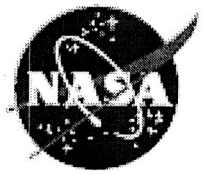

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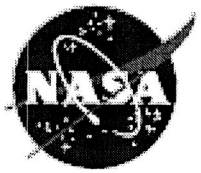
Flight Center

Usage of EESS (passive) spectrum allocations

Jeffrey R. Piepmeier
Microwave Instrument Technology Branch
NASA's Goddard Space Flight Center



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Outline

- Funded instruments in development
  - Advanced Technology Microwave Sounder (**ATMS**) on NPOESS Preparatory Mission (NPP)
  - Aquarius microwave radiometer
  - Global Precipitation Measurement (GPM) Microwave Imager (**GMI**)
  - Hydros microwave radiometer
- Proposed/notional instruments
  - Cirrus clouds submmw radiometer
  - Cold-lands microwave radiometer
  - Geostationary millimeterwave radiometer (GeoSTAR)
  - Geostationary soil moisture and salinity radiometer

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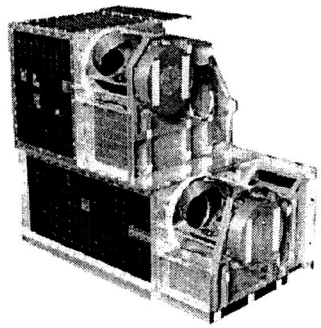
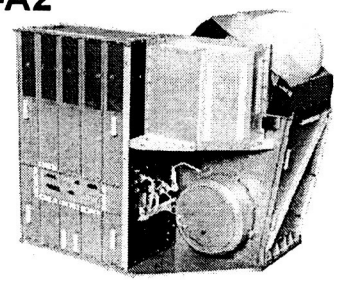
NPP/ATMS

- NPOESS vertical atmospheric sounder
- 22 channels
- 24-183 GHz

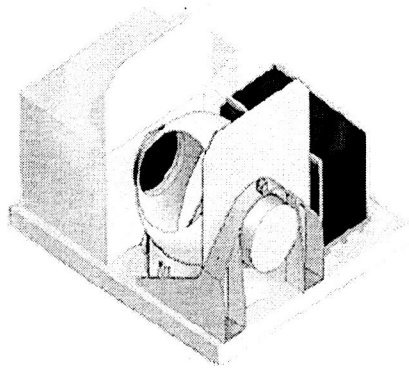
AMSU-A1



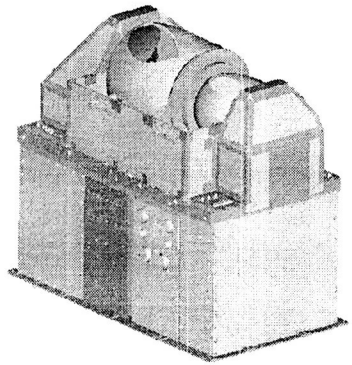
AMSU-A2



MHS



ATMS



From: *"Status of ATMS development (975 Science-Highlights, July-03),"* NASA's Goddard Space Flight Center, obtained from Dr. Ed Kim, April 2005.

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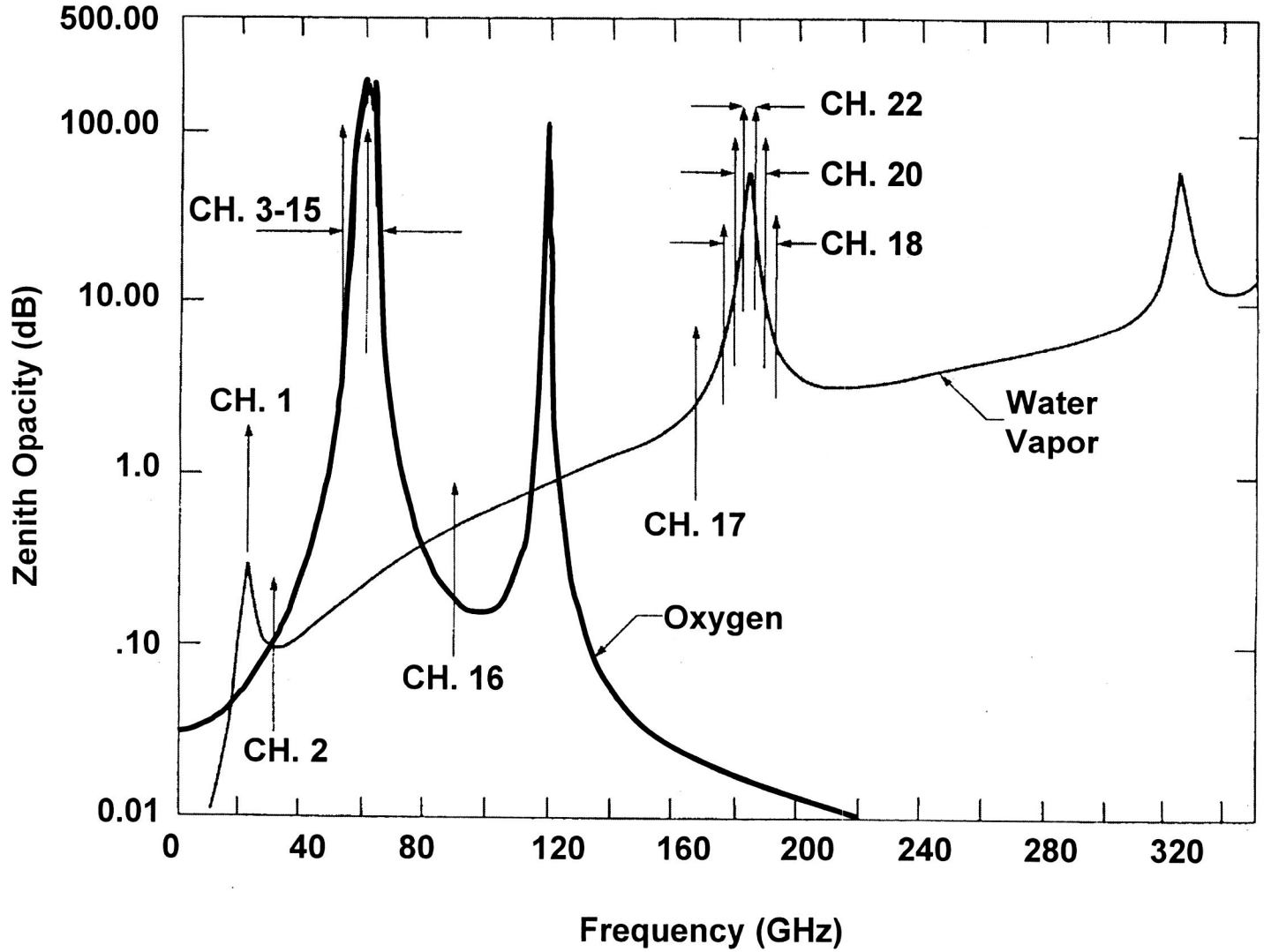
ATMS Channels and Spectra



From: *"Status of ATMS development (975 Science-Highlights, July-03),"* NASA's Goddard Space Flight Center, obtained from Dr. Ed Kim, April 2005.

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ATMS Channel Parameters

Channel	Frequency (Ghz)	Maximum Bandwidth (MHz)	Frequency Stability (MHz)	Static Beam Width θ_B (degrees)	Quasi Polarization V vertical H horizontal	NEΔT (K) Required	Calibration Accuracy (K) Required
1	23.8	0.27	<10	5.2	QV	0.90	1.00
2	31.4	0.18	<10	5.2	QV	0.90	1.00
3	50.3	0.18	<10	2.2	QH	1.20	0.75
4	51.76 [1]	0.40	<5	2.2	QH	0.75	0.75
5	52.8	0.40	<5	2.2	QH	0.75	0.75
6	53.596 ±0.115	0.17	<5	2.2	QH	0.75	0.75
7	54.40	0.40	<5	2.2	QH	0.75	0.75
8	54.94	0.40	<10	2.2	QH	0.75	0.75
9	55.50	0.33	<10	2.2	QH	0.75	0.75
10	57.290344	0.33	<0.5	2.2	QH	0.75	0.75
11	57.290344 ±0.217	0.078	<0.5	2.2	QH	1.20	0.75
12	57.290344±0.3222 ±0.048	0.036	<1.2	2.2	QH	1.20	0.75
13	57.290344 ±0.3222 ±0.022	0.016	<1.6	2.2	QH	1.50	0.75
14	57.290344 ±0.3222 ±0.010	0.008	<0.5	2.2	QH	2.40	0.75

Note 1 : Additional channel to those on AMSU and MHS

From: *"Status of ATMS development (975 Science-Highlights, July-03),"* NASA's Goddard Space Flight Center, obtained from Dr. Ed Kim, April 2005.

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Channel Parameters (Cont.)

Channel	Frequency (Ghz)	Maximum Bandwidth (MHz)	Frequency Stability (MHz)	Static Beam Width θB (degrees)	Quasi Polarization	NEΔT (K) Required	Calibration Accuracy (K) Required
15	57.290344 ±0.3222 ±0.0045	0.003	<0.5	2.2	QH	3.60	0.75
16	87-91.9	2.0	<200	2.2	QV	0.50	1.00
17	165.5 [2]	3.0	<200	1.1	QH	0.60	1.00
18	183.31 ±7	2.0	<30	1.1	QH	0.80	1.00
19	183.31 ±4.5 [1]	2.0	<30	1.1	QH	0.80	1.00
20	183.31 ±3	1.0	<30	1.1	QH	0.80	1.00
21	183.31 ±1.8 [1]	1.0	<30	1.1	QH	0.80	1.00
22	183.31 ±1	0.5	<30	1.1	QH	0.90	1.00

Note 1 : Additional channel to those on AMSU and MHS

Note 2 : Modified Frequency from 150 GHz on MHS

QV, QH : quasi-vertical, quasi-horizontal polarizations

From: *"Status of ATMS development (975 Science-Highlights, July-03),"* NASA's Goddard Space Flight Center, obtained from Dr. Ed Kim, April 2005.

Goddard Space Flight Center

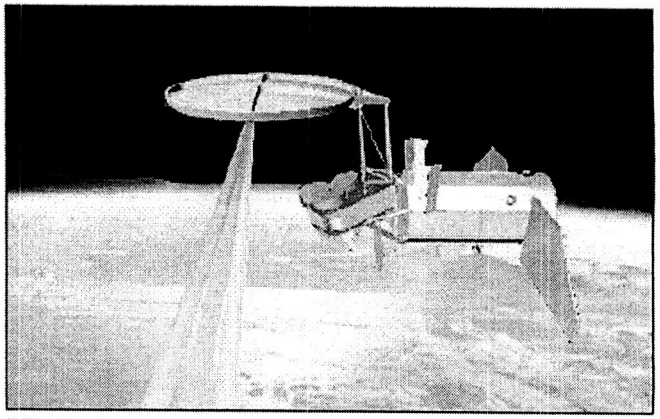
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

AQUARIUS/SAC-D

Project Overview

Salient Features

- *NASA-CONAE Partnership Science Mission*
- *NASA's L-band Radiometer / Scatterometer*
- *CONAE's Service Platform & MOC*
- *Dedicated Delta II launch vehicle provided by NASA*
- *Launch date: September 2008*
- *Aquarius Operational life: 3 years*
- *Aquarius PI: Gary Lagerloef, ESR*
- *SAC-D PI : Raul Colomb, CONAE*
- *Aquarius Project Manager: Amit Sen, NASA JPL*
- *SAC-D Project Manager: Luis Genovese, CONAE*
- *Aquarius Project Scientist: Yi Chao, NASA JPL*
- *JPL Program Manager: Steven Bard, NASA JPL*
- *NASA Program Exec.: Eric Ianson, NASA HQ*
- *NASA Program Scientist: Eric Lindstrom, NASA HQ*



JPL CONAE

Goddard Space Flight Center

http://aquarius.gsfc.nasa.gov

Science

- *Investigate the links between the global water cycle, ocean circulation and climate*
- *Make global, space-based measurements of Sea Surface Salinity (SSS)*
- *Provide 0.2 psu accuracy at monthly, 100 km resolution*
- *Observe and model seasonal and year-to-year variations of SSS, and how these relate to changes in the water cycle and ocean circulation*
- *Aquarius will yield an unprecedented view of ocean's role in climate and weather*

From: http://aquarius.gsfc.nasa.gov, April 2005.

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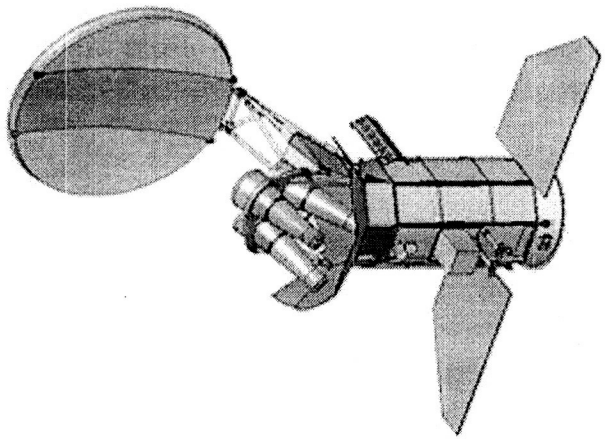
Aquarius Microwave Radiometer

- Sea surface salinity remote sensing
- 1413 MHz with 25 MHz bandwidth
- 0.05-K NEDT (12 second integration)
- Three pushbroom beams with V, H, P, & M polarizations
- Eight-day global coverage

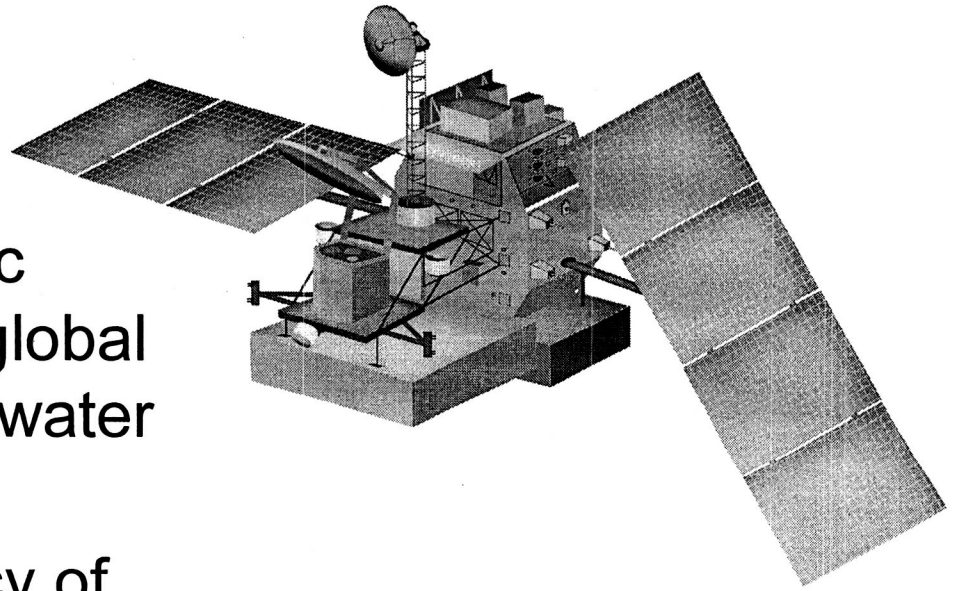


From: **http://aquarius.gsfc.nasa.gov**, April 2005.

Goddard Space Flight Center

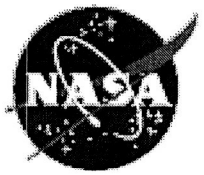
GPM/GMI

- GPM's Main Science Objectives
  - Improving the scientific understanding of the global water cycle and fresh water availability
  - Improving the accuracy of precipitation forecasts and its impact on weather
  - Providing frequent and complete sampling of the Earth's precipitation



GPM Core S/C

From: http://gpm.gsfc.nasa.gov, April 2005.



Goddard Space Flight Center

GPM/GMI – base set

Table 3-1. Required GMI Channel Set and Performance

hannel #	Center Freq.[1] f_c [GHz]	CFS [MHz] (Stab +/-) (Maximum Deviation)	Pass-band Bandwidth[1] B [MHz] (Max.)	Pol.	Integration Time[2] [ms] (for reporting NEDT)	NEDT[2] [K] (Max.)	Antenna 3 dB beam width[3] θ_{3dB} [degrees] (Max.)
1	10.65	10	100	v	9.7	0.60	1.75
2	10.65	10	100	h	9.7	0.60	1.75
3	18.70	20	200	v	5.3	0.70	1.00
4	18.70	20	200	h	5.3	0.70	1.00
5	23.80	20	200	v	5.0	0.90	0.90
6	36.50	50	1000	v	5.0	0.40	0.90
7	36.50	50	1000	h	5.0	0.40	0.90
8	89.00	200	6000	v	2.2	0.70	0.40
9	89.00	200	6000	h	2.2	0.70	0.40

From: GMI Requirements Document, NASA's Goddard Space Flight Center, obtained from M. Flaming, April 2005.

Goddard Space Flight Center

GPM/GMI - option

GMI High Frequency Channels

Required GMI High Frequency Channel Set and Required Performance

Chan. #	Center Freq. f_c [GHz]	CFS [MHz] (Stab ±) (Max. (Deviation)	Pass-band Bandwidth B[3] [MHz] (Max.)	Pol.[4]	Integration Time[5] [ms] (for reporting NEDT)	NEDT[5] [K] (Max.)	Antenna 3 dB beam width[6] [degrees] (Max.)
10[1]	166	200	4000 RF	v	2.2	1.5	0.40
11[1]	166	200	4000 RF	h	2.2	1.5	0.40
12[2]	183.31 ± A	100	3500 IF / 7000 RF	v or h	2.2	1.6	0.40
13[2]	183.31 ± B	100	4500 IF / 9000 RF	v or h	2.2	1.5	0.40

[1] The channel center frequency and bandwidths for Channels 10 and 11 lie within a band protected by NTIA allocation (Earth Exploration Satellite -- Passive).

[2] Receiver double-sideband operation is assumed for Channels 12 and 13. For Channel 12, the acceptable range for setting the value of A is 2.9 to 3.1 GHz, with preference at 3.0 GHz. For Channel 13, the acceptable range for setting the value of B is 7 to 9 GHz, with preference at 9 GHz.

[3] For Channels 12 and 13, NASA prefers narrower pass-band bandwidths than the maximum values. NASA also prefers lower radiometric sensitivity values (NEDT) and recognizes that a design trade is required for optimizing performance when selecting both pass-band bandwidth and radiometric sensitivity.

[4] There is no preference between Vertical and Horizontal linear polarization on Channels 12 and 13. The same polarization shall be used for both Channels 12 and 13.

From: GMI Requirements Document, NASA's Goddard Space Flight Center, obtained from M. Flaming, April 2005.

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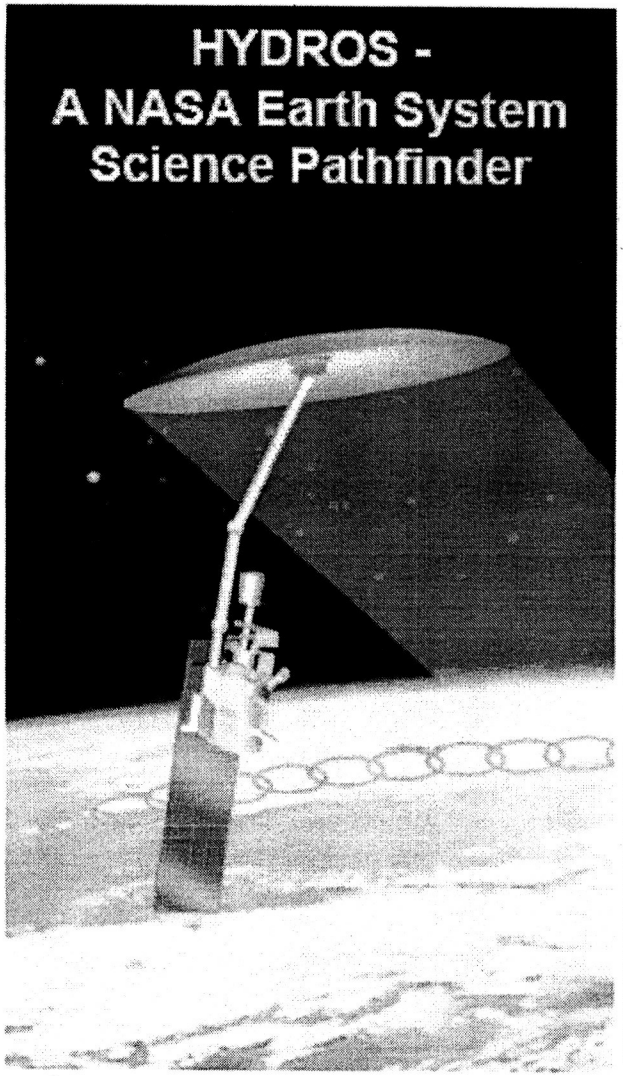
FACT SHEET: The Hydrosphere State Mission



Science Return: HYDROS Will Deliver Global Views of Terrestrial Water Cycle State Variable: Soil Moisture Content and Its Freeze/Thaw State

Soil Moisture is a Variable That Links the Global Water, Energy, and Carbon Cycles

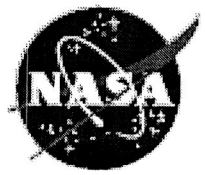
Applications Return: HYDROS Will Bring a New Era for the Capability to Predict Costly Natural Hazards (Extreme Weather, Floods, Droughts)

Initialization of the Soil Moisture State in Numerical Models Extends the Predictability of Processes Influenced by Surface Fluxes

National Security Return: HYDROS Global All-Weather Mapping Supports Battlespace Decision-Making and Force-Enhancement

Air Force	Low-Level Fog and Visibility Forecasts
Army	Terrain Trafficability Assessment
Navy	Sea-Ice Mapping

From: http://hydros.gsfc.nasa.gov, April 2005.



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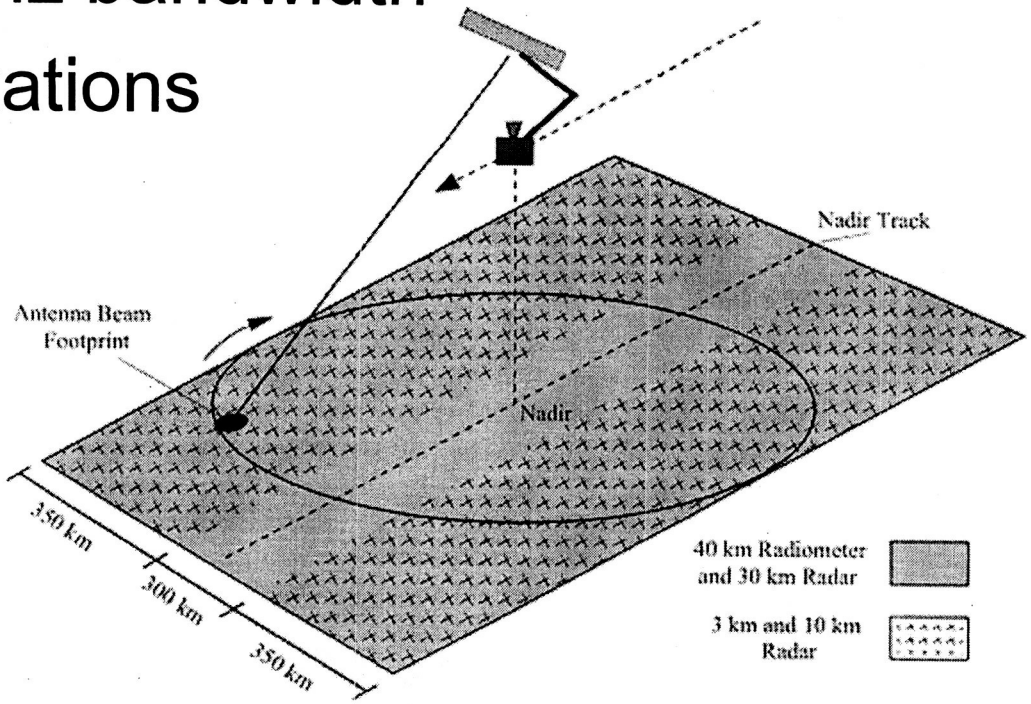
Hydros Microwave Radiometer

- Land surface soil moisture remote sensing
- Three-day global coverage
- 1413 MHz w/ 25 MHz bandwidth
- V, H, P, & M polarizations
- 0.6-K NEDT
- Conical scanning



From: **http://hydros.gsfc.nasa.gov**, April 2005.

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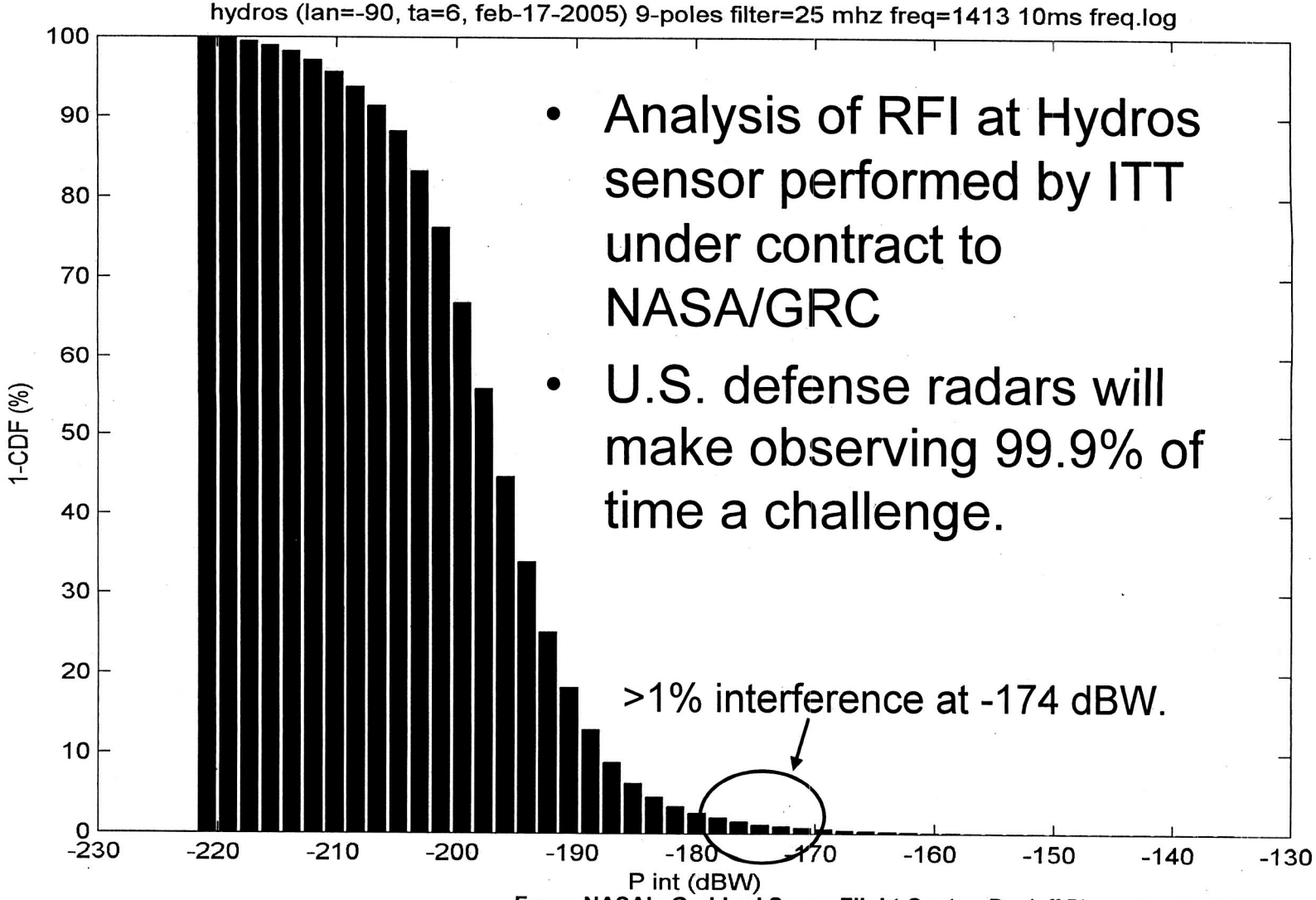
Hydros RFI Analysis



- Analysis of RFI at Hydros sensor performed by ITT under contract to NASA/GRC
- U.S. defense radars will make observing 99.9% of time a challenge.

From: NASA's Goddard Space Flight Center, Dr. Jeff Piepmeier, April 2005.

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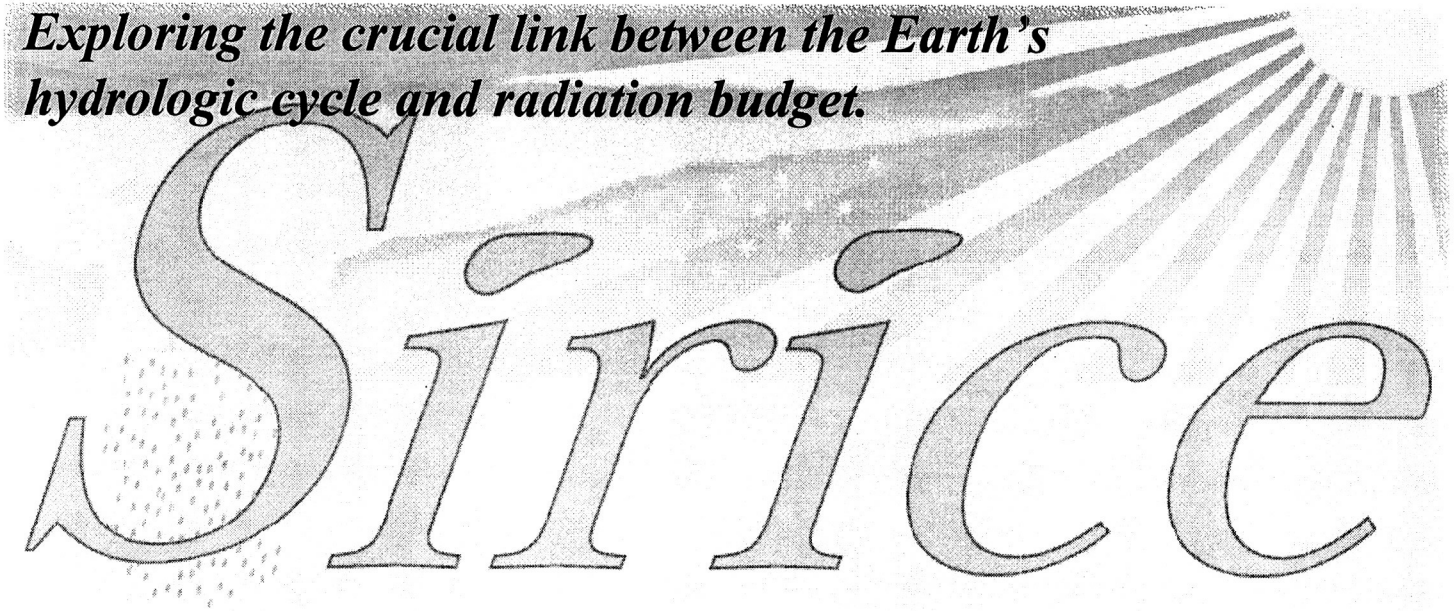
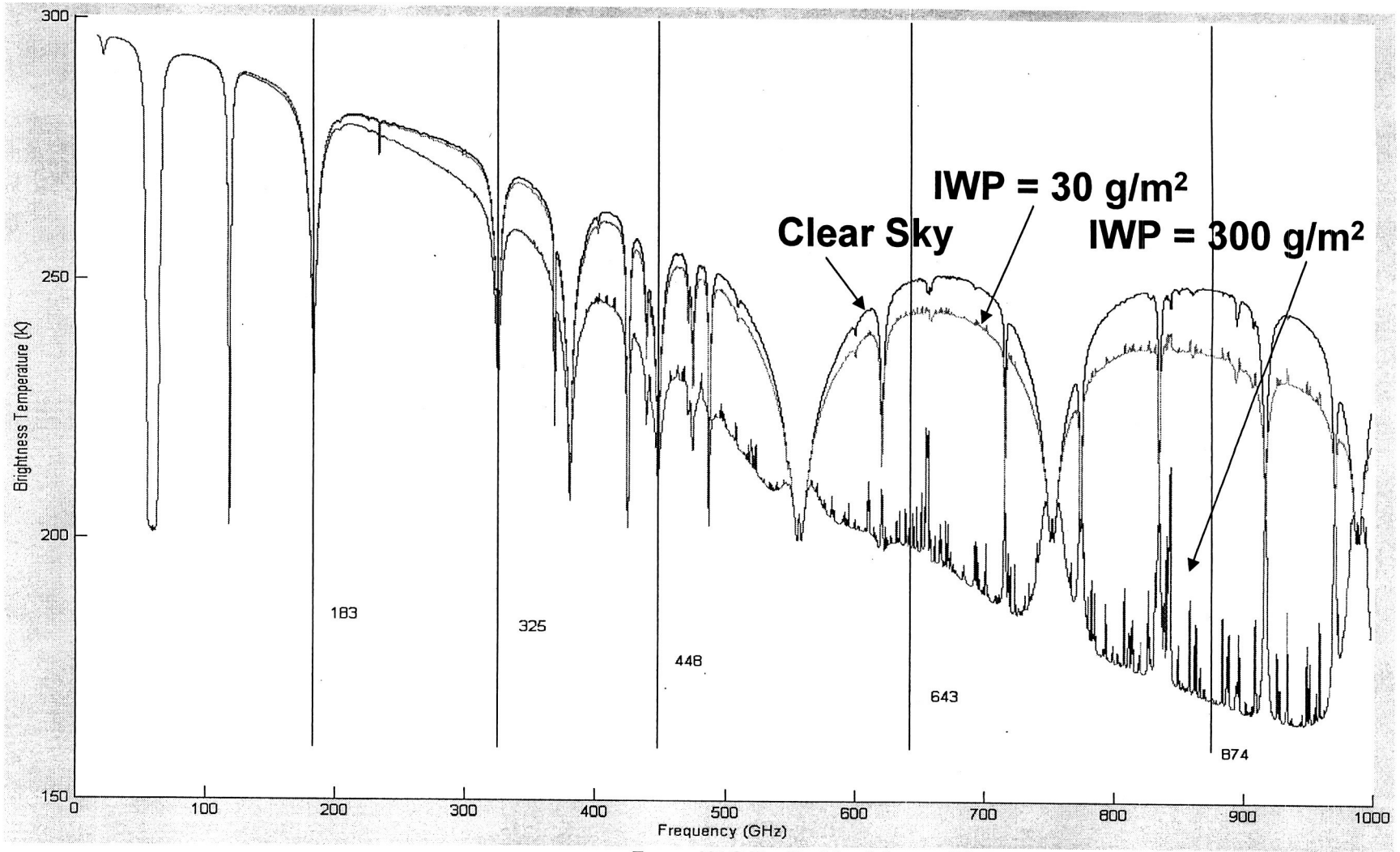
Cirrus Clouds Submmw radiometer



Submillimeter-wave and Infrared Ice Cloud Experiment (SIRICE) ESSP-4

Cirrus Clouds Submmw radiometer

Goddard Space Flight Center



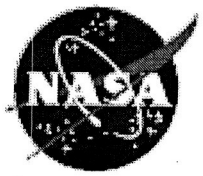
From: NASA's Goddard Space Flight Center, Dr. Paul Racette, April 2005.

Goddard Space Flight Center

Proposed Submmw Channels

Channel #	Polarization	Center Frequency (GHz)	IF center Frequency (GHz)	IF Bandwidth(GHz)	NEDT
1	V	183.310091	1.5	1.4	0.7
2	V	183.310091	3.5	2	0.6
3	V	183.310091	7	3	0.5
4	V	325.152919	1.5	1.6	1.8
5	V	325.152919	3.5	2.4	1.4
6	V	325.152919	9.5	3	1.3
7	V	448.001075	1.4	1.2	2.3
8	V	448.001075	3	2	1.8
9	V	448.001075	7.2	3	1.5
10	V	642.9	6.7	2.8	1.9
11	H	642.9	6.7	2.8	1.9
12	V	874.4	4.5	6	1.9

From: NASA's Goddard Space Flight Center, Dr. Paul Racette, April 2005.



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Cold Land Microwave Radiometer

- Enhanced measurements of snow water equivalent (SWE)
- Combine active and passive microwave
- Cold Lands Processes Pathfinder (CLPP)
  - ESSP-4
  - Use heritage channels at 19 & 37 GHz
- Cold Lands Processes Mission
  - On NASA SMD Hydrology roadmap
  - Use heritage channels at 19 & 37 GHz
  - Augment with 10.7 and 89 GHz

GeoSTAR: MW Sounder for GOES-R

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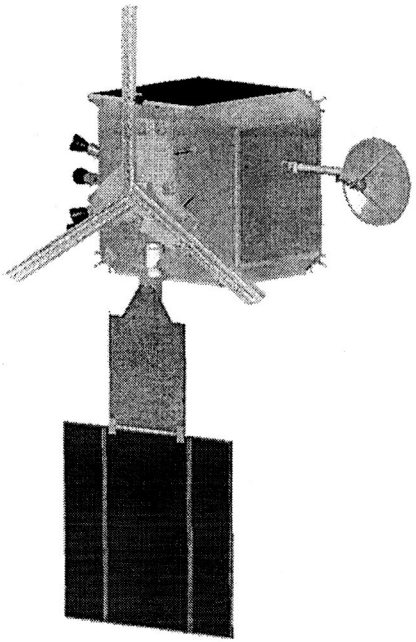
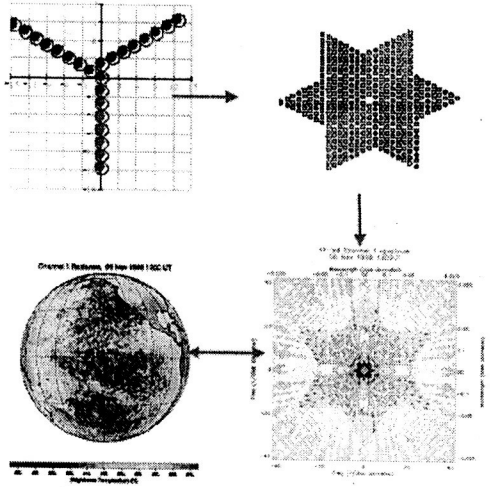
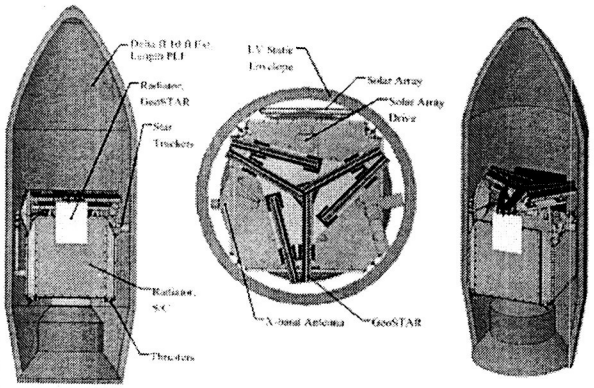


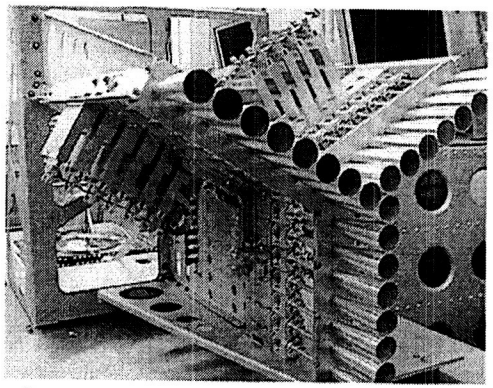
- Large aperture synthesized
- No mechanical scanning
- Continuous full-disk coverage
- Functionality similar to AMSU
  - T(p) @ 50 GHz/50 km
  - q(p) @ 183 GHz/25 km
  - NEDT < 1K
- Low sidelobes; No scan bias
- Expandable to larger apertures
- Tunable to any channels

Works in spatial Fourier domain:



Example: 50-GHz array
Each arm 2 m/100 rec's
—> 50 km resolution
Arms folded for launch
Shown in Delta II fairing





Prototype being readied for testing

Channel set not yet selected. Most likely will mimic ATMS or other's tropospheric channels

From: NASA's Jet Propulsion Laboratory, Bjorn Lambrigsten, February 2005.

Goddard Space Flight Center

Geostationary Soil Moisture and Ocean Salinity Radiometer

- Notional mission for global measurements of soil moisture and ocean salinity
- Important for energy and water cycle science
- P-band (~40 cm or 750 MHz)
  - Twice the soil penetration of L-band (i.e. closer to the root zone)
  - Less SST and more SSS sensitivity than L-band