DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C.

REPLY TO ATTN OF: AFRDS

SUBJECT: System Comparison (U)

28 FEB 1969

TO: SAFRD (Dr. Flax)

1. ~~(S/SAR)~~ We have compared the costs, performance and schedules for Air Force Program 417 and the NASA/ESSA TIROS Operational Satellite (TOS) program. The information on which the review is based has been assembled from available NASA/ESSA program documents. We have not coordinated this letter with NASA or ESSA.

2. ~~(S/NOFORN)~~ The following assumptions are made:

a. Development, maintenance and operation costs of similar systems are assumed comparable.

b. Data quality is a function not only of the sensor, but the entire system including ground readout terminals and data processing subsystems.

c. Impact of encryption is equally severe for all systems. The current NASA position is that all R&D satellites will be shut off on direction rather than carry encryption devices. ESSA is not planning use of any encryption devices through 1973.

d. Civilian and military needs for broad scale global weather data, analysis and prognosis are common. NOMSS will meet military needs for this type of data except for frequency of observation.

e. The TIROS-M and Improved TOS (ITOS) satellites through 1973 are designed for operation only at ascending node times of 0900 or 1500 hours. Any other operation time will require development of a new spacecraft at a cost of at least $18 million (TIROS-M spacecraft development cost) and about two years time.

3. ~~(S/SAR)~~ Attachment 1 is the latest available summary of the NASA/ESSA programs. Attachment 2 shows the latest launch schedule. Attachment 3 is a draft of the recent DOD/NASA cost analysis in the meteorological satellite program area. Attachment 4 summarizes recurring costs for the two programs and their performance is compared in Attachment 5. Paragraph 12.1 of Section 12 in the Program 417 joint service plan summarizes the philosophy of a military meteorological satellite system.

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a. At present, ESSA plans only one TIROS-M/ITOS spacecraft on-orbit through 1974 at a 1500 ascending node time.

b. The 800 NM altitude of the ITOS satellites generates a problem in transmitting tactical quality data (.5 NM resolution) from the satellites to ground terminals. At present, it appears that the space-ground communications bandwidth required to handle the proposed ITOS-D 1/2 NM resolution data will exceed the state-of-the-art in the 1973 time period.

c. Based on the recent DOD/NASA cost savings analysis of the meteorological satellite area it was recommended that the planned system of one civilian satellite (TIROS/ITOS) and three Program 417 (Block V) satellites be continued for the near term.

d. A conflict in priorities results if the ITOS satellite coverage capability is limited because of partial subsystem failures. The primary ITOS coverage priority is the Continental U.S. The tactical military area of interest is overseas. Thus, an additional satellite would have to be launched for military coverage during crisis periods in the event of partial ITOS satellite failures. ESSA is presently not planning this kind of back-up.

e. NASA/ESSA plans for spacecraft power necessary for accommodation of military needs are vague at present.

4. ~~(S/SAR)~~ Our conclusion is that Program 417 can satisfy military meteorological satellite requirements at about 1/3 to 1/2 the on-orbit costs of the ITOS system which is dedicated to national/international users.

WALTER R. HEDRICK, JR.
Brigadier General, USAF
Director of Space
DCS/Research and Development

5 Atch
1. Summary (U).
2. Launch Schedule (U).
3. Cost Analysis ~~(S/SAR)~~
4. Summary of Recurring Costs ~~(S/SAR)~~.
5. Summary of Performance ~~(S/SAR)~~.

ATMOSPHERIC MEASUREMENTS FROM SATELLITES

Robert M. Rados

"When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager unsatisfactory kind." Lord Kelvin

Man's quest to understand, predict, and cope with his environment depends on his ability to measure it and to apply these measurements to models or hypotheses. Since man's environment is global and its changes are effected by a global distribution of the individual parameters, to understand and predict depends on a global observation.

Man's ability to measure his environment has steadily increased in the past two centuries with the use of barometers and anemometers. It has advanced not only in quantity but also in type with ability to calculate atmospheric constituents and temperature profiles. It has advanced by means of various tools or platforms such as balloons, buoys, and aircraft. The advent of the space age has enhanced man's ability to obtain the needed type and quantity of atmospheric measurements. Data obtained by satellites complement measurements from other platforms as a source of information to enable complete global observation and to help understand and predict atmospheric phenomena.

Atmospheric measurements made by using satellites as a platform have been those of cloud imaging and radiation and the measurements which can be inferred or deduced from these. Satellites used so far are the TIROS, Nimbus, and ATS (Figure 1). The current operational meteorological satellites (ESSA's), based on TIROS-type spacecraft, are spin-stabilized platforms placed in a sun-synchronous near-polar orbit to provide complete global coverage of the earth and its atmosphere once each day. These satellites provide both global and local readout of the cloudcover and some measure of reflected and emitted solar radiation. An improved operational system now under development will provide, in addition to global and local readout of daytime earth's cloudcover by TV cameras, observations of day and nighttime cloudcover through the use of an infrared radiometer. This will provide two observations in the day and one at night over the complete earth.

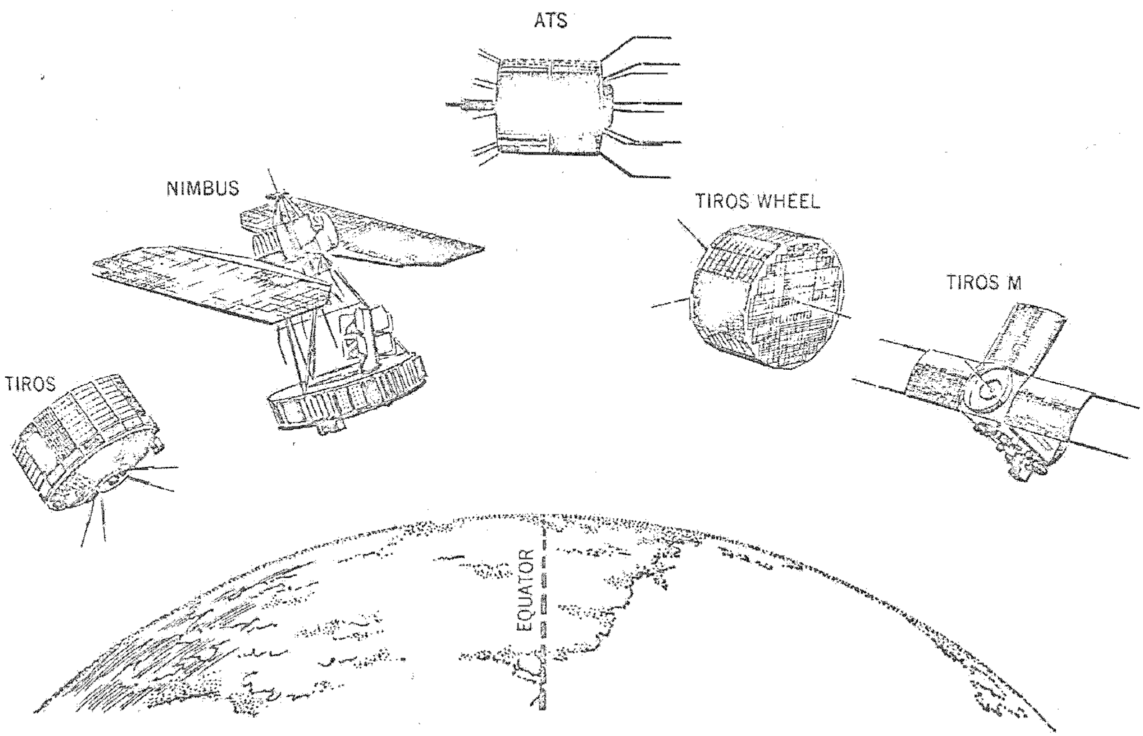


FIGURE 1. NASA METEOROLOGICAL SATELLITES

The Nimbus is an earth-oriented three-axis spacecraft that serves as a platform to deve advanced measurement techniques. Like the TIROS and ESSA series, [illegible] system designed to provide complete earth coverage once per day for the visual observation and twice per day for radiation type measurements. The ATS satellites are designed to test and develop atmospheric measurement systems (and communications systems) from geosynchronous altitudes, thus providing continuous observations of specific areas of the earth. Although the ATS spacecraft are both spin- and gravity-gradient stabilized, those which provided the atmospheric measurements were spin-stabilized. Projected for the future is an operational geosynchronous satellite system for continuous measurement of atmospheric parameters and for collecting and relaying of measurements from other platforms such as remote stations and buoys.

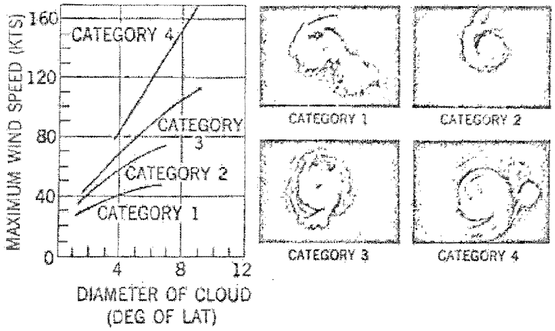
The accompanying table is a chronology of satellites which have provided atmospheric measurements and the specific sensors which were flown, a listing of planned satellites with their atmospheric sensors, and some vital statistics on the sensors which have been flown or which are under development.

Sensors on the satellites flown to date were designed to map cloudcover by using visual and radiometric sensors and to map telluric and reflected solar radiation in the various spectral bands. Most sensors being developed for future use represent improvements of present sensors to provide better spatial and spectral resolution. Some will observe in several spectral bands to allow the inference or deduction of several atmospheric parameters — for instance, temperature distribution. More importantly, they will provide a source of input to the numerical weather-prediction program which has been hampered until now by the lack of global observations.

Excellent descriptions and applications of these measurements appear in papers by W. Bandeen, "Experimental Approaches to Remote Atmospheric Probing in the Infrared from Satellites," GSFC X622-68-146 (May 1960), and W. Nordberg, "Development of Meteorological Satellites in the U. S.," GSFC X626-68-311 (Aug. 1968).

TIROS 1 was intended to demonstrate that satellites could be used to make atmospheric observations and that these observations could be used in weather analyses and forecasts. The first pictures received left little doubt that these two purposes were fulfilled. However, what was not obvious at the time was the extent to which instrumentation could be developed and the extent to which use could be made of these observations. The gradual evolution of technology, both engineering and scientific, has significantly advanced our ability both to measure and to apply these measurements.

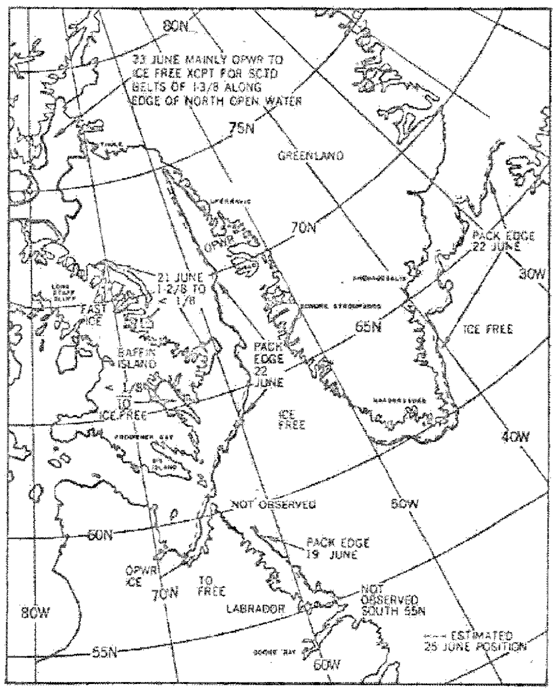
First, the weather satellites have evolved into an operational system that can view the complete earth daily. From this capability comes a variety of assets: these include the ability to detect and map all cloud structures, and especially to detect and follow hurricanes, jet streams, and other mesoscale phenomena. For instance, we now have techniques which not only allow the location of the spiral bands, but also permit reasonable est es of wind speeds in the storm (Figure 2). Jet streams can be detected by their



(From: A. Timchalk, L. F. Hubert, and S. Fritz. "Wind Speeds from TIROS Pictures of Storms in the Tropics." Meteorological Satellite Laboratory Report 33, U. S. Department of Commerce, Weather Bureau, February 1965)

FIGURE 2. CLASSIFICATION AND NOMOGRAM FOR ESTIMATION OF WIND SPEED

relation to cirrus clouds. A satellite system permits us to track and to observe the structure of macroscale phenomena

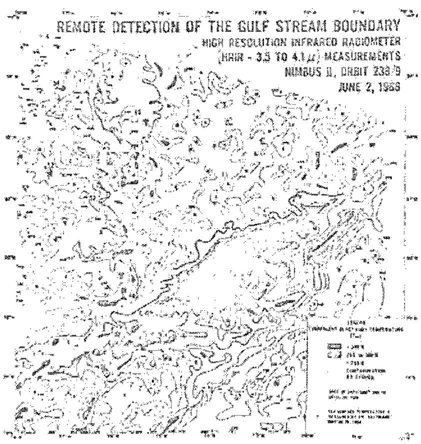


(From: U. S. Naval Oceanographic Office)

FIGURE 3. PROVISIONAL SATELLITE ICE CHART, JUNE 1968

and to study the climatology of clou stems and movements on a global basis. This leads to the development of reference atmospheres for use in many fields and to an understanding of the energy flux from low to high latitudes.

Snow cover and sea ice can be readily identified in satellite photographs. Charts of ice boundaries (Figure 3) are prepared and distributed regularly to shipping, military, resupply of arctic bases, and other interests. The continued performance of the satellite and the study of the visual images will provide the basis for a better understanding of the atmospheric processes on a global basis.



(From: G. Warnecke, L. M. McMillen, and L. J. Allison. "Ocean Currents and Sea Surface Temperatures Observations from Meteorological Satellites." NASA Technical Note (to be published, 1969).)

FIGURE 4.

From a corrective standpoint, satellite observations have shown that the average albedo of the earth and its atmosphere is some 5 percent below calculations based on extrapolations of land-based measurements. This difference may be explained by the over-estimate of total cloudcover from land-based observations as opposed to the observations made from satellites orbiting outside the atmosphere and viewing the total cloudcover.

Incorporation of the APT system into weather-satellite systems has provided the local user with a wealth of information in real time. Forecasting is less accurate, the longer the time from the observations and analyses used as its basis. A real-time picture of a cloud structure decreases the time period and increases forecasting accuracy.

These are only a few applications of data from the current operational system. If we now look to the application of the systems flown on the research spacecraft, and the capabilities of those specifically planned, we need little imagination to recognize their potentials in an operational system. The high-resolution infrared radiometer flown on Nimbus and the radiometers planned for the improved operational systems make observation at night as feasible and as pra .l as visual scanning during the day. In addition, these data can be interpreted to provide reflected-surface temperatures, either ground or cloud-top. Further inference or correlation with other measurements will permit determination of the cloud height and, to some extent, of the cloud type, a parameter that is vital in numerous applications of cloud measurements. The availability of surface temperature in cloud-free areas (Figure 4) allows the analyses of ocean currents relative not only to a temperature field but also to the direction of movement.

Several of the sensors to be flown on Nimbus B2 and D, as well as the vertical temperature profile radiometer planned for a future improved operational spacecraft, will provide radiation measurements from which the vertical distribution of temperature can be inferred or computed on the basis of correlations with other measurements. Some will also furnish data for use in calculating the distribution of other atmospheric constituents such as water vapor and ozone. These measurements, important in the synoptic methods of atmospheric analysis, are vital to the dynamical or numerical weather-prediction program which promises to provide atmospheric circulation analyses and forecasts for periods much longer than currently possible. The mere number of variations of sensors that can obtain these measurements is evidence of their importance: The IRIS (infrared interferometer spectrometer) is a Michelson-type interferometer designed to measure the earth's spectral radiances in the 5- to 20-micron wavelength interval, with a spectral resolution equivalent to 5 reciprocal centimeters. These radiances will be used to determine the characteristics of ozone and water vapor and to infer the temperature structure of the atmosphere. The SIRS (satellite infrared spectrometer) is a Fastie-Ebert grating spectrometer designed to measure earth's spectral radiances in the carbon dioxide absorption band for inferring the temperature structure of the atmosphere (Figure 5). The VTPR (vertical temperature profile radiometer) contains 8 filters (6 in the carbon dioxide band, 1 in the water vapor band, and 1 in the window). It is intended solely to infer temperature profiles.

In addition to these sensors, there are the quasi-satellite instruments like IRLS and OPLE which can collect and rapidly distribute in situ measurements from remote stations, buoys, balloons, etc. IRLS (the interrogation, recording and location system) is designed to obtain near-real-time data generated by unmanned instrumented platforms in the atmosphere (balloons) and on the earth's surface (buoys). Data from these platforms are automatically transmitted to orbiting spacecraft for subsequent readout at ground stations. The data can be used to locate the station; and, if the station (such as a balloon) is moving with the wind, the wind can be calculated. OPLE is a system similar to IRLS with the major exception that position is determined by the U. S. Navy's ground-based Omega navigational system. The OPLE (Omega position-location experiment) is compatible with geosynchronous satellites, whereas IRLS is compatible with polar-orbiting spacecraft.

Recent exploration of the ATS-1 images of cloudcover (Figure 6) on an hourly basis has demonstrated the potential of defining winds in the tropical areas and the

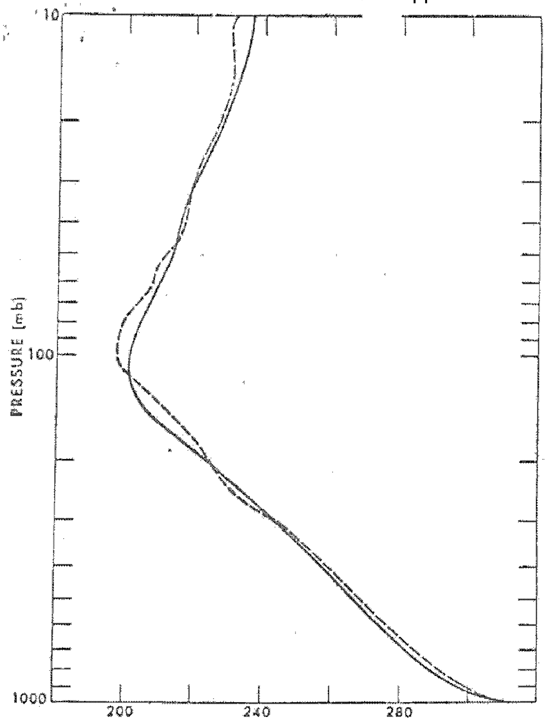


FIGURE 5. DEDUCED TEMPERATURE PROFILE IN CLEAR SKIES FROM DATA IN THE 15-MICRON CARBON DIOXIDE BAND ACQUIRED AT 7:57 A.M. CST BY A BALLOON-BORNE VERSION OF SIRS (SOLID LINE). THE BALLOON WAS LAUNCHED TO AN ALTITUDE OF 100,000 FT. ON SEPTEMBER 11, 1964 FROM PALESTINE, TEXAS. THE DASHED LINE IS THE NOON CST PROFILE FROM THE FORT WORTH RADIOSONDE. (AFTER WARK ET AL., 1967).

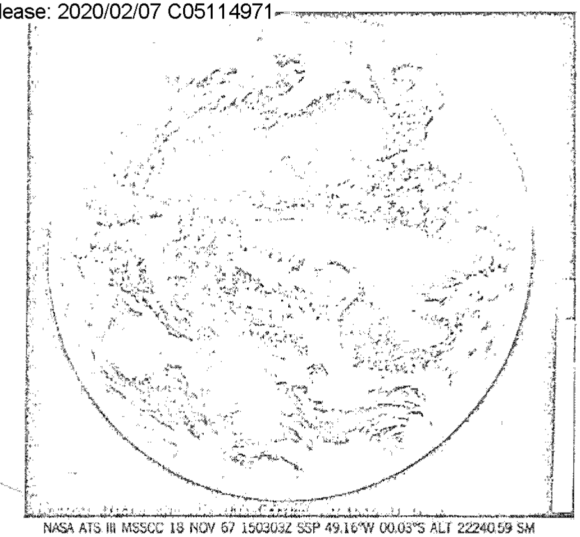


FIGURE 6. ATS-3 SPIN-SCAN COLOR CAMERA PHOTOGRAPH, NOV. 18, 1967, 1800Z

movement of vorticity patterns from the southern to the northern hemisphere. Briefly, the estimation of cloud type and height and their dependence upon movement (as opposed to dynamical forces evidencing stationary cloud structure), together with the recognition of identical clouds from one image to another at hourly intervals, afford an opportunity to measure winds and vorticity. These measurements have pointed to the probability of air motion from the southern hemisphere with cyclonic motion to the northern hemisphere with anticyclonic motion. Initiation of a continuous-viewing capability by means of an operational synchronous-satellite system means that these observations can be applied to a verification of this hypothesis and can thus lead to a better understanding of the worldwide exchange of atmospheric energy.

The use of WEFAX through the ATS I and III satellites has demonstrated the practicality of transmitting data collected and analyzed at a central location to users in remote or distant locations which either cannot provide facilities of their own or cannot obtain these analyses more efficiently.

Current ideas for future satellites are primarily extensions of current capabilities, such as improved radiometric observations. We can also use satellites to measure sferics and sea state through the use of microwave radiometers, lasers, etc.

Just as the possible applications of current technology (use of multicolor imaging, for instance) elude us now, so did the applications of visual and radiometric measurements ten years ago. We are better able to visualize the possibility of using satellites to obtain regularly the measurements required, but not necessarily sufficient, to understand and predict our environment. These measurements include those made globally and on a quasi-continuous basis.

Our ability to apply these measurements will decide whether or not we can advance in our understanding. More specifically, we are faced with the problems of processing and applying the wealth of data available from all sources, but particularly from satellites. The "data explosion" is real. Space-age technology has exceeded our ability to assimilate and apply the measurements. Just as atmospheric scientists of the World War II era were educated and stimulated in the use of upper-air data, we must educate and stimulate the scientists in the use of satellite data. The potential is great. We have the ability to measure on a global scale, to provide measurements from outside as well as inside our environment, and to make these measurements available in real time. Our knowledge of the atmosphere should not be of "a meager and unsatisfactory kind," but of an abundant and powerful kind which can help to solve some of the pressing problems of our civilization.

Approved for Release: 2020/02/07 C05114971

Designation		Launch Date	Orbit (Nominal)		Meteorological Sensor Complement	Remarks
Prelaunch	In orbit		Inclination (degrees)	Altitude (n.m.)		
Nimbus F		–	–	–	–	
ATS F		–	–	–	–	
ATS G		–	–	–	–	

TIROS - Television InfraRed Observational Satellite
OT - Operational TIROS - (ESSA-funded spacecraft in TIROS program)
TOS - TIROS Operational System (ESSA-funded operational program)
ITOS - Improved TIROS Operational System - (ESSA-funded operational program)
ESSA - Environmental Sciences SAtellite - (TIROS OT-2 & OT-3 - TOS & ITOS satellites)
ATS - Application Technology Satellite
D/N - Day and night capability
S&LR - Stored and local readout capability
B&W - Black & white

ATMOSPHERIC SENSORS

- RADIOMETRIC

MRIR - Medium Resolution Infrared Radiometer (5-degree field-of-view, 30-nm resolution) 5-channel scanning instrument flown on TIROS & Nimbus with varying sensor spectral bands (microns), as follows:

TIROS II & III	TIROS IV	TIROS VII
6.0 - 6.5	6.0 - 6.5	14.8 - 15.5
8 - 13	8 - 12	8 - 12
0.2 - 6	0.2 - 6.0	0.2 - 6.0
8 - 30	—	8 - 30
0.5 - 0.75	0.55 - 0.75	0.55 - 0.75

Nimbus II	Nimbus B-2
6.7	6.7
10 - 11	10 - 11
14 - 16	14 - 16
5-30	20 - 23
0.2 - 4.0	0.2 - 4.0

Application: Cloudcover mapping
Storm tracking
Surface temp.
Cloudtop heights
Radiation balance
Tropospheric water vapor
Stratospheric temp. and circulation

Wide-Angle Cone - A low (350 nm)-resolution unchopped radiometer to measure the equivalent blackbody temperature and albedo of the earth within its 50-degree field-of-view

TIROS II, III & IV

Application: Radiation balance

Omnidirectional - A pair of hemispheric shells, one white and one black, to measure long- and short-wave radiation over the entire earth's disc

TIROS III, IV & VII

Application: Radiation balance (long-wave emission - albedo)

FPR (Flat Plate Radiometer) - A variation of the omnidirectional radiometer

ESSA II, V, VII - TOS-G - TIROS-M - ITOS A,B,C

Application: Same as omnidirectional

HRIR - High Resolution Infrared Radiometer (scanning) - with spectral bands (microns) as follows:

Nimbus I & II	Nimbus B
3.5 - 4.1 (5-nm res)	0.7 - 1.3 (D) (5-nm res) 3.5 - 4.1 (N) (5-nm res)

TIROS M & ITOS

0.52 - 0.73 (VIS) (2-nm res)
10.5 - 12.5 (IR) (4-nm res)

Application: Cloudcover mapping
Storm tracking
Surface temp.
Cloudtop height (absolute emission measurements, nighttime only)

IRIS - InfraRed Interferometer Spectrometer

Nimbus B-2 5-20 micron, spectral resolution 5 cm^{-1}

Nimbus D 6.3 - 50 micron, spectral resolution 3 cm^{-1}

Application: Vertical profiles (Temp. H_2O, O_3, etc.)

SIRS - Satellite InfraRed Spectrometer

Nimbus B-2 - 8 channels (7 in CO_2, 1 in 11-micron window - spectral resolution 5 cm^{-1}

Nimbus D 14 channels (7 in CO_2, 6 in rotational H_2O, 1 in 11-micron window, spectral resolution 5 cm^{-1}

Application: Vertical temp. profiles (Nimbus B-2)
Vertical profiles, temperature & H_2O (Nimbus D)

THIR - Temperature Humidity Infrared Radiometer

Nimbus D - 10.5 - 12.5 micron, 4-nm resolution
6.5 - 7.0 micron, 12-nm resolution

Application: Cloudcover mapping
Storm tracking
Surface temp.
Cloudtop heights
Air mass discrimination - vertical motion
Jet stream location

FWS - Filter Wedge Spectrometer

Nimbus D - 1.2 - 2.4 microns
3.2 - 6.4 microns

Application: Determine liquid water or ice content of clouds (1.2 - 2.4)
Vertical temp. profile (4.3 CO_2 band)
Vertical H_2O profile (6.3 H_2O band).

MUSE - Monitor of Ultraviolet Solar Energy - Measures solar radiation on 5-100 A wide spectral intervals from 1200 A to 2600 A

Nimbus B-2 & D

Application: Energy input into the stratosphere

BUV - Backscatter UltraViolet - Spectrometer to measure intensity of solar radiation reflected by atmosphere in 14 intervals, each 10 A wide over spectrum from 2500 to 3400 A

Nimbus D

Application: Vertical distribution of ozone

- PLANNED FOR ITOS

VHRR - Very High Resolution Radiometer - 0.5 nm resolution
0.6 - 0.7 microns visual channel
10.5 - 12.5 microns IR channel
Specific operational spacecraft not assigned

Application: Cloudcover mapping
Storm tracking
Surface temp.
Cloudtop heights
Albedo

VTPR - Vertical Temperature Profile Radiometer - 8 channels in the CO_2 band, 1 in the H_2O rotation band, 1 in the 11-micron window. Field-of-view is 2 degrees; linear resolution is 25 miles

Application: Vertical temperature profiles

Proposed - Very High-Resolution Radiometer for Synchronous Altitudes

A scanning radiometer operating in the 10.5 to 12.5-micron spectral region containing an 8-inch-aperture diameter cassegrain telescope and a cooled (80°K) detector to provide subsatellite ground resolution of approximately 8 nm

Application: Cloudcover mapping
Storm development/tracking
Surface temp.
Cloudtop heights
Upper level winds

- CAMERA SYSTEMS

1/2" VID - Standard TIROS vidicon - 500-line

W - Wide-angle lens - 104° (74° side to side)

M - Medium-angle lens - 78° (56° side to side)

N - Narrow-angle lens - 12.7° (10° side to side)

TIROS and ESSA I

AVCS - Advanced Vidicon Camera System - 1" vidicon - 800 line - .45 - .65 microns. Nimbus I, II - ATS II - ESSA III, V, VII - TOS-G - TIROS-M - ITOS A, B, & C.

APT - Automatic Picture Transmission - 1" vidicon - 800 line - 0.45 - 0.65 microns. to side)0.45 - 0.65 microns - provide local readout only.
TIROS VIII - Nimbus I, II - ESSA II, IV, VI, VIII - TOS-H - TIROS-M - ITOS A,B, C.

IDCS - Image Dissector Camera System - 0.45 - 0.65 microns. - 760 line
ATS III - Nimbus B-2, D

CHRO LOGY OF METEOROLOGICAL SATELLITE

Designation		Launch Date	Orbit (Nominal)		Meteorological Sensor Complement	Remarks
Prelaunch	In orbit		Inclination (degrees)	Altitude (n.m.)		
TIROS A-1	TIROS I	Apr. 1, 1960	48	400	2-1/2" vid (1W+1N lens)	First met. sat.
TIROS A-2	TIROS II	Nov. 23, 1960	48	400	2-1/2" vid (1W+1N lens) 1 MRIR 1 wide-angle conrad.	First IR
TIROS A-3	TIROS III	July 12, 1961	48	400	2-1/2" vid (2W lens) 1 MRIR 1 wide-angle cone rad. 1 omnidir. rad.	
TIROS D	TIROS IV	Feb. 8, 1962	48	400	2-1/2" vid (1W+1M lens) 1 MRIR 1 wide-angle cone rad. 1 omnidir. rad.	
TIROS E	TIROS V	June 19, 1962	58	400	2-1/2" vid (1W+1M lens)	
TIROS F	TIROS VI	Sept. 18, 1962	58	400	2-1/2" vid (1W+1M lens)	
TIROS G	TIROS VII	June 19, 1963	58	400	2-1/2" vid (2W lens) 1 MRIR 1 Omnidir. rad.	
TIROS H	TIROS VIII	Dec. 21, 1963	58	400	1 APT 1-1/2" vid (W lens)	First APT
Nimbus A	Nimbus I	Aug. 28, 1964	Sun-sync	600	1-trimetrogon AVCS 1 HRIR (S&LR) 1 APT	First HRIR
TIROS I	TIROS IX	Jan. 22, 1965	Sun-sync	400/1600	2-1/2" vid (2W lens)	First worldwide cov. - first cart-wheel mode
TIROS (OT-1)	TIROS X	July 2, 1965	Sun-sync	400	2-1/2" vid (2W lens)	Axial mode
TIROS (OT-3)	ESSA-I	Feb. 3, 1966	Sun-sync	400	2-1/2" vid (W lens)	First opnl. sys.
TIROS (OT-2)	ESSA-II	Feb. 28, 1966	Sun-sync	750	2 APT	First opnl. sys.
Nimbus C	Nimbus II	May 15, 1966	Sun-sync	600	1-trimetrogon AVCS 1 HRIR (S&LR) 1 MRIR	
TOS A	ESSA III	Oct. 2, 1966	Sun-sync	750	2 AVCS 1 FPR	
ATS B	ATS I	Dec. 7, 1966	Geosync	–	1 SSCCE (B&W) WEFAX	First meteor. geosyn sat.- first WEFAX
TOS B	ESSA IV	Jan. 26, 1967	Sun-sync	750	2 APT	
ATS A	ATS II	Apr. 6, 1967	–	–	1 AVCS	
TOS C	ESSA V	Apr. 20, 1967	Sun-sync	750	2 AVCS 1 FPR	
ATS C	ATS III	Nov. 5, 1967	Geosync	–	1 SSCCE-color 1 IDCS WEFAX OPLE	First color- First data collection
TOS D	ESSA VI	Nov. 10, 1967	Sun-sync	750	2 APT	
Nimbus B	–	May 18, 1968	Launch vehicle failure		See Nimbus B-2	

Designation		Launch Date	Orbit (Nominal)		Meteorological Sensor Complement	Remarks
Prelaunch	In orbit		Inclination (degrees)	Altitude (n.m.)		
ATS D	ATS IV	Aug. 10, 1968	Launch vehicle failure	—	1 IOC	
TOS E	ESSA VII	Aug. 16, 1968	Sun-sync	750	2 AVCS 1 FPR	
TOS F	ESSA VIII	Dec. 15, 1968	Sun-sync	750	2 APT	
PLANNED AS OF JANUARY 1969						
Nimbus B-2		May 1969	Sun-sync	600	1 IRIS 1 SIRS 1 HRIR (D/N) (S&LR) 1 MRIR 1 MUSE 1 IDCS 1 IRLS	
TOS-G	ESSA 9	Feb. 1969	Sun-sync	750	2 AVCS 1 FPR	
TOS-H		On call	Sun-sync	750	2 APT	
ATS E		Aug. 1969	Geosync	—		
TIROS M		May 1969	Sun-sync	775	2 AVCS 2 APT 2 HRIR (S&LR) 1 SPM 1 FPR	
Nimbus D		Mar. 1970	Sun-sync	600	1 IRIS 1 SIRS 1 FWS 1 BUV 1 THIR 1 SCR 1 MUSE 1 IDCS 1 IRLS	
ITOS A		Nov. 1969	Sun-sync	775	2 AVCS 2 APT 2 HRIR (S&LR) 1 FPR 1 SPM	
ITOS B		On call	Sun-sync	775	2 AVCS 2 APT 2 HRIR (S&LR) 1 FPR 1 SPM	
ITOS C		On call	Sun-sync	775	2 AVCS 2 APT 2 HRIR (S&LR) 1 FPR 1 SPM	
ITOS D		On call	Sun-sync	775	—	
ITOS E		On call	Sun-sync	775	—	
Nimbus E		—	—	—	—	

SSCCE - Spin Scan Cloud Cover Experiment

ATS-B - Black & White - ATS I
ATS-C - Three Color - ATS III

IOC - Image Orthicon Camera (Day/Night) also contains movable mirrors to select specific areas. 800-TV-line horizontal resolution and 620-TV-line vertical resolution.

ATS IV

- PROPOSED

High-Resolution Color Camera Experiment (for Synchronous Orbit)

A two-camera system (5000 line each), one to image the entire earth with ground resolution of 1.8 miles/TV line and one covering 2° with stepping capability and approximate resolution of 0.2 mile/TV line.

High-Resolution Multi-Spectral Camera

A 2-inch return-beam vidicon with resolution in excess of 4000 TV lines or 200-ft. ground resolution while viewing a 100 × 100-statute-mile area.

- OTHER

WEFAX - WEather FACsimile - Transmission of weather data by satellite facsimile

ATS I, III

OPLE - Omega position location equipment - Data collection from remote sensors

ATS III

IRLS - Interrogation, recording and location system

Nimbus B-2 - Data collection and ranging
Nimbus D - Data collection, ranging, and wind tracing

SPM - Solar proton monitor - Measure flux of protons in the 10, 30 and 60-Mev range and electrons in the 100 and 750-kev range

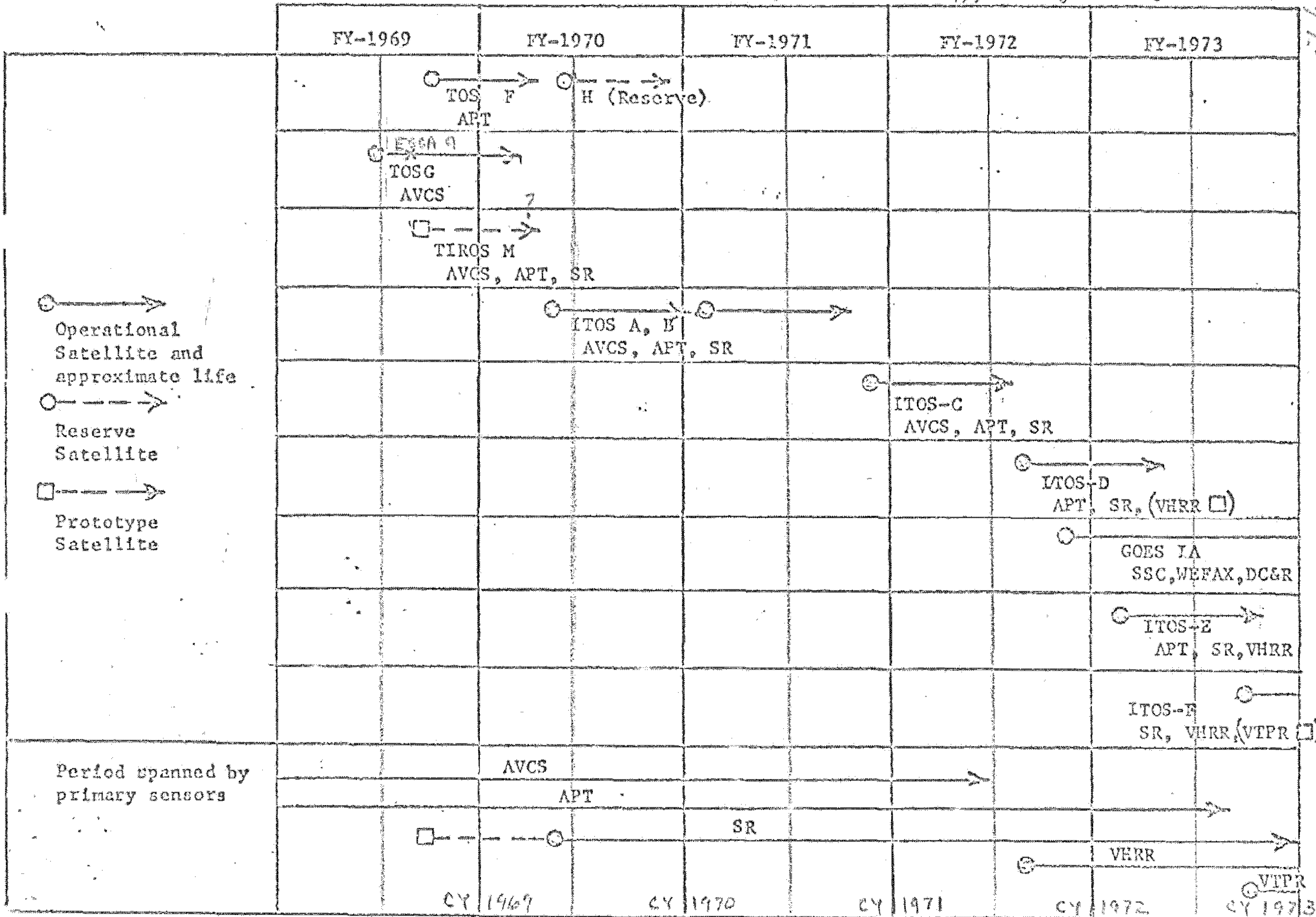
TIROS-M, ITOS A, B, C

SCADS - Scanning Celestial Attitude Determination System - Attitude determination to better than 0.1 deg. accuracy in three axes

Not scheduled

Figure 8. Projected Schedule for Operational Satellites and Primary Sensors

(See FOREWORD for Schedule Limitations Imposed by Technology, Funding and Requirements)



NOTE: How should ATS-1 be shown?

WORKING PAPER

A. Satellite System Combinations to Meet Requirements:

NOTE: One civilian satellite is imperative in view of international aspects. Costs shown are in millions and reflect total on-orbit costs including all launch services.

Separate Civil-Military System		All Civil		Planned Mixture	
1 Civil Satellite	$9.6	4 Civil	$38.4	1 Civil	$9.6
4 Mil Satellites	10.9		-	3 Mil	8.2
TOTAL	$20.5		$38.4		$17.8

B. Development and Production Costs: ($ in millions)

NASA (R&D)	FY-69	Estimated FY-70
Supporting Research & Technology	4.8	4.9
TIROS/TOS Improvements	5.8	5.2
NIMBUS	31.9	29.2
ATS Experiments	1.3	.7
Launch Vehicle (NIMBUS Only*)	7.6	6.8
R&D TOTAL	$51.4	$46.8

*ATS launch vehicle costs are charged to the ATS program.

ESSA (Production-Reimbursable)	FY-69	FY-70
ITOS	10.0	6.0
Launch Vehicle/Service	2.2	4.2
Prod. TOTAL	$12.2	$10.2
NASA/ESSA TOTAL	63.6	57.0

DOD	FY-69	FY-70
Development (Block V)	10.6	9.5
DEV. TOTAL	10.6	9.5
Production - Spacecraft (Block V)	0	4.5
Launch Vehicles/Service (1.7+1.5)	3.2	3.2
PROD. TOTAL	3.2	7.7
DOD TOTAL	13.8	17.2

Attch #2

WORKING PAPER

SUBJECT: Analysis of Possible Near-Term Cost Savings in the NASA/DOD Meteorological Satellite Program Area (U)

TO: Homer E. Newall
Associate Administrator
National Aeronautics and
Space Administration

Dr. John S. Foster, Jr.
Director of Defense Research
and Engineering

Introduction:

(U) Based on the Terms of Reference drafted 23 July 1968, a small group of NASA/DOD personnel met during the period of 25 July to 14 August 1968 to review program alternatives and determine any possible near-term cost savings. Mr. David Johnson of ESSA was invited to meet with the group on 25 July in the capacity of an expert technical advisor.

(U) Military operational requirements, including current and planned ways of meeting them, as well as R&D responsibilities and efforts were reviewed and discussed. The discussion which follows, is based on this review and on those inputs provided by Mr. Johnson on 25 July.

Discussion:

~~(S/SAR)~~ In the discussion of the kinds of observations needed from the operational system, the military requirements considered were those contained in Attachment 1. Civilian requirements were stated by Mr. Johnson to be essentially the same as the military although no formalized parametric requrements listing was obtainable from ESSA. Civilian observation frequency requirements were not considered to be as stringent as those of the military. Further, the civilian need is for global stored data as well as global, realtime direct readout of APT (Automatic Picture Transmission) type data. The military also requires these types of data but with special emphasis on global coverage with timely direct, or stored readout data in specified

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areas of military interest. Moreover, in view of the state-of-the-art expected in the 1968-1971 period, the discussion was limited to operational meteorological satellite capabilities having visual and infrared sensors to determine cloud distribution and tops. Various satellite system combinations (military, civilian, or mixed) were considered which would theoretically meet these requirements. As shown in Attachment 2, a system consisting of one civilian and four military satellites would cost about $21 million annually. A system composed of four civilian satellites would cost about $38 million annually, and the currently planned system which is composed of one civilian and three military satellites, would cost about $18 million annually. The discussions clearly indicated that although numerous alternatives appear to be possible for the long range, there appears to be no area of overlap which could be eliminated, curtailed or combined to effect cost savings over the next few years. The group concluded that so far as the near-term is concerned, the presently planned cooperative system composed of one civilian and three military satellites is the best solution.

~~(S/SAR)~~ The problems associated with the adoption of a different civilian/military system concept were considered to be enormous due to the nature of the programs involved, international commitments, and other operational problems, such as availability of data and security requirements. For example, in accordance with a 1963 bilateral agreement between the United States and the USSR, data from the meteorological satellites of both countries are exchanged over a direct link between Washington and Moscow. Under the U.S. policy for peaceful use of space, data from U.S.

satellites is freely available to the World Meteorological Community through the World Meteorological Center. The Automatic Picture Transmission (APT) system on the TIROS Operational Satellite (TOS) program has been publicly announced in the United Nations with all members invited to participate in the program. Meteorologists in over 50 countries have begun to place major emphasis on dependable routine receipt of the APT pictures for operational forecasting. Thus, the APT-equipped satellites have become an integral part of the World Weather Watch, an international meteorological observation system, now under development. During 1967, the National Environmental Satellite Center (NESC) provided training and study facilities for the World Meteorological Organization, NATO and AID Fellows from Argentina, Australia, Belgium, Hungary, India, Israel and Poland for periods ranging from one week to six months. Scientists from many other countries also visited NESC for shorter periods during which they were briefed on satellite activities. The operation of a classified military system as an integral part of the national civilian system in such an environment would be most difficult, would probably still require separate facilities, and even under the best circumstances, would severely complicate U.S. international relations.

~~(S/SAR)~~ In the area of research and development, it was determined that NASA currently conducts experimental projects and fundamental research for both programs at an annual cost of about $47 million. The results of these efforts are used by NASA and DOD in the development of the individual operational systems. DOD developments are planned at an annual rate of about $10 million. No areas of overlap in the development of flight hardware, which is conducted by both agencies were uncovered and continued reciprocal visibility into both development programs, was considered vital.

Recommendations:

Based on the above review, we recommend that:

1. ~~(S/SAR)~~ The current military and civilian system mix be continued for the near-time. Future planning, as in the past, should consider the cost effectiveness of other system combinations as well as the validation of the stated civilian and military requirements.

2. ~~(S/SAR)~~ The present R&D programs be continued.

3. (U) Military and civilian programs receive continuing review for the purpose of eliminating any overlapping and duplicatory effort and presenting effective solutions in the RDT&E efforts of both agencies.

4. (U) No further study with regard to near-term cost savings be made at this time.

RECURRING COSTS

(Including Spacecraft, Boosters and Launch Services)

	Program 417			TOS/TIROS-M/ITOS	
CY 1968	Block IV	$2.5 M		TOS(APT)	$6.2 M
				TOS(AVCS)	$6.2 M
1969	Block V	$3.0 M ea.	69	TIROS-M, ITOS A	$9 M ea.
1970		$3.5 M	70	ITOS [illegible], B	$9 M ea.
1971		$3.5 M	71	ITOS C	$9 M
1972		$3.5 M	72	ITOS D, E	$9 M ea.
1973		$4.8 M		~~ITOS E~~	$9 M

417/NOMSS COST RATIO

CY 1968	1/2.5
1969	1/3
1970	1/2.5
1971	1/2.5
1972	1/2.5
1973	1/1.9

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417/NOMSS Satellite Costs, Performance and Launch Schedules

SYSTEMS PERFORMANCE

	Program 417		TOS/TIROS-M/ITOS	
CY 1968	Block IV cost. $2.5 M/launch	1 Satellite On-Orbit 1 Day Observation (Obs) .8 NM Resolution (Res) Synoptic/Tactical Quality Flexible ~~Ascending Node (A/N)~~ observation time (O.T.)	TOS(APT) cost $6.2 M/launch	1 Satellite On-Orbit 1 Day Obs ~4 NM Res. Synoptic Quality Fixed 0900 ~~A/N~~ O.T.
			TOS (AVCS) $6.2 M/launch	1 Satellite 1 Day Obs. 2 NM Res Synoptic/Tactical Fixed 1500 ~~A/N~~ O.T.
1969	Block V $3.0M/launch	3 Satellites 3 Day/Night Visual Obs. (Res - 2 NM to ½ Moon) 3 Day/Night IR Obs (Res-2NM) ~~([illegible])~~ Synoptic/Tactical Tactical Encrypted 3 Day Tactical (~~1/3 NM~~) visual obs (Res - 1/3 NM)	TIROS-M $9 M	1 Satellite 1 Day Visual - 2 NM Res. ~~(Uses 1966 Block IV Vidicon)~~ 1 day, 1 night IR Obs ~~IR Obs (4 NM)~~ (Res-4NM) Fixed 1500 ~~A/N~~ O.T. (0900 Possible) No encryption
1970 - 71	Block V $3.5m/launch	Same as Above Plus Gamma Radiation Detector, USN Readout. Provisions for Command/ Stored Data Encryption if directed.	ITOS A,B,C $9 M/launch	Same as TIROS-M. No plans for RF power for direct USN Readout.
1972	Block V $3.5m/launch	Add Vertical Temperature Spectrometer and ~~IR 3~~ Day/Night ~~Resolution~~ IR obs ~~of 1/3 NM~~ (Res. 1/3 NM)	ITOS D $9 M	1 Satellite Same as above plus direct readout (½ NM Res.) 1 Day Visual 1 Day, 1 Night IR if communication bandwidth problem solved. Vertical Temp. Profile.
1973	Block V $4.8M/launch	Improved sensor res ~~Sensor res Resolution~~	ITOS E $9M	Same as ITOS D.

Atch 5

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