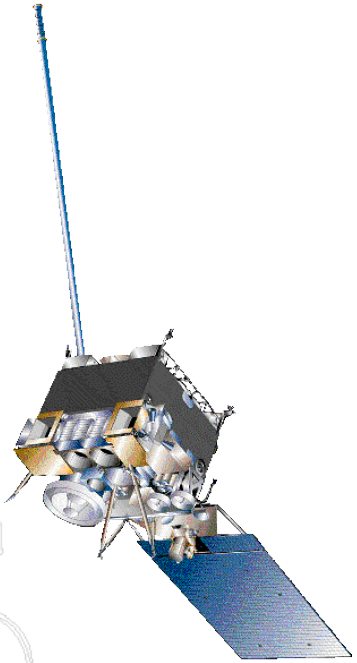
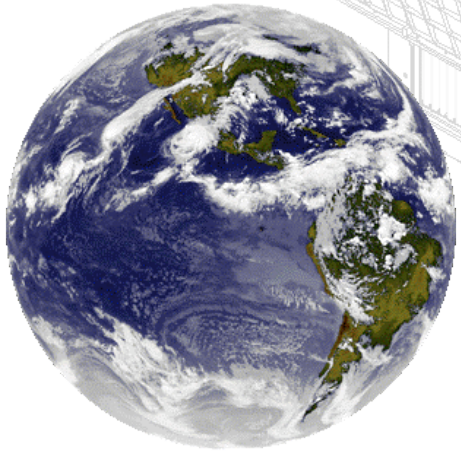
GEOSTATIONARY SOUNDING:



Current and Future GOES Sounders

Kent Sprunger
Chris Archer
Chris Lietzke
Steve Johnson



March 3, 2002

- **ACKNOWLEDGMENTS**
  - The authors thank Jeanine Murphy/NASA GSFC for granting us permission to use her paper presented in 1996 as a starting point for this paper.
  - The CrIS EDR Algorithm developed by AER, Inc. was used to compare the current sounder product to the predicted ABS product.
  - Further information can be found on the Internet. Go to the home page of the GOES Project Scientist, Dr. Dennis Chesters, http://rsd.gsfc.nasa.gov/goes/ and information from the University of Wisconsin at http://cimss.ssec.wisc.edu/goes/.

- **REFERENCES**

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  - Performance Specification for GOES-NO/PQ Imager and Sounder Instruments, Rev -, NASA-Goddard Spaceflight Center, Doc No S-415-05, March 28,1996.
  - Menzel, W. Paul and James F.W. Purdom, Introducing GOES-I: The First of a New Generation of Geostationary Operational Environmental Satellites, Bulletin of the American Meteorological Society, Vol. 75, No. 5, May 1994.
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  - Performance and Operation Requirements Document (PORD), DRAFT, NASA-GSFC, Document No. S-xxx-xxx, June 15, 2001
  - Menzel, W. Paul, Introducing the Advanced Baseline Sounder (ABS), GOES Users' Conference, May 22-25, 2001
  - Murphy, Jeanine E. and Sanford W. Hinkal, GOES Sounder Overview, in GOES-8 and Beyond, Edward R. Washwell, Editor, Proc. SPIE 2812, page numbers 174-181 (1996)
  - Preliminary Design Review for GHIS Engineering Model, August 1997

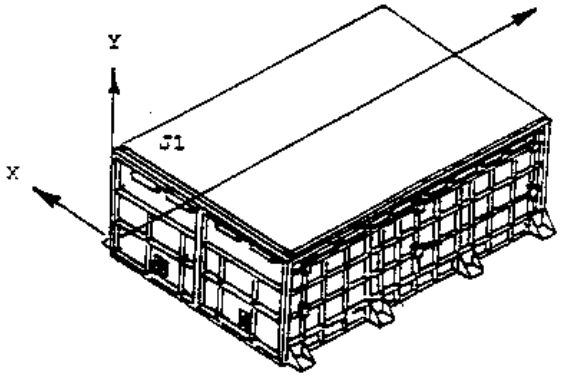
"Long & Winding Road" topics for today:

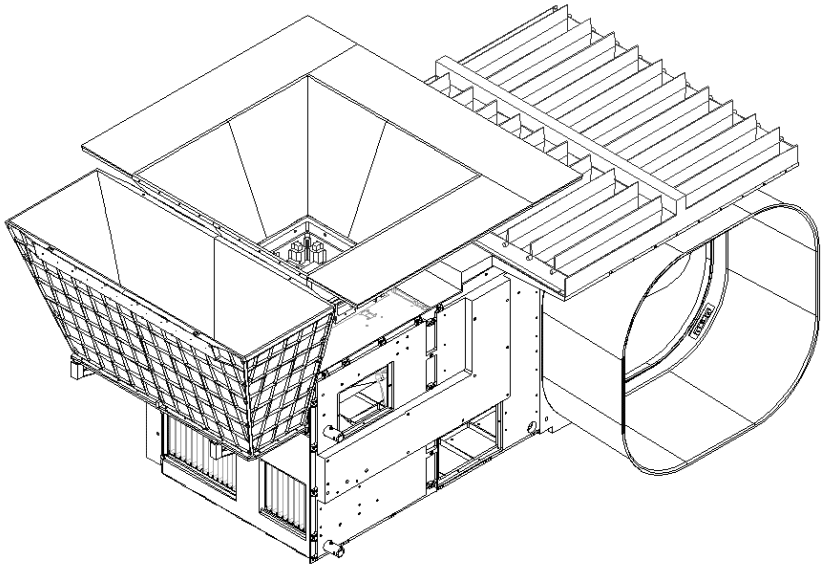
- *Current:* **GOES-NOPQ Sounder**
- *Shelved design:* **GOES High-resolution Interferometric Sounder (GHIS)**
- *Future*: **Advanced Baseline Sounder (ABS)**
- **ABS Modeled Performance**

GOES-NOPQ Sounder Overview

GOES-NOPQ Sounder
Instrument Modules

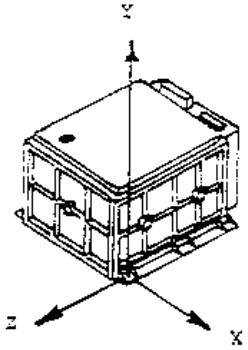
Electronics Module (E-box)





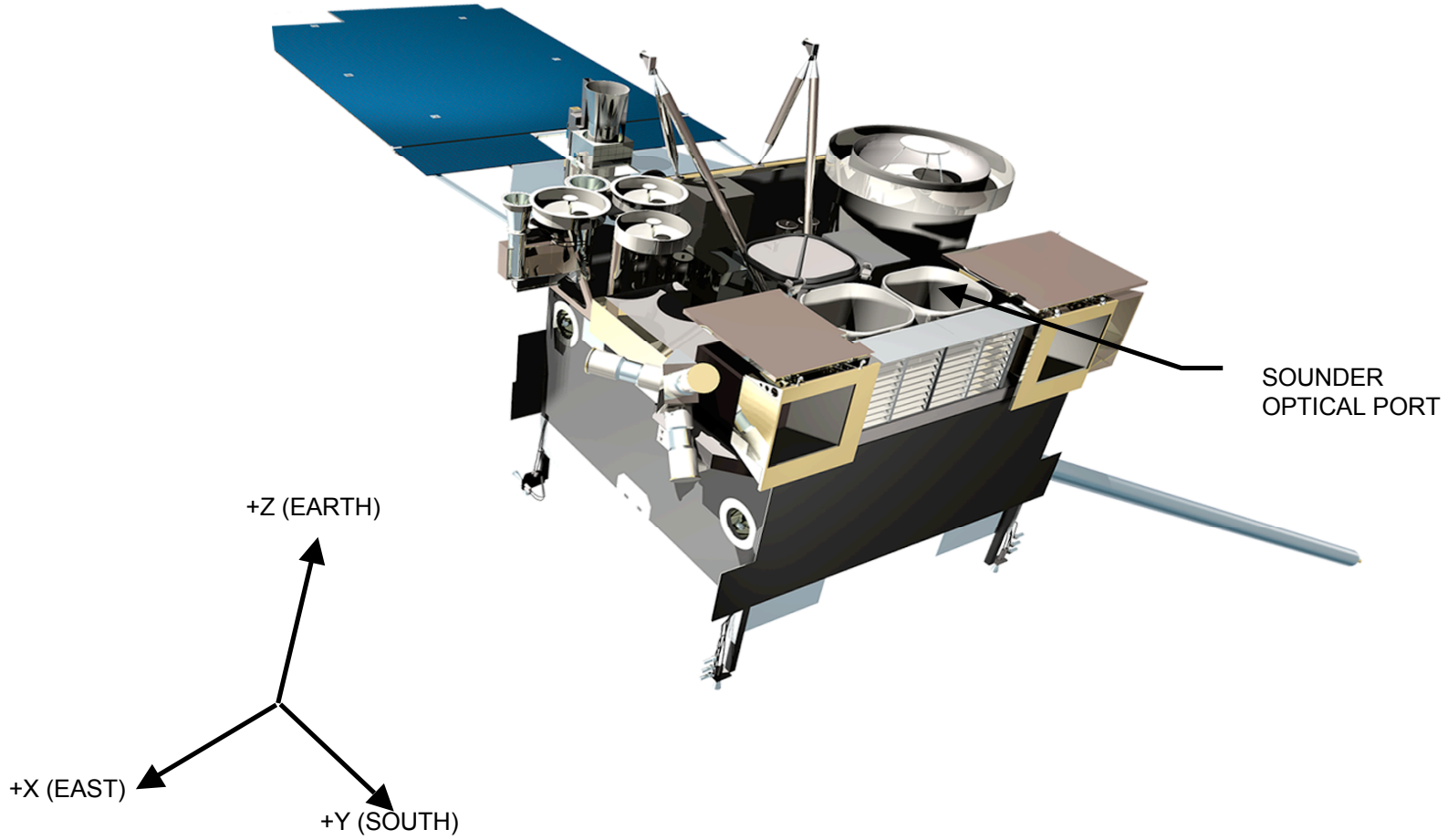
Sensor Module

Power Supply Module

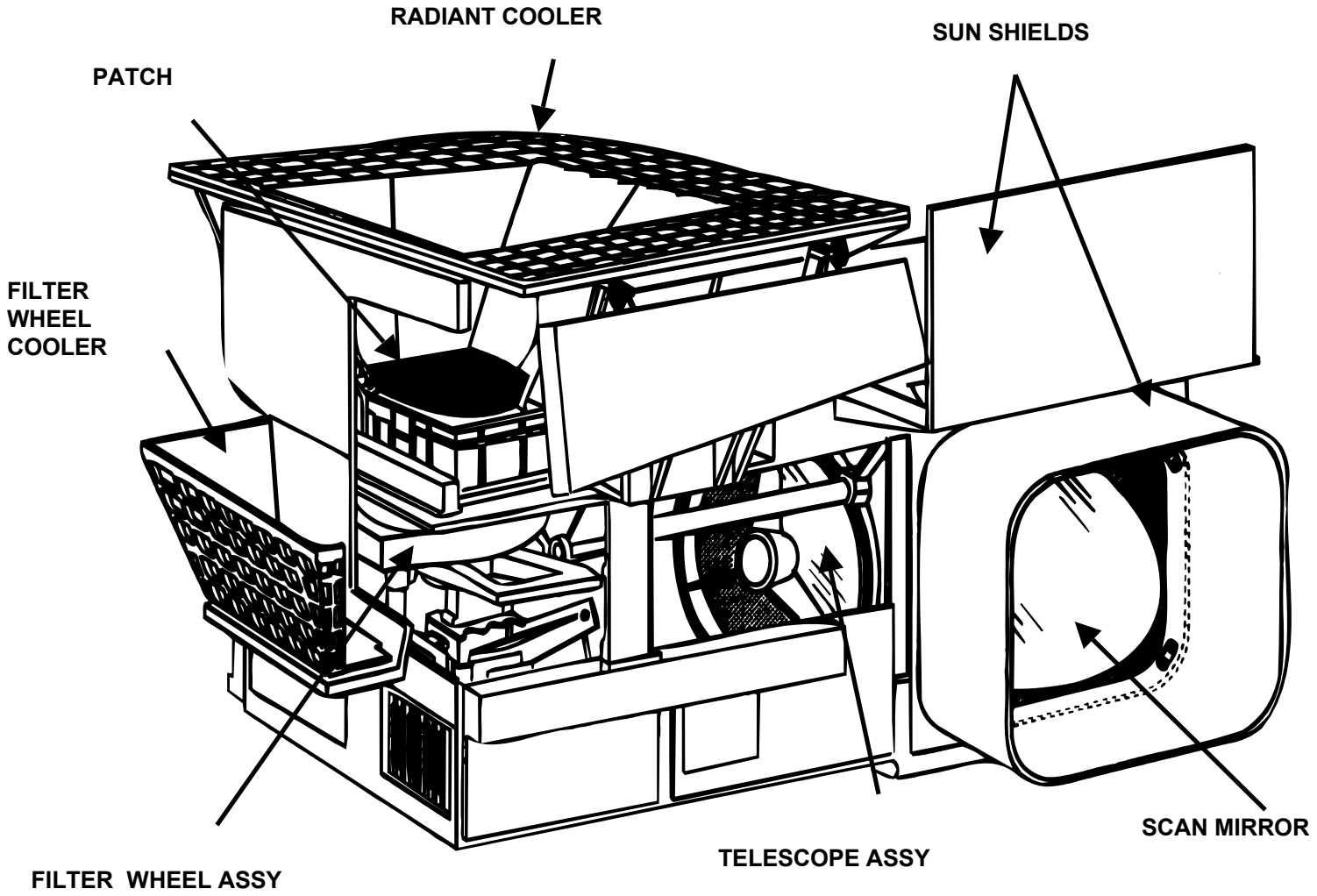


Modules Not Shown To Scale

GOES-NOPQ Spacecraft



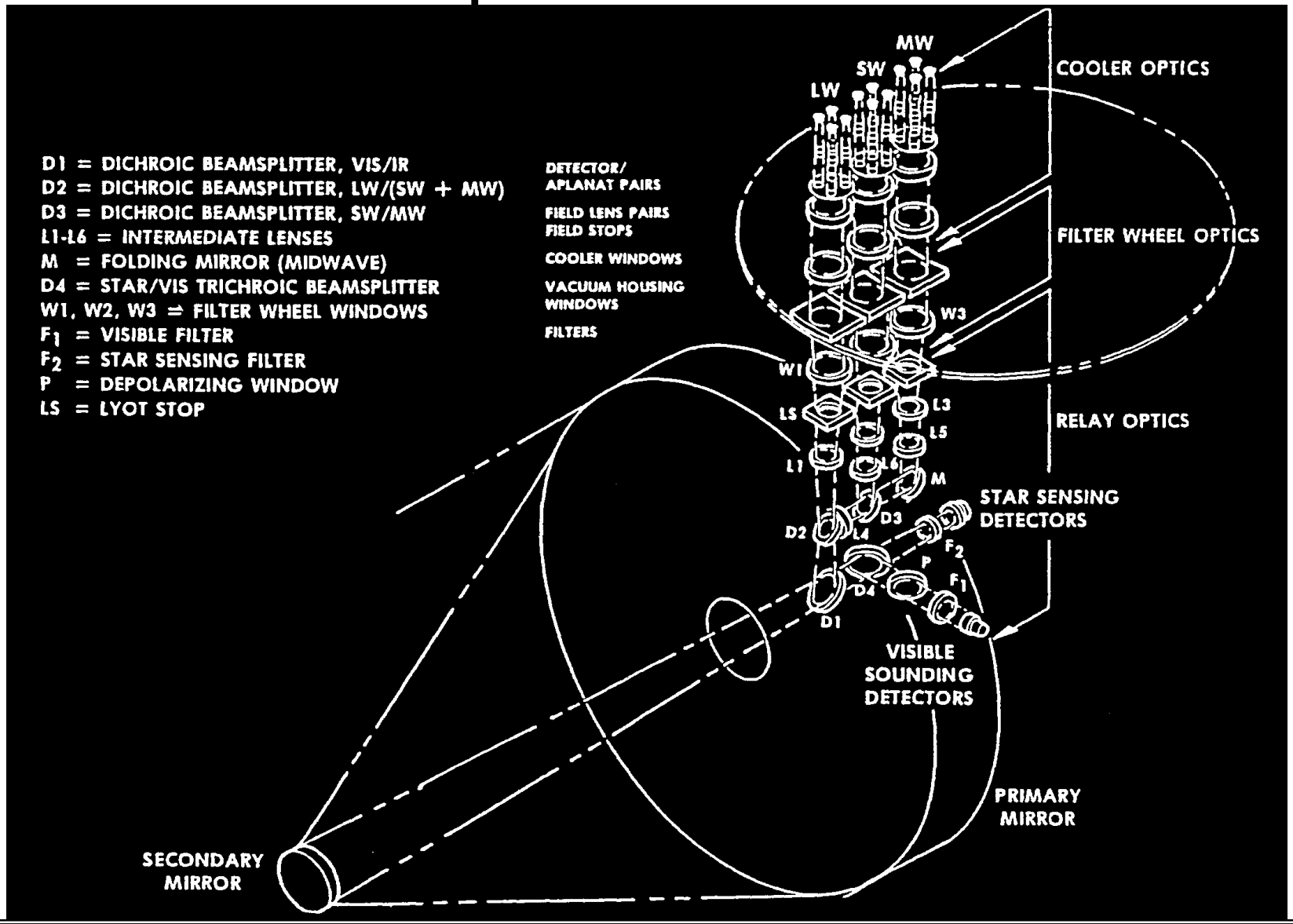
GOES-NOPQ Sounder
Sensor Module



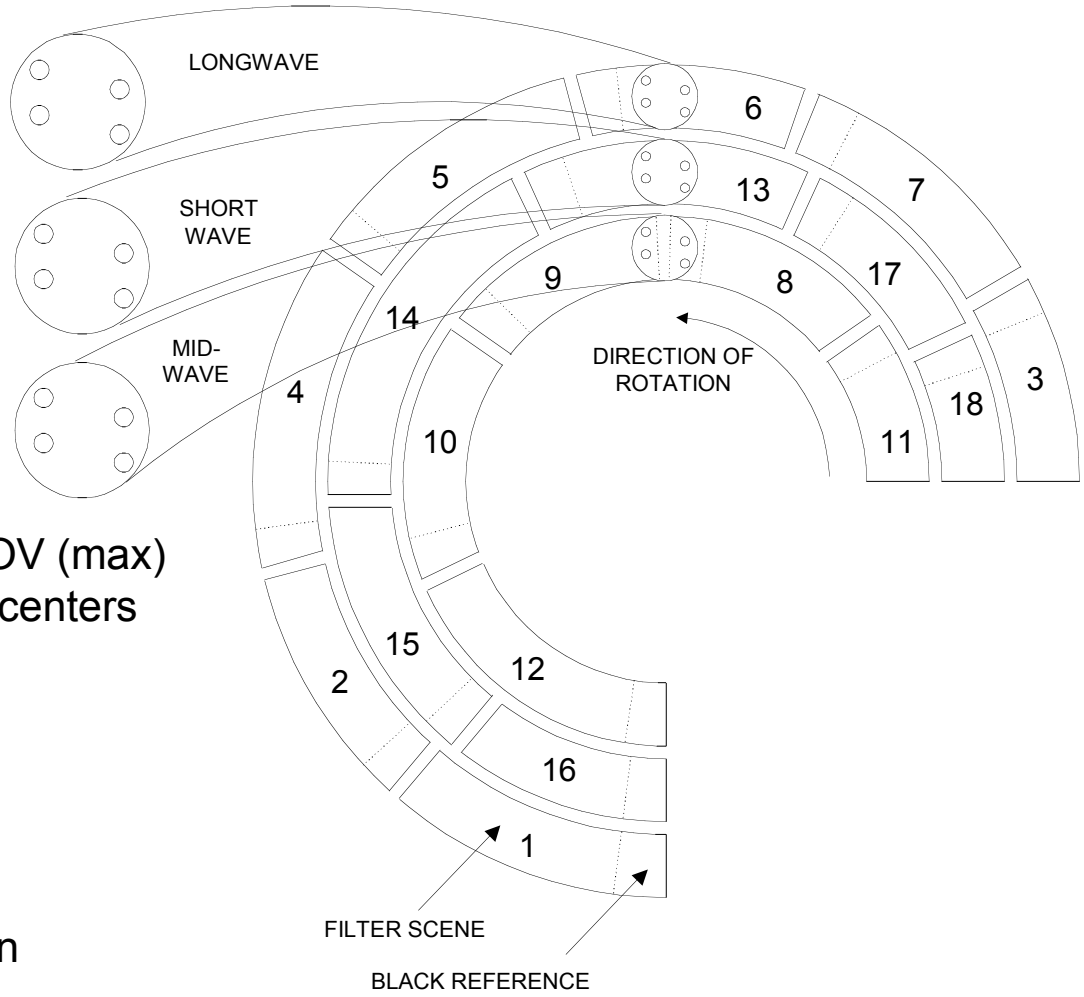
GOES-NOPQ Sounder
Spectral Characteristics

Channel	Central Wavelength (cm^{-1})	Central Wavelength (μm)	Half-Power Bandwidth (cm^{-1})	Specified NEΔN ($mW/(m^2/sr/cm^{-1})$)	Meteorological Parameter Determined
1	680	14.71	13	1.43	Stratosphere temperature
2	696	14.37	13	1.43	Tropopause temperature
3	711	14.06	13	0.69	Upper-level temperature
4	733	13.64	16	0.69	Mid-level temperature
5	748	13.37	16	0.57	Low-level temperature
6	790	12.66	30	0.28	Total precipitable water
7	832	12.02	50	0.23	Surface temp, moisture
8	907	11.03	50	0.16	Surface temperature
9	1030	9.709	25	0.33	Total ozone
10	1345	7.435	55	0.16	Low-level moisture
11	1425	7.018	80	0.12	Mid-level moisture
12	1535	6.515	60	0.15	Upper-level moisture
13	2188	4.570	23	0.013	Low-level temperature
14	2210	4.525	23	0.013	Mid-level temperature
15	2245	4.454	23	0.013	Upper-level temperature
16	2420	4.132	40	0.0080	Boundary layer temperature
17	2513	3.979	40	0.0082	Surface temperature
18	2671	3.744	100	0.0036	Surface temperature, moistu
19	14367	0.696	1000	0.05%Albedo	Cloud cover

GOES-NOPQ Sounder
Optical Elements



GOES-NOPQ Sounder
Filter Wheel and Channel Separation



Detectors:
- Four Detectors per channel (IR & Visible)
- Each detector has 8.7 km (242.6 μrad) IGFOV (max)
- Neighboring detectors on 10 km (280 μrad) centers

Filter Wheel
- Rotating wheel inserts selected filters into the optical path
- Wheel rotation is synchronized with stepping motion of the scan mirror (10 steps/sec)
- Rotation speed is 600 rpm

GOES-NOPQ Sounder
On-orbit Calibration

- IR Channels
  - Internal Calibration Target
    - 4 second view of the internal blackbody every 20 minutes establishes a high temperature baseline for calibration in orbit
  - Space Looks
    - 4 second view of space every 2 minutes for reference
  - Electronic Calibration
    - Amplifiers and data stream are checked by an electronic staircase signal during each blackbody cycle.

GOES High-resolution Interferometric Sounder (GHIS)

-- Engineering Model PDR in 1997 --

GHIS -- in 1997

Key Mission Requirement:

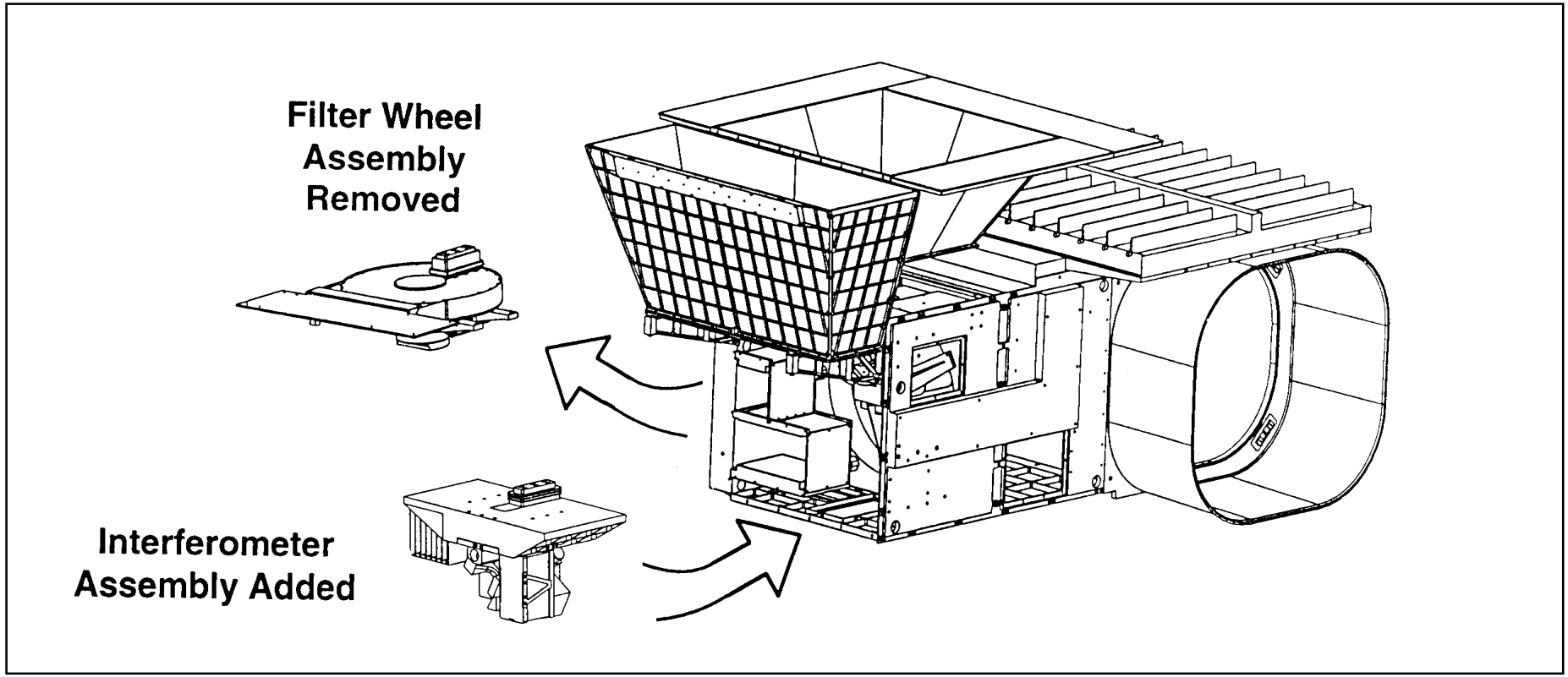
Achieve < 1.0°K temperature retrieval accuracy with < 1 km vertical resolution

Completed Objectives:

- **Develop preliminary design for Flight Model EDU**
- **Detailed design for Engineering Model**
- **Address key technical risks through technology demonstrations and simulations**

In May, 1997, notice was received to terminate the GHIS program due to insufficient out-year funding to support Flight Model development

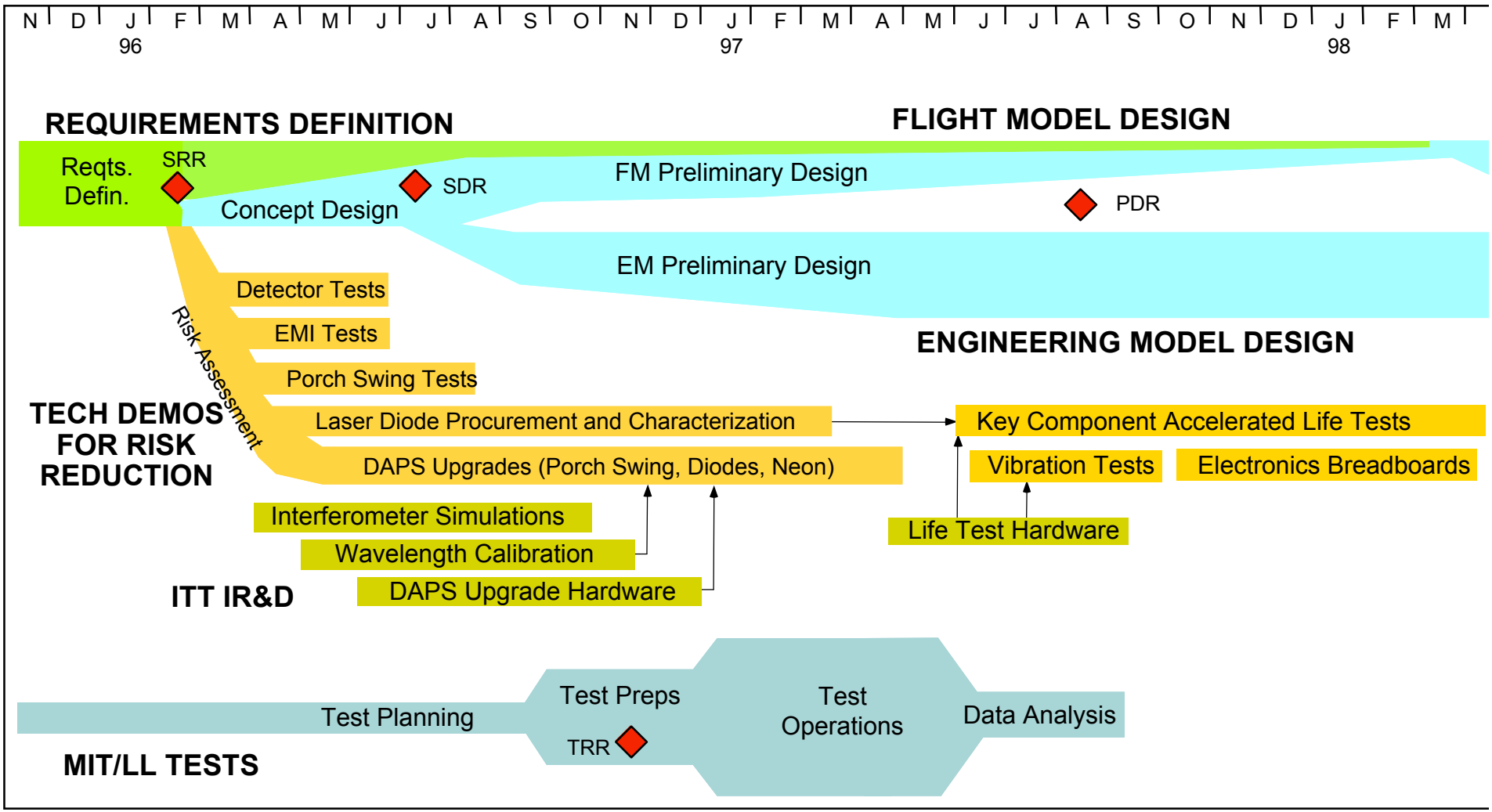
The ITT GHIS Program Demonstrated the Feasibility of ABS by Adding an Interferometer to the GOES Sounder



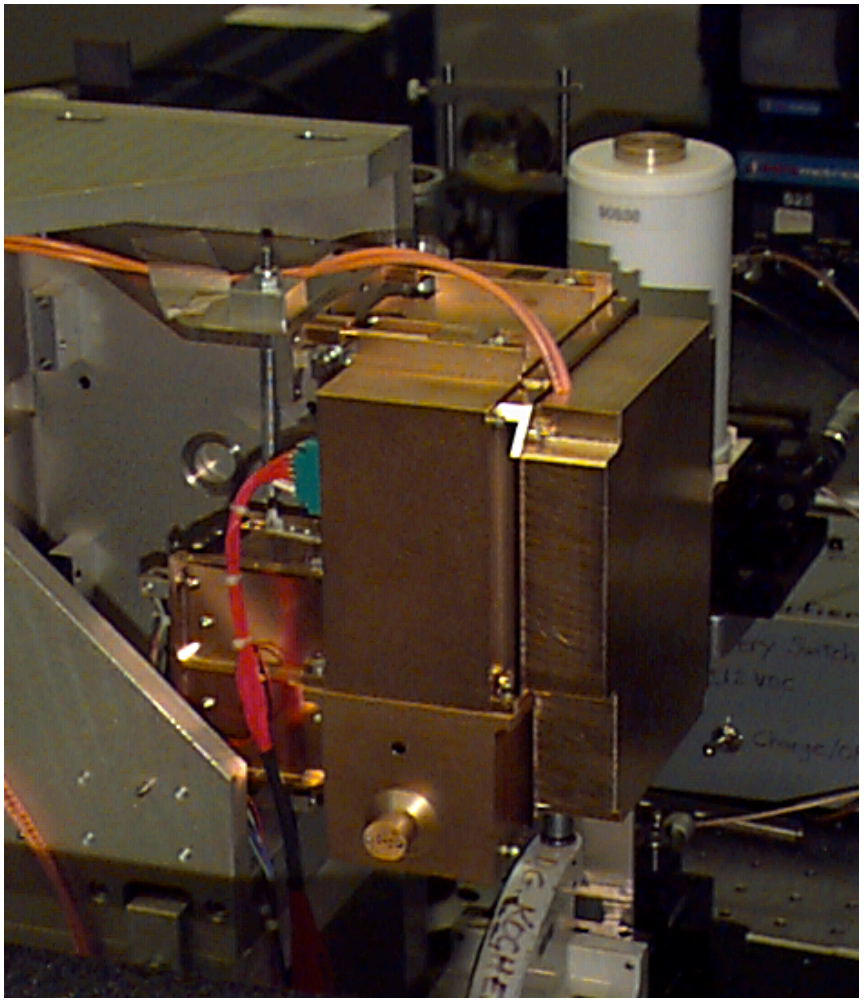
GHIS Study Was Funded By the GOES Program Office in 1995-1997

GHIS Reached PDR and Demonstrated a Prototype (w/1,336 channel capability) in the GOES SN02 Sounder

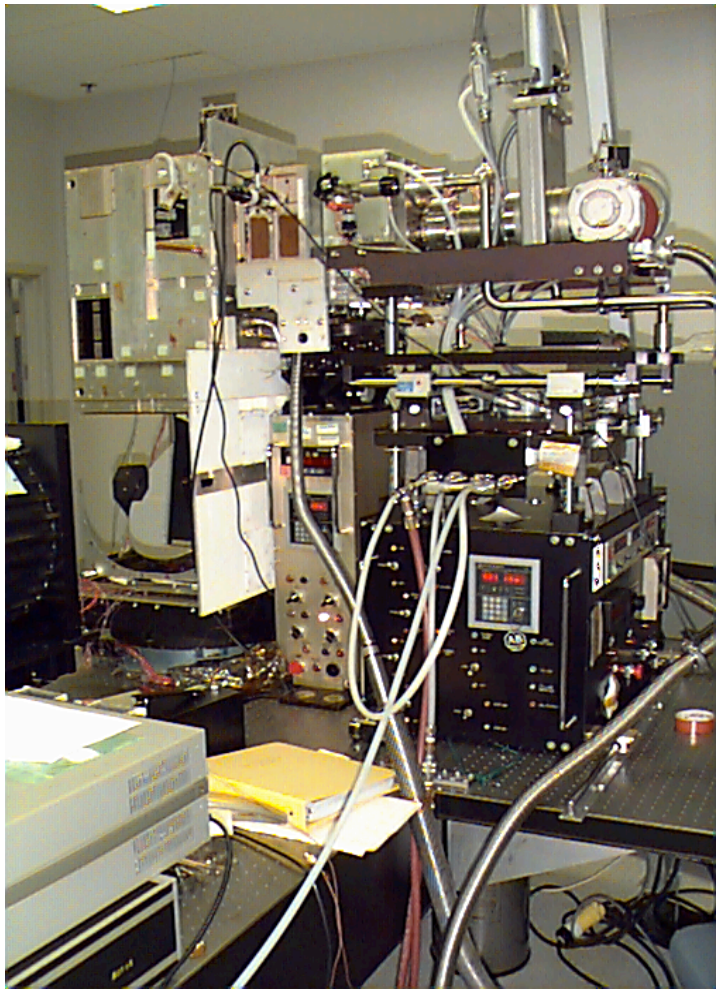
GHIS Activities / Milestones



ITT Successfully Installed an MIT/LL-Built Prototype of the GHIS Interferometer in the SN02 Sounder

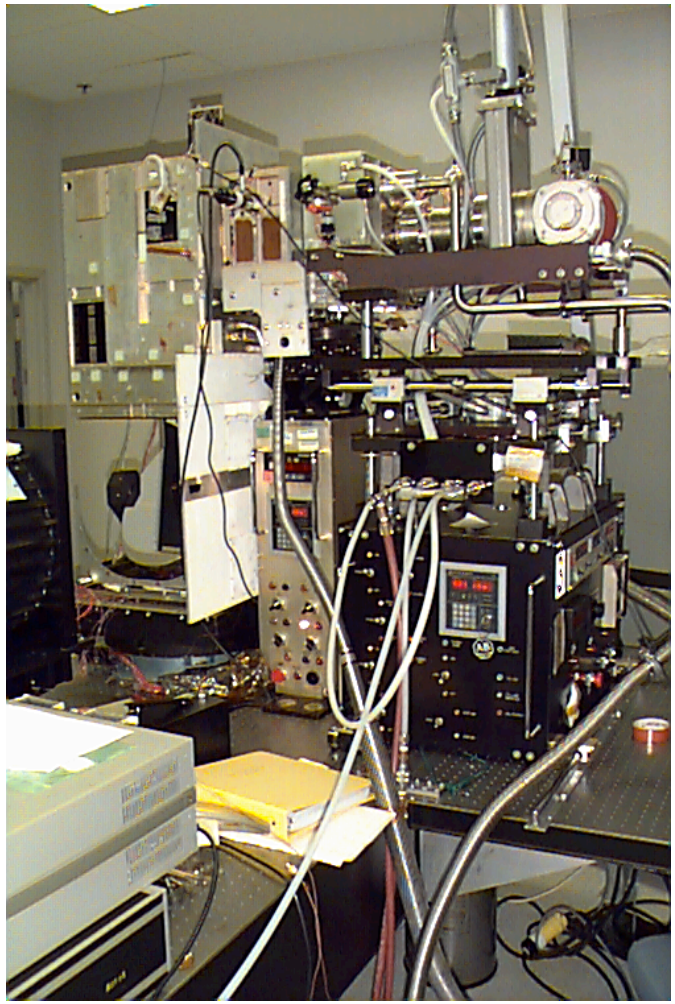


MIT/LL Interferometer in Subsystem Test Fixture



Interferometer Installed and Operating in GOES SN02 Sounder

MIT/LL Interferometer Tests in SN02 Were Successfully Completed



SN02 Interferometer Test Results:

- Operation of an interferometer in the GOES Sounder was clearly demonstrated
- Alignment process went smoothly, wit the help of an interface matching plate
- Control and signal processing system worked well
- Integrated test objectives were satisfie

Benefits & Status of GHIS

- **Advanced IR Sounder developments have benefited from Synergy between GHIS technologies and NPOESS CrIS instrument requirements**
- **GHIS Program Restart is a Viable Option at ITT A/CD**
  - **Personnel remain available for possible program restart**
  - **Interferometer skills base has been retained and applied to NPOESS / CrIS**
  - **Synergy with CrIS development and operational applications of new technologies could significantly reduce GHIS non-recurring costs**
  - **a GEO hyperspectral sounder is still possible within the next 5 years rather than after another 10 years**

Advanced Baseline Sounder (ABS)

ABS Sounding Performance
(Accuracies and Vertical Resolution in Clear Air)

Altitude Range	Observational Accuracy		Observational Accuracy		Vertical Resolution	
	Temperature THRESHOLD	Temperature GOAL	Humidity THRESHOLD	Humidity GOAL	THRESHOLD	GOAL
Surface – 300 hPa	± 1.0 K	± 0.5 K	± 10%	± 5%	Surface – 500 hPa 0.3 – 0.5 km layers 500 – 300 hPa; 1 – 2 km layers	Surface – 500 hPa < 0.3 – 0.5 km layers 500 – 300 hPa < 1 – 2 km layers
300 hPa – 100 hPa	± 1.0 K	± 0.5 K	± 20%	± 10%	1 – 2 km layers	< 1 – 2 km layers
100 hPa and above	± 1.0 K	± 0.5 K	N/A	N/A	2 – 3 km layers	< 2 – 3 km layers

ABS Instrument Requirements
(Critical Parameters)

Parameter		ABS Threshold Requirement	ABS Goal Requirement	GOES N/Q Requirement
Ground Sample Distance$_{max}$	Visible	1 km	1 km	10 km
	650 - 1200 cm^{-1}	10 km	8 km	10 km
	1210 - 1740 cm^{-1}	10 km	4 km	10 km
	2150 - 2720 cm^{-1}	10 km	4 km	10 km
Ensquared energy$_{min}$ (The detector signal produced by radiance from the square grid defined by the ground sample distance divided by the total detector signal produced by scene radiance.)	650 - 1200 cm^{-1}	90%	90%*	73% or 78%**
	1210 - 1740 cm^{-1}	90%	67%*	78%**
	2150 - 2720 cm^{-1}	90%	67%*	85%**
	*The threshold ensquared energy values are for a ground sample distance (GSD) >8 km. The goal ensquared energy values are for a GSD of ≤4 km. For other values of GSD, the ensquared energy requirement shall be scaled linearly between the requirements for 8 km and 4 km. ** The GOES-N/Q requirement (encircled incident energy) is for detector signal produced by radiance from one circular IGFOV divided by the total detector sig produced by scene radiance.			

ABS Instrument Requirements, Cont'd
(Critical Parameters)

Parameter		ABS Threshold Requirement	ABS Goal Requirement	GOES N/Q Requirement
IR Spectral bands and spectral resolution	650 - 1200 cm^{-1}	880 bins (0.625 cm^{-1} resolution)	Same as threshold	9 channels (13 - 50 cm^{-1} half-power bandwidth)
	1210 - 1740 cm^{-1}	424 bins (1.25 cm^{-1} resolution)		3 channels (55 - 80 cm^{-1} half-power bandwidth)
	2150 - 2720 cm^{-1}	228 bins (2.5 cm^{-1} resolution)		6 channels (23 - 100 cm^{-1} half-power bandwidth)
$NEdN_{max}$ ($mW/m^2/sr/cm^{-1}$)	650 – 670 cm^{-1}	1.0	1.25*	NA**
	670 – 685 cm^{-1}	0.7	0.88*	1.43
	685 – 700 cm^{-1}	0.5	0.63*	1.43
	700 – 1150 cm^{-1}	0.15	0.19*	0.69 – 0.33
	1150 – 1200 cm^{-1}	0.3	0.38*	NA**
	1210 – 1740 cm^{-1}	0.06	0.15*	0.12 – 0.16
	2150 - 2720 cm^{-1}	0.008	0.02*	0.013 – 0.0036
	*The threshold NEdN values are for a threshold ground sample distance (GSD). If the GSD is less than the threshold, the NEdN requirement can be increased in inverse proportion of the GSD. **The GOES-N/Q Sounder does not have IR channels in this spectral range.			

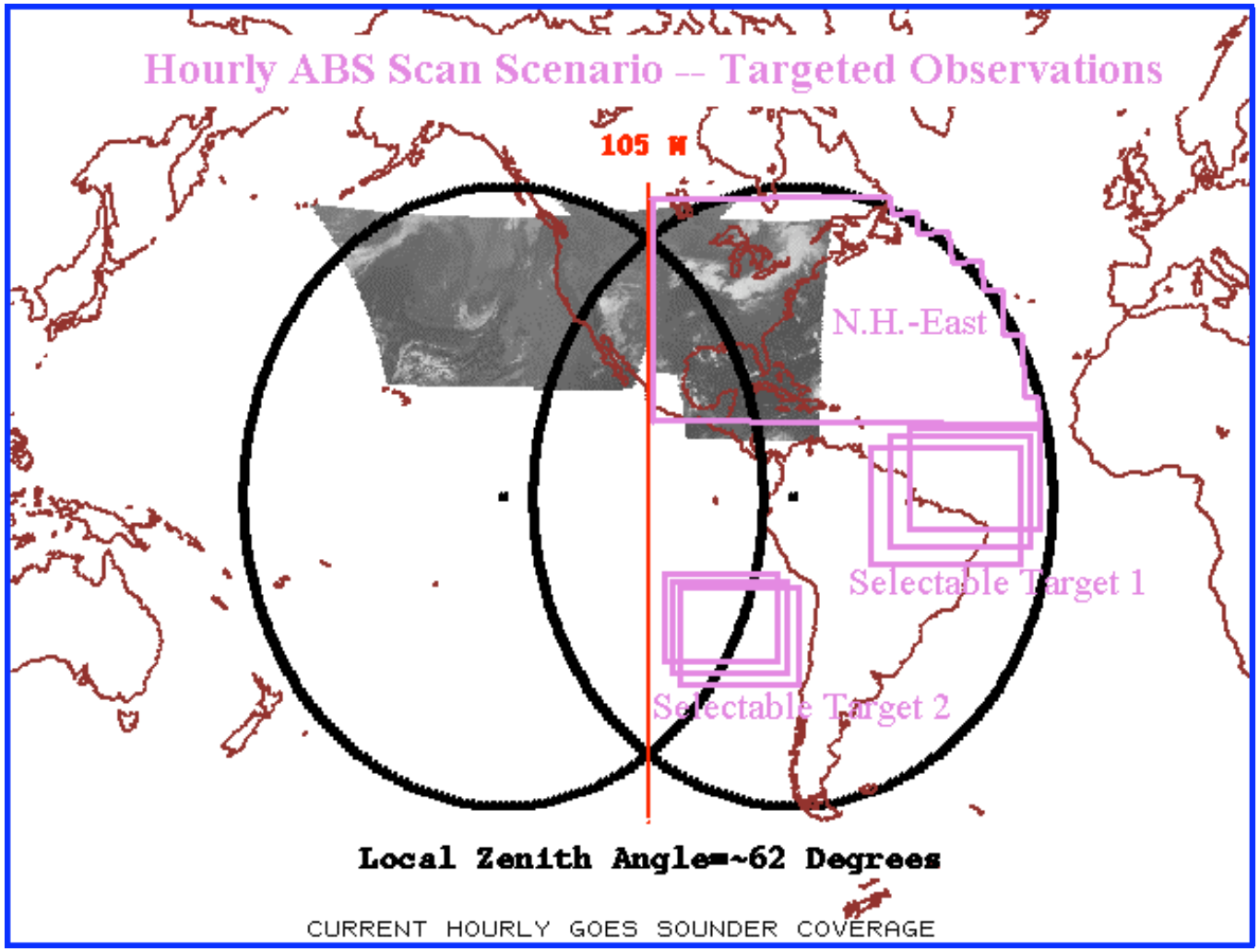
ABS Instrument Requirements, Cont'd
(Critical Parameters)

Parameter	ABS Threshold Requirement	ABS Goal Requirement	GOES N/Q Requirement
Coverage rate	In 60 minutes, scan one region within 62 degrees local zenith angle*	In 60 minutes, scan one full disk	In 60 minutes, scan one CONUS and one Gulf of Mexico region**
Regional and Mesoscale (when required)	Must be supported and selectable	Must be supported and selectable	Must be supported and selectable

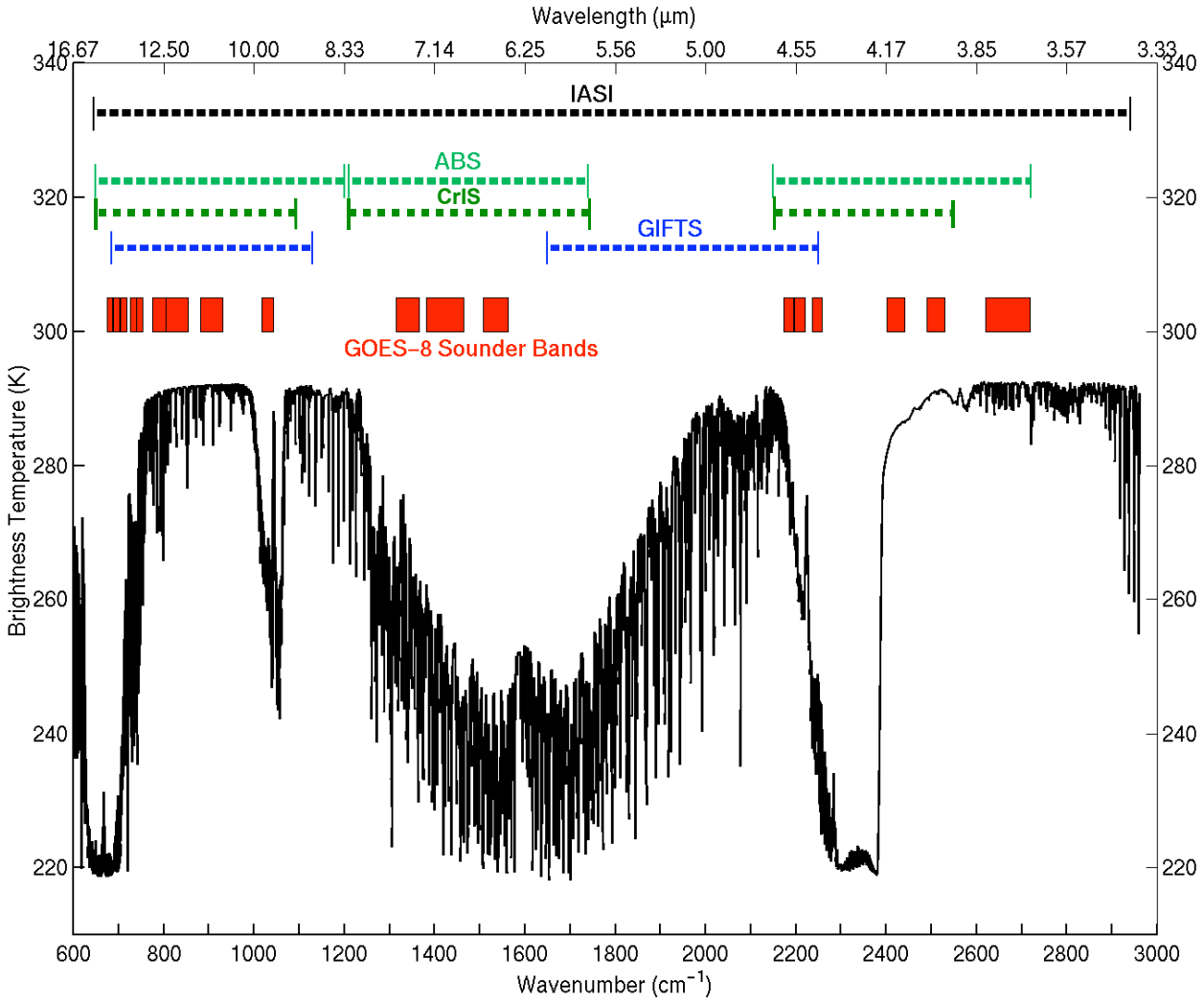
*Although only scan half of the region of overlap between the eastern and western satellites, nominally at 105W, as shown in Scan Scenario slide.

**An image for one hour of the infrared window channel from the GOES East and West instruments are shown in Scan Scenario slide.

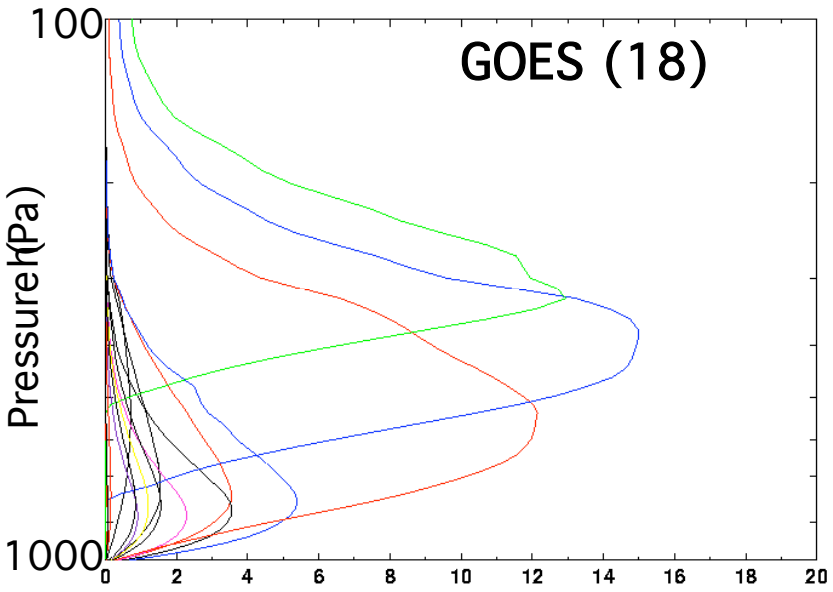
ABS Scan Scenario

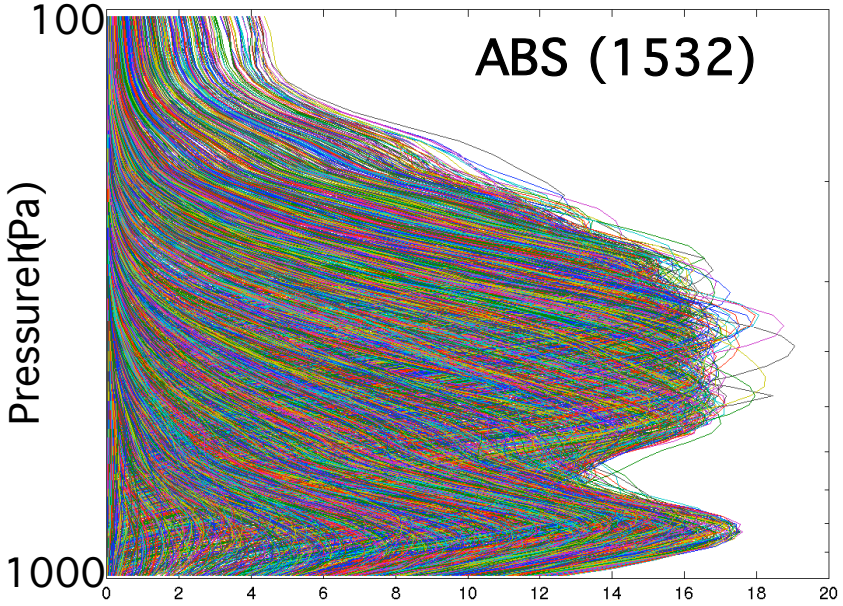


IR Spectral Coverage
ABS (1,532) and GOES Sounder (18)



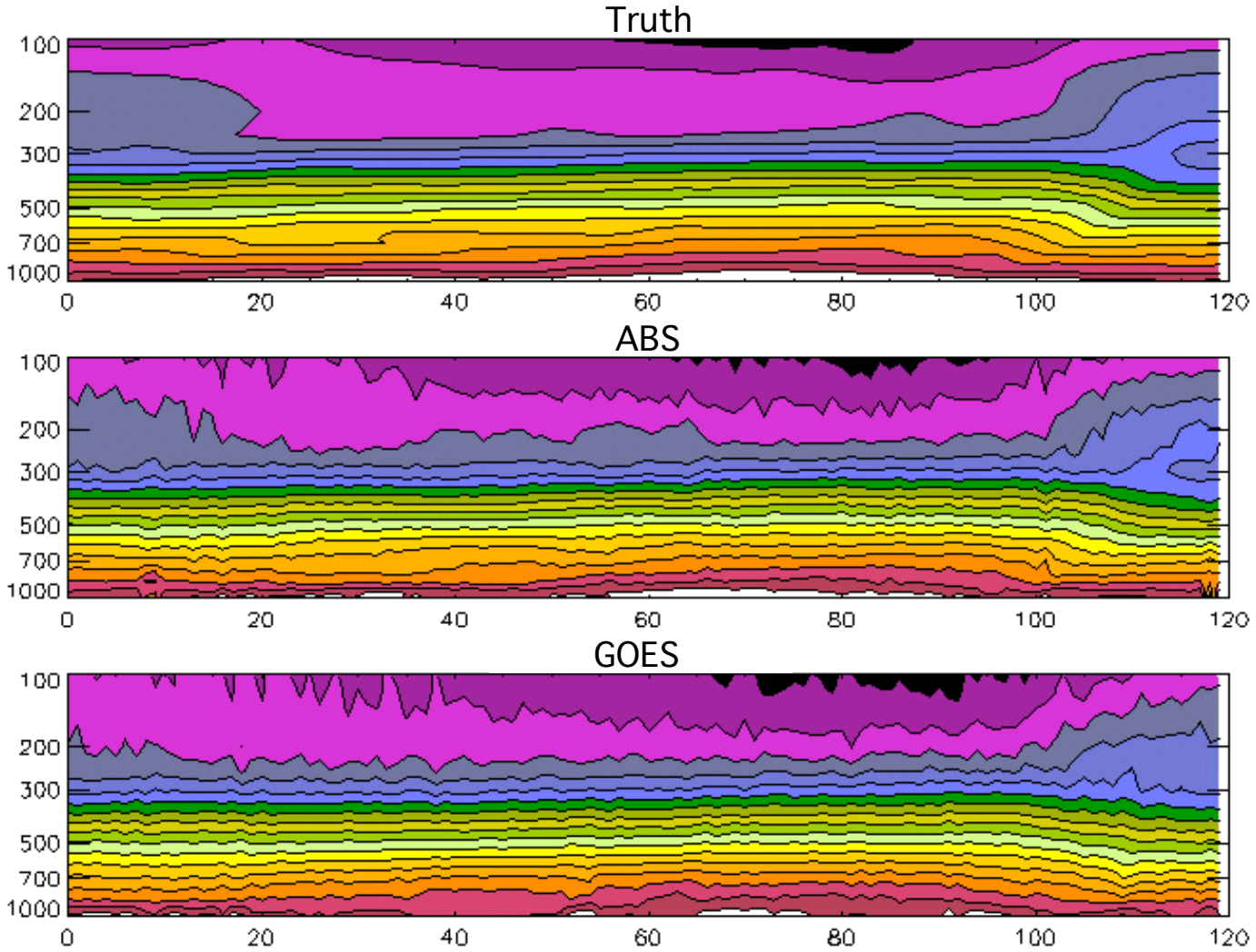
Moisture Weighting Functions
ABS (1,532) and GOES Sounder (18)





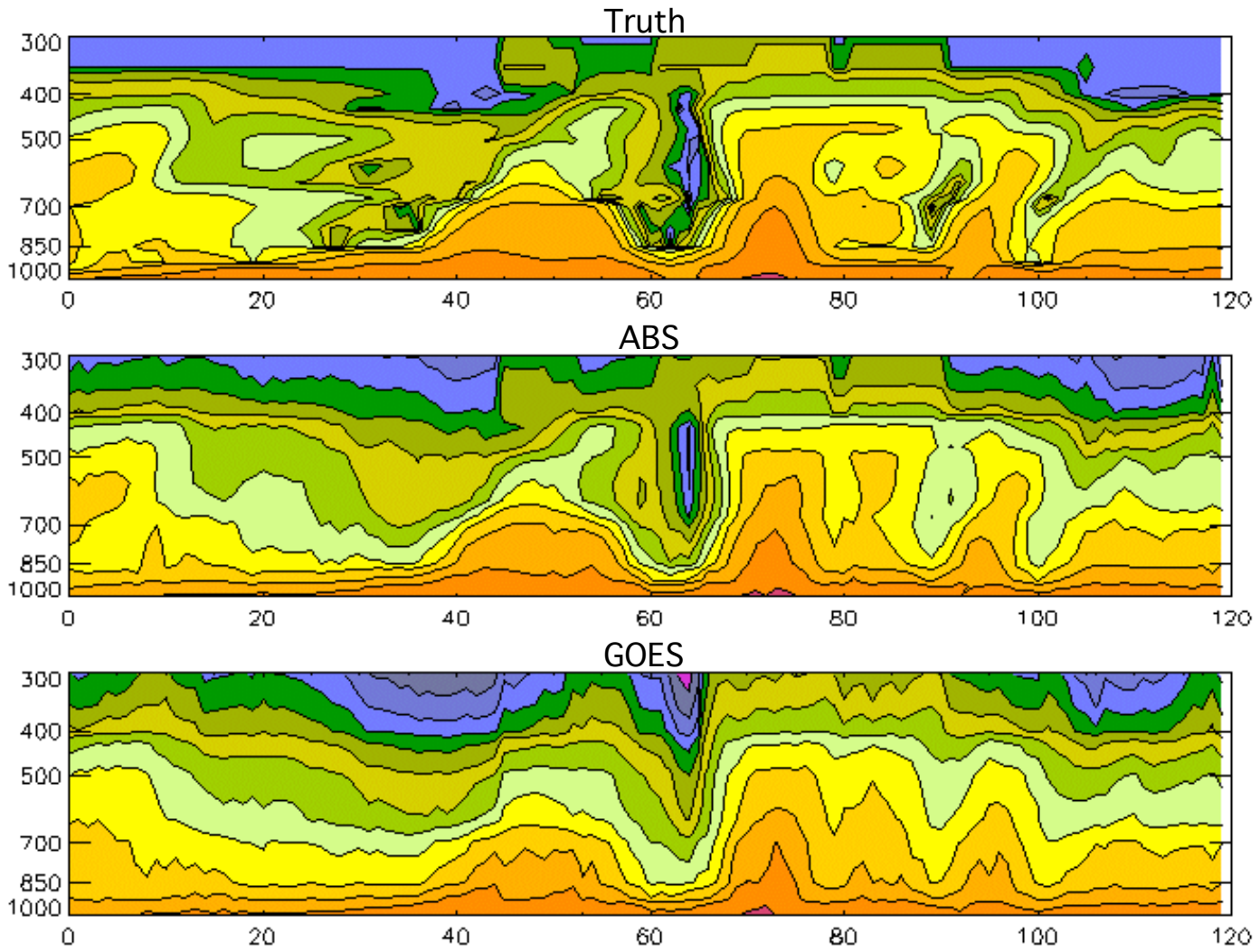
Modeled Performance of Advanced Baseline Sounder (ABS)

Vertical Structure of Retrieved Temperatures
(ABS vs. GOES)



ITT Industries
Engineered for life

Vertical Structure of Retrieved Moistures
(ABS vs. GOES)



Conclusions

- Advanced IR Sounders for GEO are climbing a “long and winding road”
- The required technologies are ready
- Eventual benefits will be tremendous with improved:
  - Resolutions:
    - » temporal
    - » spectral
    - » spatial

Major data product improvements fc

- » nowcasting
- » short-range weather forecasts
- » longer-range NWP updates