Lecture 4 (9-21-83)
21 September 1983

GEOSTATIONARY METEOROLOGICAL SATELLITES

I. Historical summary from Lecture 1.

A. Suomi's idea for a spinscan camera, which Newell of NASA agreed to fly on ATS-1. Launched in 1966. (ATS = Applications Technology Satellite.) A second camera flown on ATS-3. Both had a major impact, demonstrating value of continuously viewing severe storms.

B. Based on ATS results, construction of an operational system was approved.

C. We also began discussions with other countries to encourage them to build geostationary satellites also, especially for the Global Weather Experiment.

II. SMS - GOES. Spacecraft series.

A. The first five spacecraft were built by Ford Aerospace and Communications ~~Company~~ Corporation.

- The Visible and ~~Infra-red~~ Infrared Spin Scan Radiometer (VISSR) was built by Santa Barbara Research Center (SBRC) of Hughes Aircraft Company.
- Operational prototypes were called Synchronous Meteorological Satellites (SMS) 1 and 2
- The follow-on satellites funded by NOAA were called Geostationary Operational Environmental Satellites (GOES) 1, 2 and 3.

All five satellites were identical in design.

B. The next five satellites have been or are being built by Hughes Aircraft Co.

- GOES 4, 5 and 6 have been launched.

- GOES G and H are under construction, with G to be delivered in the first half of 1986.
- All five satellites are identical in design.

C. From a <u>functional</u> point of view, the operation and ground interfaces of the two series of GOES were nearly identical, except for the experimental atmospheric sounding capability on the spacecraft beginning with GOES 4.

Therefore, I will ~~compare the two series, emphasizing the differences~~ review the current Hughes design (e.g., GOES-4) and indicate the differences between it and the earlier GOES spacecraft.

√Figure 4-1 (slide) - image of GOES-4 spacecraft.

D. ∘ Spacecraft spin axis; spin rate 100RPM.
- ∘ Mechanically despun antenna (Ford: electrically despun)
- ∘ Sun shield for telescope mirror (Ford: inside body)
- ∘ Telescope aperture = 40cm.

(SLIDE OFF)

- ∘ Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) used. (Ford: used VISSR only).
  - 4 additional IR detectors and filter wheel added to VISSR for sounding capability.
  - VAS can operate in 3 modes:
    (1) VISSR; identical to VISSR used in earlier satellites
    (2) Multispectral imaging: Visible channel plus any three of the IR channels.
    (3) Sounding mode.
- ∘ The High Energy Proton and Alpha Detector (HEPAD) added to the Space Environment Monitor (SEM) beginning with GOES-4. (Formerly used on the TIROS N series.)

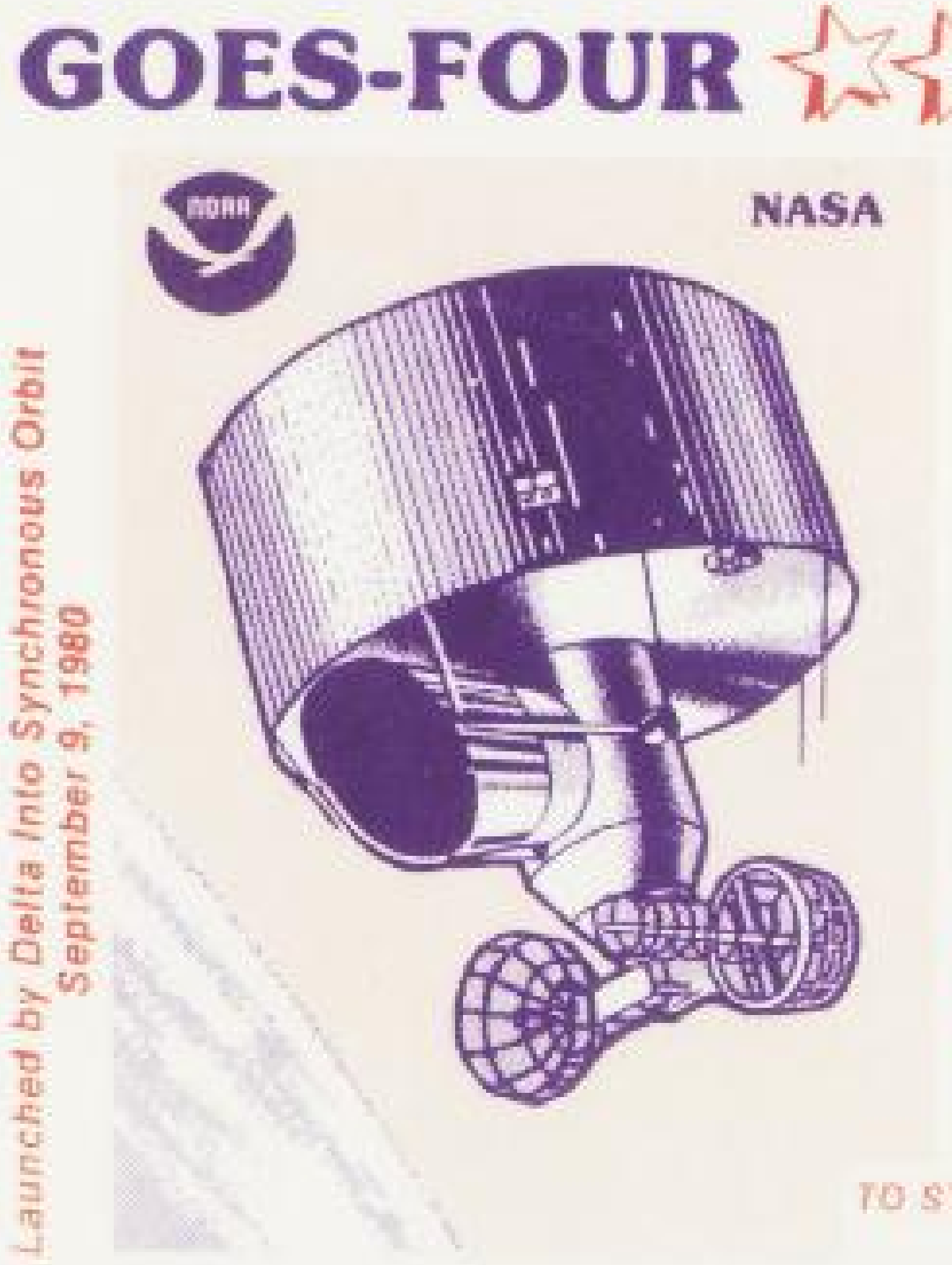

Fig. 4-1 Substitute

- Other functions of data broadcast (WEFAX + stretched VISSR) and data collection remain unchanged.

✓ Figure 4-2 (slide): - Reliable Delta launch vehicle used to launch GOES spacecraft, here - GOES 4. Note 9 (?) strap-on solid rocket motors for added boost.

Figure 4-3 (Vu-graph): SMS & GOES launch history.

SMS-1 thru GOES-3 : Ford S/C with VISSR

GOES 4 thru GOES-H : Hughes S/C with VAS

GOES - NEXT available about 1989.

✓ Figure 4-4 (slide) : Coverage of the two - GOES system.

solid line = max. extent of useful imaging; winds limited to about 50° of great circle radius.

dashed line = limit of reliable communication range.

GOES-6 is west satellite (135° W. longitude)

GOES-5 is East satellite (75° W. ")

Older GOES used for wefax only broadcasts; located at 107° W. for good coverage of North and South America.

✓ Figure 4-5 (slide): International coverage by geostationary Meteorological satellites.

Meteosat (Europe),	0°
Insat (India)	74° E.
GMS (Japan)	140° E.
GOES-West (USA)	135° W.
GOES - East (USA)	75° W.

Figures 4-6, 4-7, 4-8 (Vu - graphs)

Details of GOES spacecraft design.

- Point out "fail-soft" nature of 8 vis, 2 IR detectors.
- Trilateration and ranging system (3 ground stations) used for very accurate sub-point location.

Fig. 4-2 GOES-4 Launch

Fig. 4-3 SMS & GOES Launch History

SMS-GOES LAUNCHES

SMS = SYNCHRONOUS METEOROLOGICAL SATS.

GOES = GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES

SMS-1	5 MAY 1974	FORD SATS. WITH VISSR
SMS-2	6 FEBRUARY 1975	
GOES-1	16 OCTOBER 1975	
GOES-2	6 JUNE 1977	
GOES-3	16 JUNE 1978	
GOES-4	9 SEPTEMBER 1980	HUGHES SATS. WITH VAS
GOES-5	22 MAY 1981	
GOES-6	28 APRIL 1983	
GOES-G	UNDER CONSTRUCTION FOR 1986 DELIVERY	
GOES-H		

GOES-NEXT ?? (ABOUT 1989)

Figure 4-3

Fig. 4-4 Coverage of the two-GOES System

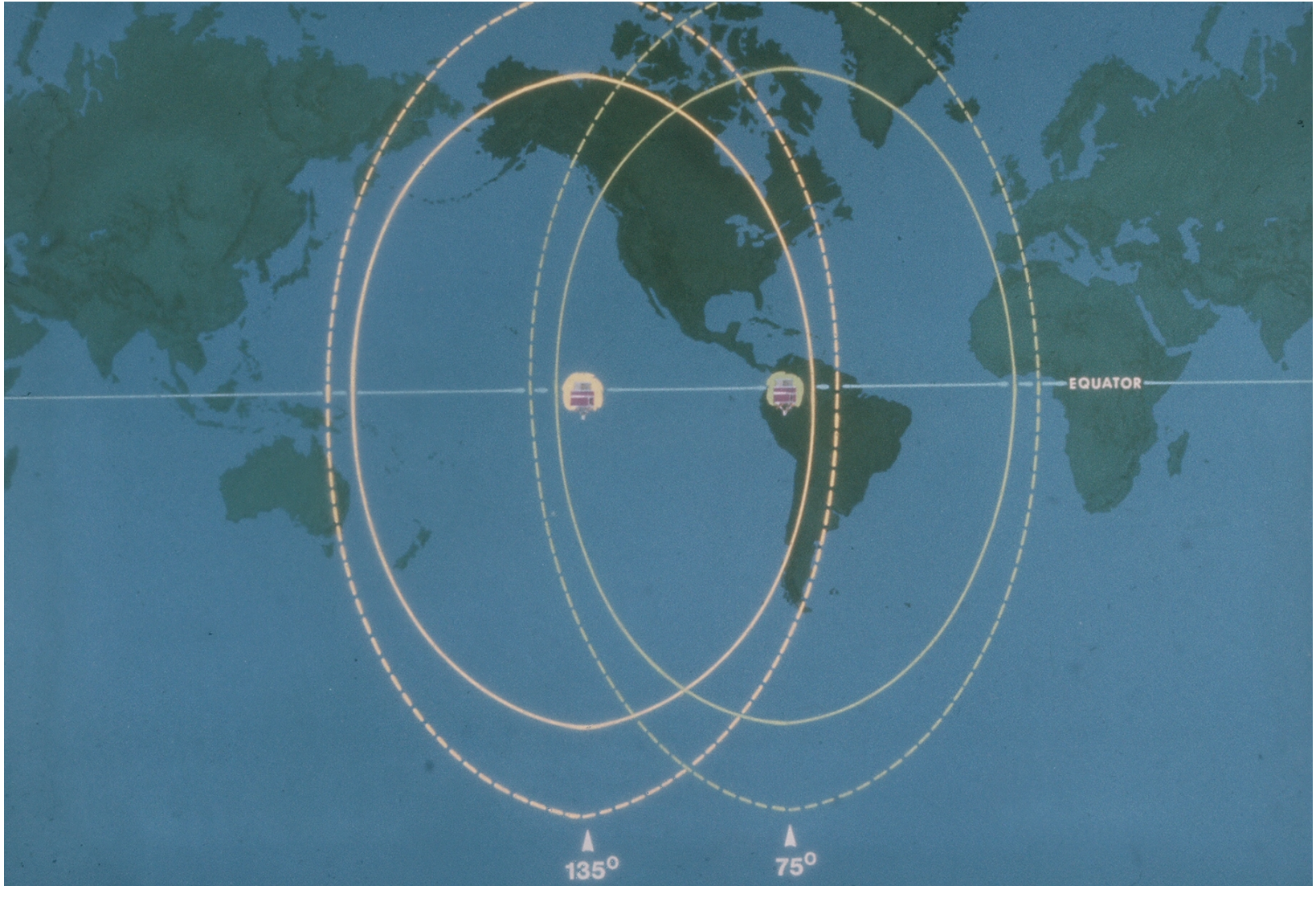

Fig. 4-5 International Coverage of Geostationary Meteorological Satellites

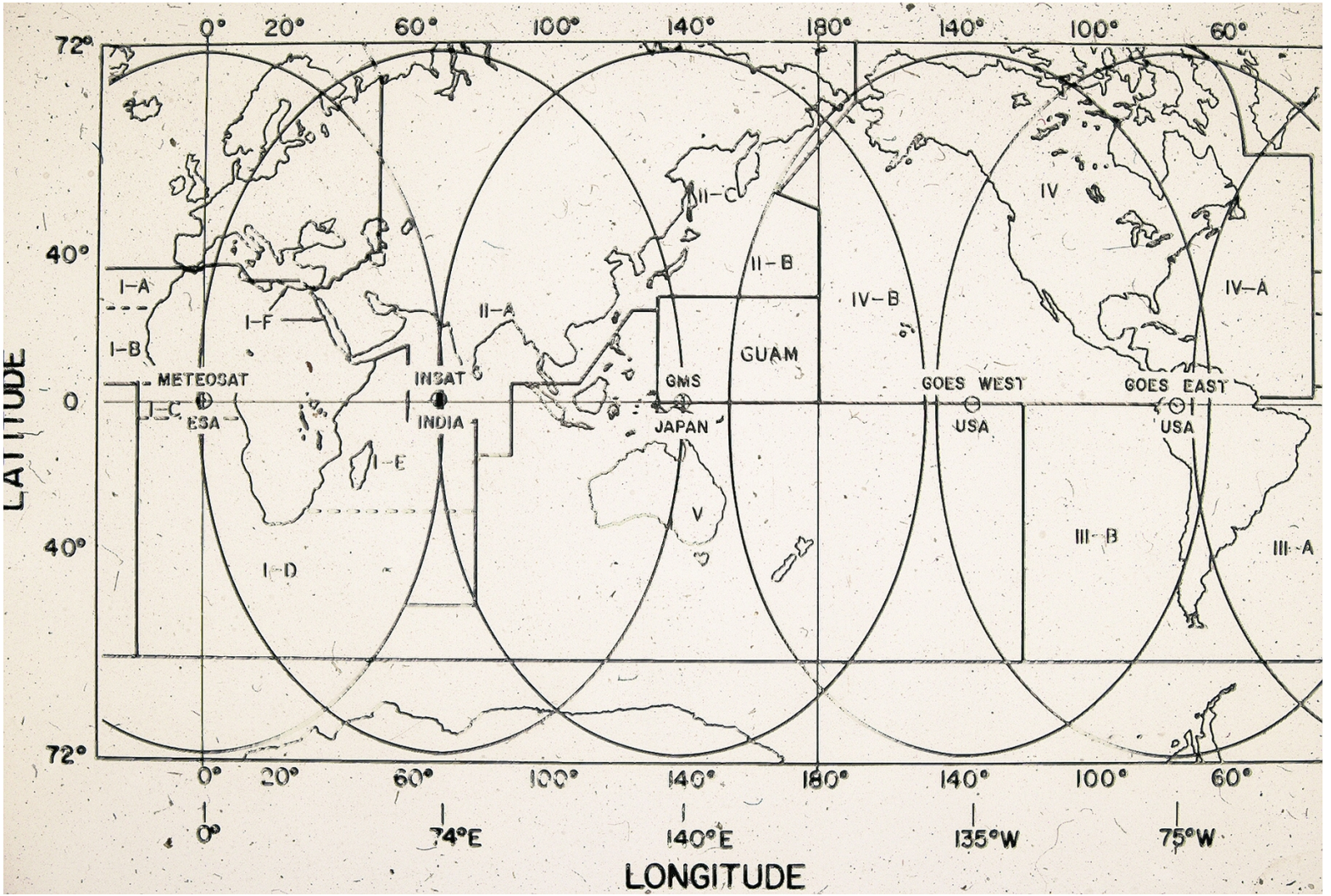

Fig. 4-6

G. O. E. S.

ORBIT: 35,800 km., geostationary

STABILIZATION: SPIN -- 100 RPM
N_2 GAS JETS FOR AXIS AND ORBIT PLANE ADJUSTMENT, AND "STATION-KEEPING".

TELESCOPE: Aperture = 40 cm. diameter.
Satellite spin gives West to East scan.
Stepping mirror gives North to South scan.
1821 Mirror steps for full earth disk.
8 photomultipliers in N-S line give 8 "lines" of visible image for each mirror position.
Mirror steps once per spin in imaging mode.
8 x 1821 = 14568 visible scan "lines" for full disk and takes 18.21 minutes to obtain. (1821 steps ÷ 100 RPM)
Each photomultiplier has IFOV of 0.025 (WEST-EAST) X 0.021 (NORTH-SOUTH) MILLIRADIANS (MR); ground resolution ≐ 0.9 km. at nadir.
SPECTRAL INTERVAL = 0.55 to 0.75 micrometers
INFRARED IMAGES: TWO (REDUNDANT) HgCdTe (mercury-cadmium-teluride), cooled to 94°K.
0.192 MR SQUARE, ~7 km. resolution
10.5 to 12.6 micrometers.

Figure 4-6

MORE G.O.E.S.

VISSR ATMOSPHERIC SOUNDER (VAS)

SAME AS VISSR TELESCOPE (ABOVE) PLUS 4 MORE IR DETECTORS, FILTER WHEEL, AND 2 MORE OPERATING MODES:

- Multispectral imaging: FULL VISIBLE PLUS ANY THREE IR CHANNELS. AT 14KM. RESOLUTION.
- Sounding mode: 12 CHANNELS
  - TEMPERATURE: 5 IN 13.3-14.7 μm. CO_2 BAND
    2, 4.44 & 4.52 μm " "
  - H_2O: 3, 6.72, 7.2 and 12.66 μm.
  - WINDOWS: 2, 3.94 and 11.24 μm.
    (μm = micrometer)
  - DWELL-SCAN, up to 7-9 spins for $\frac{\text{signal}}{\text{noise}}$
  - ABOUT 1 HOUR FOR 20 DEG. LATITUDE ZONE

ADDED DETECTORS 0.384 MR square, ~14 KM RES.
TWO INDIUM ANTIMONIDE, TWO HgCdTe

TELESCOPE DATA LINKS

VISSR/VAS OUTPUT: 28 M.B.S. BANDWIDTH
1670-1700 MHz (ALSO TELEMETRY, DATACOL. OUTPUT, ETC.)

"STRETCHED VISSR": 1.75 MHz BANDWIDTH
1687.1 MHz

(UP-LINK IN 2025-2120 MHz BAND, INCL. COMMANDS)

WEFAX: 1691 MHz ; APT FORMAT

STILL MORE G.O.E.S. !

DATA COLLECTION SYSTEM

SMALL, LOW POWERED PLATFORMS. { 5 WATTS, 10db gain Ant.

100 CHANNELS PER SATELLITE

FOUR OPERATING MODES

- SELF-TIMED (SCHEDULED)
- INTERROGATED
- EVENT THRESHOLD
- RANDOM REPORTING

DIRECT RECEPTION OR CENTRAL PROCESSING.

FROM PLATFORM TO SATELLITE: 400-403 MHz BAND

INTERROGATION TO PLATFORM: 468-469 MHz BAND.

(DATA COLLECTED RELAYED TO GROUND VIA WIDE BAND LINK, 1670-1700 MHz.)

TRILATERATION AND RANGING SYSTEM –

FOR ACCURATE SUB-POINT LOCATION.

SPACE ENVIRONMENT MONITOR

(1) Solar X-rays

(2) Particle detectors: Protons, alpha, electrons

(3) HEPAD from TIROS N beginning with GOES-4 (High Energy Proton + Alpha Detector)

(4) Magnetic field (direction and strength)

FIGURE 4-8

✓ Figure 4-9 (~~Vu-graph~~ slide)
Outline of GOES data system.
Advantages of the Central Data Distribution System but may not be applicable in China because of lack of high quality communications.

III. Comparison of Geostationary Metsats and relative merits.

Figure 4-10 (Vu-graph) Compares current GOES, GMS, METEOSAT + INSAT.
(I have only limited information about INSAT.)

- USSR - GOMS (From WMO No-411)
  - Visible resolution 1 to 2 km.
  - Infrared (8-12 μm) 5 to 8 km.
  - "Direct Transmitting Radio Equipment"
  - DCS "being planned on basis of recommendations of the CGMS"
  - Understand that it will be 3-axis stabilized.
- Key disadvantages of current GOES design:
  - Non simultaneous WEFAX (LR FAX) broadcast
  - Non simultaneous imaging and sounding.
  - Need more precise stabilization (more gas), to minimize motion during 24 hour cycle, and gridding.
  - Higher IR resolution (but costly!)
  - Microwave soundings (not yet feasible)

GEOSTATIONARY SATELLITE SYSTEM

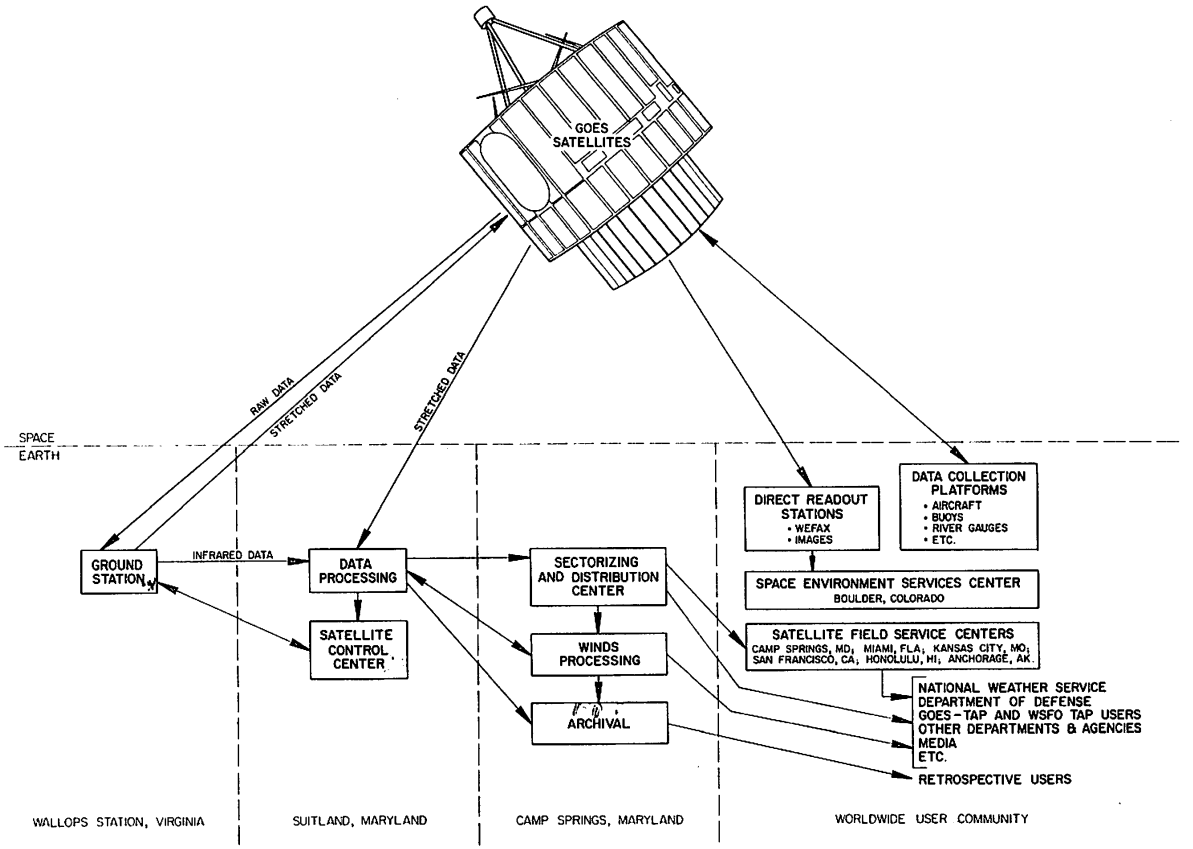

Figure 4-9 (SLIDE)

Fig. 4-10

COMPARISON OF GEOSTATIONARY METSATS

	GOES 4-6	JAPAN GMS	METEOSAT	INSAT (3)
• STABILIZATION	SPIN	SPIN	SPIN	3-AXIS ← winds?
• IMAGING				
- NO. CHANNELS	2/1+3/12	2	2/3	2
- RESOLUTION	0.9+7/0.9+14/14	1.25+5 km.	2.5+5/all 5 km.	?
- ON-BOARD "STRETCH"	NO	NO	YES	NOT NEEDED
• BROADCAST				
- FULL TIME, FULL RESOLUTION	YES	NO	NO	NO
- HIGH RESOLUTION CHANNEL.	↑	SHARED (2)	FULL TIME	NO
- LR CHANNEL OR WEFAX	SHARED (1)	SHARED (2)	FULL TIME	NO !
• COMPATIBLE DATA COLLECTION SYSTEM	YES	YES	YES	NO

(1) WEFAX TRANSMITTED WHEN NOT ACQUIRING AND BROADCASTING IMAGES AT FULL RESOLUTION.

(2) BECAUSE OF GROUND SYSTEM, GMS ONLY PERFORMS ONE OF THREE FUNCTIONS AT A TIME: (1) ACQUIRE IMAGES, (2) BROADCAST HIGH RESOLUTION IMAGES, OR (3) BROADCAST LR (WEFAX) IMAGES.

(3) INSAT MET. CAPABILITY LIMITED BECAUSE IT IS MULTI-PURPOSE SATELLITE.

Figure 4-10