survey missions garner some benefit from the availability of Hyperspectral Sounding Data. Having continuous, high time, high spatial and high vertical atmospheric profiles, in addition to the other Sounder data products, provided the ability for other remote sensing missions to produce better science and extend their missions in various ways.

3. What processes exist to evaluate and prioritize procurement of data?

NOAA has in the past, used Cost Benefit Analysis to gauge the economic benefit of various programs. Both the original CBA for GOES-R in 2003 and a follow-on study in 2007 identified significant economic benefit from having both a Hyperspectral Sounder and Advanced Imager on the GOES-R mission. Table 60 (from page 96) from this study is shown below.

Table 60. Allocation of Benefits by Instrument

	Benefit Portion		Present Value of Benefits ($M)		
Case Study	**HES**	**ABI**	**HES**	**ABI**	**Total**
Aviation					
Avoidable weather-related delays	100%		$504		$504
Volcanic ash plumes		100%		$265	265
Energy					
Electricity	50%	50%	1,256	1,256	2,512
Natural gas transmission	50%	50%	10	10	19
Natural gas utilities	50%	50%	16	16	32
Irrigated agriculture	50%	50%	545	545	1,090
Recreational boating		100%		141	141
Total			$2,331	$2,232	$4,563
Portion of benefits			51%	49%	

from: ***"An Investigation of the Economic and Social Value of Selected NOAA Data and Products for Geostationary Operational Environmental Satellites (GOES), submitted by CENTREC Consulting LLC, Feb. 2007"***

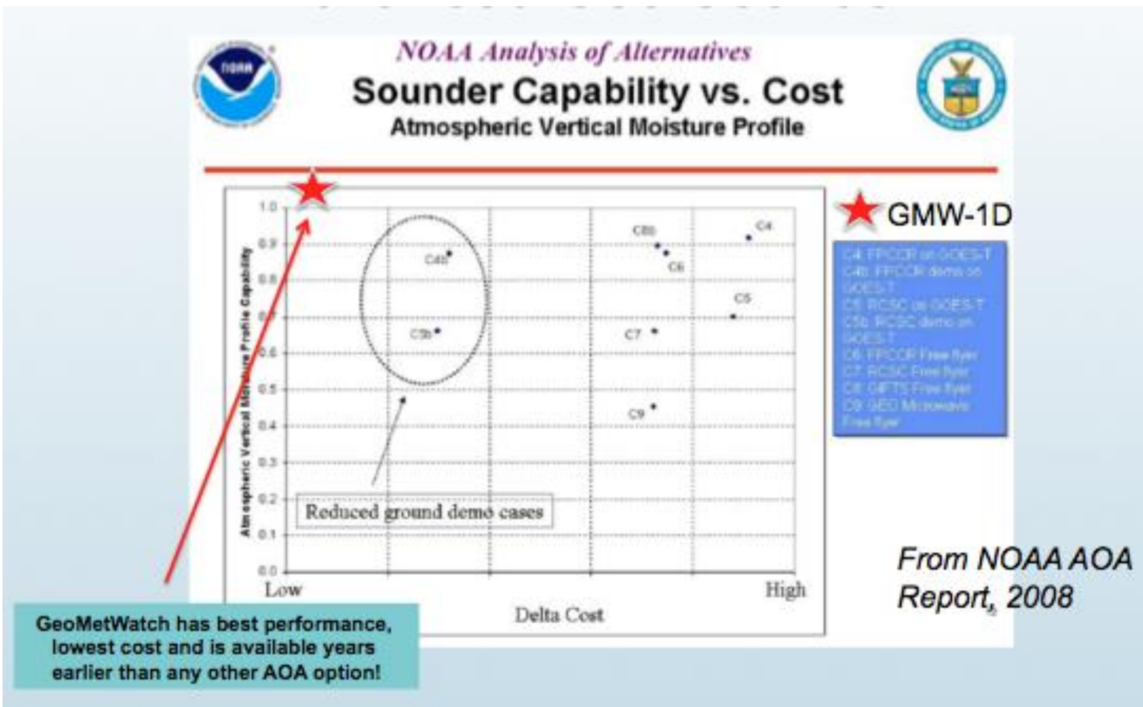
Every other Economic benefit study that I have seen has shown similar or great benefit due to Geostationary Hyperspectral Sounding. In Eumetsat's analysis of mission priorities for the MeteoSat Third Generation Mission (MTG), Hyperspectral GEO Sounding was the highest ranked requirement. There is extensive documentation of how the MTG requirements are determined on the *Eumetsat* website.

Given the clear economic benefit of these data, I cannot rationally explain why other demanifested missions have higher priority than GEO Sounding at NOAA. Another type of analysis performed by NOAA NESDIS after HES that was canceled was an Analysis of Alternatives (AOA). This study evaluated a reduced capability sounding mission as an alternative to HES. This study concluded that there was no reasonable option for adding Advanced Sounding Capability to GOES-R that would satisfy requirements given the price and risk profiles mandated by the study.

It is significant to note, that in the AOA, the most capable option identified sufficient to meet mission requirements was the NASA GIFTS mission. However, the estimated price in implement that option was estimated to be $600M-$1100M. This was the implementation cost, and the cost to fly a GIFTS mission as an operational alternative to HES.

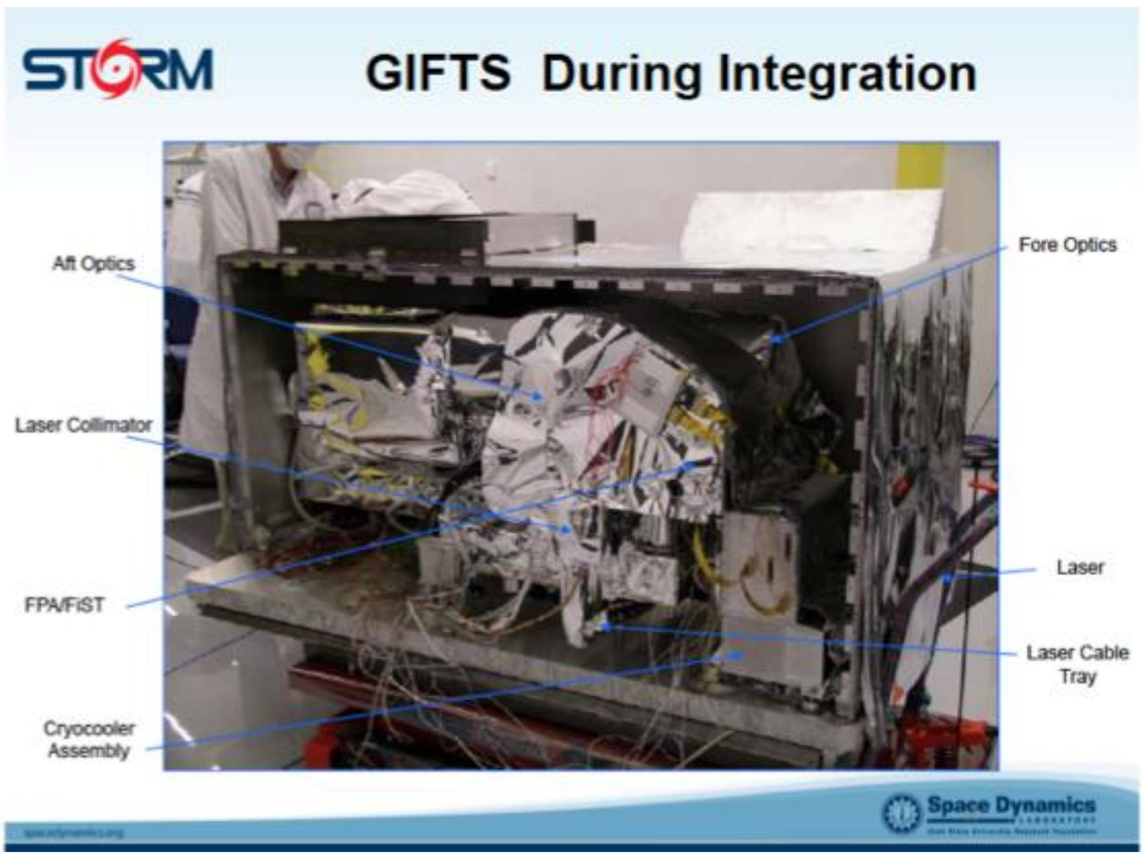
I will note that the GeoMetWatch Mission utilizes an improved GIFTS design and there is ZERO development and implementation cost, so that in the methodology of the AOA, a commercial GIFTS would appear to be a recommendable option. This is what GeoMetWatch offers.

Below is the summary figure from the AOA report, C8 represents a GIFTS sensor, the Red Star represents a commercial version. The vertical axis represents performance relative to the original HES vertical atmospheric profile requirements. The horizontal requirement represents relative cost. The GMW-1D mission is the lowest cost option and is specified to exceed the performance of all options studied.



4. **Current Status of commercial sources.**

GeoMetWatch represents a real capability. We have a functional hardware prototype and the entire ground segment architecture and data products have been developed. GeoMetWatch leverages over $300M of previous NASA and NOAA investment through our partners at Utah State University and University of Wisconsin at Madison. This technology is now available for commercial use because the predecessor programs under which they were developed have been canceled. The primary legacy program for the GMW Commercial Sounder is the NASA GIFTS mission. GeoMetWatch has funded a commercial version of the GIFTS sensor, called STORM. GeoMetWatch has Space Dynamics Laboratory of the Utah State University Research Foundation under contract as a preferred sensor provider and has exclusive agreements with SSEC of the University of Wisconsin at Madison to develop and provide the software needed to produce GeoMetWatch Weather products. GeoMetWatch is in the process of completing hosting and contractual agreements to fly our first mission over Asia-Pacific region (110E). This mission has been enabled by customer commitments to purchase the GMW data and develop data centers for utilization and dissemination of the data in the region. The total customer commitments expressed through US Export Import bank Letters of Interest and MOU agreements is in excess of $200M USD/ year for the Asia region. GMW has a small window to implement a US sounder in the 2015 to 2016 timeframe, but that option will expire by the summer of 2012. Later options to fly over the US will then be available in 2017-2020. GMW can prioritize a US mission with a customer commitment for the US longitude sector. Projected locations will be in the proximity of 130 W and 70 W longitude. GMW has provisional agreements with operators in the US Sector and we plan to use the same bus and sensor configuration for a US mission as for the 110E mission.



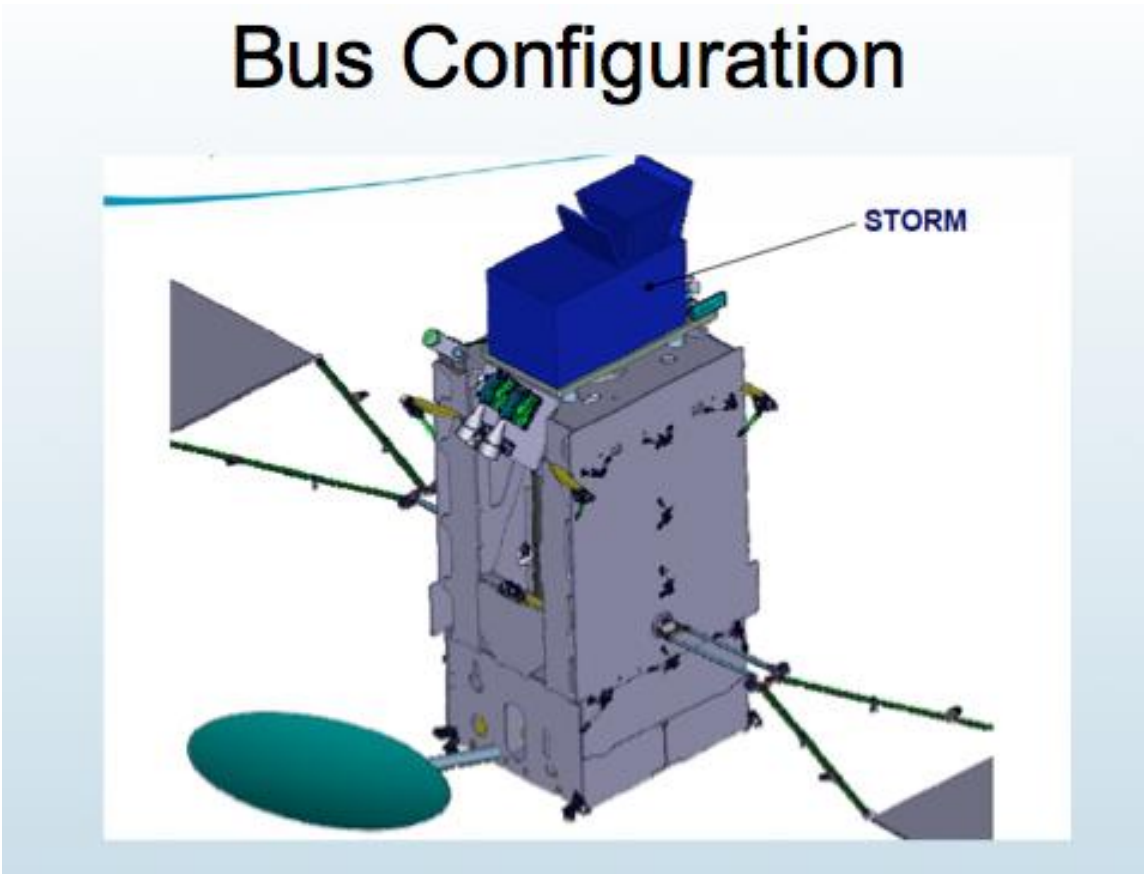
The above figure shows the current Hardware unit of the GIFTS sensor, which is the STORM prototype.

STORM Top-Level GIFTS / STORM Comparison

Parameter	GIFTS	STORM
Spectral Bands	LW: ≤685 cm^{-1} to ≥1130 cm^{-1} SMW: ≤1650 cm^{-1} to ≥2250 cm^{-1} VIS: ≥0.725 µm to ≤0.875 µm	same
Spectral Resolution	7 resolutions in range 0.6 - 36.7 cm^{-1}	0.6, 1.2, and 9.6 cm^{-1}
FPA Field-of-view (FOV)	14.3 mrad (0.82°)	same
Field-of-regard (FOR)	≥0.306 rad (17.53°) (pointing mirror design: 0.450 rad)	same
IR FPA format	128 X 128 pixels, 60 µm pixel pitch	same
Noise equivalent spectral radiance (NESR) goal	LW: ≤0.4 mW/(m^2-sr-cm^{-1}) SMW: ≤0.06 mW/(m^2-sr-cm^{-1})	same
Calibration accuracy goal	≤ 1K (3σ)	same
Data Rate	Max: 70 – 80 Mb/sec Nom: 58 – 73 Mb/sec	same
Mass*	200 kg	300 kg
Volume	1.8 X 1.0 X 1.4 m^3	same
Power*	535 W	550 W avg, 650 W peak
Thermal Rejection *	Design assumed yaw-flip	≥400 W @ 0 °C

* Mass, power, and thermal rejection change due to expected no-yaw-flip operations

The above figure shows a comparison between the NASA GIFTS sensor and GMW STORM.



The above figure shows the current hosting configuration of the STORM sensor on the TAS bus.

GeoMetWatch will start a full Sensor contract in 2012 and anticipates additional contracts to other US companies later this year

5. **Barriers that prevent a commercial option.**

The biggest impediment in the US region is the lack of a customer commitment. GMW is willing to enter into provisional or conditional commitments to provide data, but without an identified customer, we cannot finance a commercial option.

On a related note, commercial providers continue to lack on advocate within the US government. This role was formally held by the Director of the Office of Space Commercialization, but that position is currently unfilled. We need an advocate.

6. How other countries evaluate mission requirements and role of new technologies.

Eumetsat has a comprehensive process to first identify requirements and then identify the technology needed to implement these requirements. The historical role of ESA is to fund the development of these technologies to the point where they are considered mature and ready for implementation. Then Eumetsat funds this implementation. Up until the new technology is proven and ready, the previous generation technology continues in operation, even to the point of flying both new and old technology on the same mission. The advantage of this methodology is that program risk and gaps associated with the development of new technology is minimized, along with the impact of having no data at all. Eumetsat's analog in the US is NOAA and ESA's analog is NASA. The US has deviated from this path in recent decades by attempting to both develop and implement new technology as the same time. In my view this has been one of the principal causes of cost overruns and schedule delays on the NPOESS and JPSS programs and has contributed to the cancellation of HES on GOES-R.

In the area of evaluating competing observation technologies and managing various observing strategies and data gaps, Eumetsat, ESA and partner agencies have used Observational System Simulation Experiments (OSSE), and also data denial experiments from existing missions to evaluate the impact of data gaps. Both of these methods are useful for determining the relative role of different observation technologies and how they contribute to the overall weather forecast mission. Both of these techniques require computer and manpower resources to properly simulate and evaluate the technologies being considered. The benefit of both is that by evaluating these techniques and strategies early, decisions can be made before expensive development programs are started. In the long run, this saves a tremendous amount of money and lost effort.

However, even with these evaluation methodologies, funding pressures for next generation programs also exist and all members of Eumetsat and ESA with whom I have spoken are open to the capability and cost savings of commercial alternatives to complement whatever capability they implement in dedicated missions.

7. Quality Assurance Protocols.

Customer satisfaction will be a primary concern of GeoMetWatch and assurance that our products meet the requirements of our end users will be paramount. For these reasons, we have chosen a sensor spec and mission requirements that meet or exceed those of the most capable mission which will fly in the next decade (Eumetsat MTG IRS). In addition, we will insure our mission, both for launch failure, premature on-orbit failure and inability to meet mission requirements. GMW also plans a robust system architecture with an on-ground spare and eventual on-orbit spare capability at each orbit location. This means that all GMW customers will have uninterrupted service when the system is fully deployed. It is imperative that an observation system utilized for daily weather forecast capability is available 24/7. It is also a business imperative to keep our customers happy. GMW is willing to enter into conditional purchase agreements, where the quality of the data is verified by the end customer prior to final contract.

8. Recommendations on how to best evaluate most cost-effective and diverse combination of weather capability.

There are various ways to evaluate the roles of diverse capability. For similar measurements, simple inspection of observing frequency, resolution and coverage offer good first order comparison. For severe weather observation over the US, where short-term and continuous observations are the goal, this is our primary basis of comparison between an advanced commercial sounder in GEO and an advanced sounder on NPP/JPSS. An advanced GEO sounder is superior because it requires no sophisticated analysis, it simply makes 10's to 1000's of times more observations over the United States than a comparable observation on NPP/JPSS.

In the area of medium range and long- range Numerical Weather Prediction (NWP), the analysis requires more sophistication, in that the longer the forecast, the more global coverage is needed. For this reason, a system of Polar orbiting Weather satellites (not just one) is superior to a SINGLE GEO Imager/Sounder. However, the answer is not as clear cut when a global GEO hyperspectral system is compared with a Polar orbiting LEO system. This is the significant question to be addressed by new OSSE's that not only have the needed resolution to adequately compare these advanced technologies, but also the global coverage to assess the relative roles of a global Geo and Polar orbiting system. Additionally, OSSE's are desired by commercial providers to optimize the observing strategies needed to provide maximum weather observation benefit to our global customers. Finally, as Advanced GEO systems come online, true gap analysis may be used to assess the relative role of both Polar and GEO systems using real data.