TIROS – **T**elevision and **I**nfra-**R**ed **O**bservation **S**atellite series

Parameter	TIROS I	TIROS II	TIROS III	TIROS IV	TIROS V	TIROS VI	TIROS VII	TIROS VIII[12]	TIROS IX[5]	TIROS X[9]
Launch Date	1/4/1960	23/11/1960	12/7/1961	8/2/1962	19/6/1962	18/9/1962	19/6/1963	21/12/1963	22/1/1965	2/7/1965
Deactivated	19/6/1960	1/2/1961	30/10/1961	30/6/1962	5/5/1963	11/10/1963	3/2/1966[1]	1/7/1967[2]	15/2/1967[3]	3/7/1967[4]
Lifetime	79 days	69 days	108 days	125 days	320 days	388 days	978 days	1258 days	754 days	732 days
Pictures	19389	25574	24000	23370	48547	59830	111047	88662	76604	59119
Launcher	Thor-Able	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta	Thor-Delta
Site	ETR	ETR	ETR	ETR	ETR	ETR	ETR	ETR	WTR	ETR
Pre-launch	A1	A2	A3	A9	A50	A51	A52	A53	A54	OT-1
Designation	1960 2A 1960 β 2	1960 16A 1960 π 1	1961 17A 1961 ρ 1	1962 2 A 1962 β 1	1962 25A 1962 αα 1	1962 47A 1962 αψ 1	1963 24A[11]	1963 54A	1965 4A	1965 51A
Catalog No	29	63	162	226	309	397	604	716	978	1430
Apogee	867 km	837	937	972	1119	822	743	878	2967	957
Perigee	768 km	717	854	817	680	783	713	796	806	848
Inclination	48.392°	48.530°	47.898°	48.3°	58.1°	58.2°	58.2°	58.5°	96.4°	98.6°
Period	99.24’	98.26’	100.4’	100.4’	100.5’	98.7’	97.4’	99.3’	119.2’	100.6’
Mass	120 kg	125	129	129	129	127	135	119	138	127
Camera 1	TV-NA	TV-NA	TV-WA	TV-WA 3/5/62	TV-WA 14/5/63	TV-WA 21/10/63	TV-WA	APT 31/8/64	TV-WA	TV-WA
Camera 2	TV-WA	TV-WA	TV-WA	TV-MA 10/6/62	TV-MA 7/7/62	TV-MA 29/11/62	TV-WA	TV-WA	TV-WA 26/7/65	TV-WA -/9/65
IR		•	•	•			•			
IRP		•	•	•			•			
HB			•	•			•			
EP							•			
BCN TX 1[6]	108.00	108.00	108.00	136.23[10]	136.23	136.23	136.23	136.23	136.23	136.23
BCN TX 2[6]	108.03	108.03	108.03	136.92	136.92	136.92	136.92	136.92	136.92	136.92
TV TX 1[7]	235	235	235	235	235	235	235	**136.95**	235	235
TV TX 2[7]	235	235	235	235	235	235	235	235	235	235
IR TX[8]	None	237.8	237.8	237.8			237.8			
Command										

ETR USAF Eastern Test Range, Cape Canaveral, Florida
WTR USAF Western Test Range, Vandenberg AFB, California

Note 1 Sporadic operation continued until 12/7/1961
2 Abandoned this date after Post Operational Engineering Evaluation period started 22/1/1966
3 Post operational Engineering evaluation
4 Abandoned this date after Post Operational Engineering evaluation started on 1/6/1966
5 was to be ESSA prototype sun synchronous orbit in "wheel" configuration but guidance system failure caused non-sun sync elliptical orbit
6 Beacon transmitters
7 TV transmitters, operated on command, sequential when over control station
8 Infrared transmitter, operated simultaneously with TV transmitter
9 Sun synchronous orbit
10 NASA Telemetry moves to 136-137 Mc ITU band in 1960, Command moves to 148-150 Mc band in 1963.
11 COSPAR ID number replace SAO Greek letter in 1963
12 TIROS-VIII APT received by Henderson and Ferguson on the roof of the Tillies Building, LaTrobe St, on Christmas Eve. (24/11/1963)

TIROS Television and Infrared Observation Satellite

Spacecraft description: an 18 sided right polyhedron, 42" across diagonal edges, 22½" high, sides and top covered with 9260 1 x 2 cm solar cells. The receive λ/4 monopole antenna on top. A pair of crossed dipole antennas, fed in quadrature from hybrids to produce circular polarization, from 4 transmitters (2 Beacon, 1 TV and 1 IR are attached to the base plate. 9-12 rpm spin axis parallel to orbit plane (axial mode). Passive thermal control.
The major sub-systems were attached to the base plate.

Television camera subsystem
Infrared Observation subsystem
Attitude Reference subsystem
Dynamics control subsystem
Telemetry and Tracking subsystem
Power supply subsystem

Television camera subsystem – 2 independent systems, each with 1 camera, 1 tape recorder and 1 transmitter

TV
Television cameras

TV-WA	Wide angle	104° FOV	1206 km	3.2 km res
TV-MA	Medium angle	80° FOV	725	1.6 km res
TV-NA	Narrow angle	13° FOV	121	0.8 km res

0.7 to 0.9 micron spectral sensitivity,
12.7mm (½") ruggedized vidicon,
solenoid operated shutter, 1.5 millisecond speed,
fiducial marks – central cross and corner marks
500 lines image
2 s read time, 250 lines/sec read rate,
62.5 khz video bw,
30 second picture taking repeat time,

Magnetic Tape Recorders

400 feet at 50 ips
record start/stop/continuos playback
32 picture capacity (48 on TIROS-9) with 30 sec repeat, 100 second replay time
Tape recorder channel 1: TV video on 85 khz sco (70-100khz bandwidth)
Tape recorder channel 2: Sun or North reference pulses (Position Indicator) on 10khz sco

TV transmitters

Both on 235.0 MHz, 2W, FM, circular polarized

Infrared sub-system

IR - 5 channel medium resolution
Scanning Radiometer, a 5 channel reflected solar and emitted radiation radiometer
45 Hz chopper gave alternate space/earth view
6-6.5 micron water vapour on 100-150 Hz sco
8-12 micron atmospheric radiation (14-16 CO_2 on TIROS-3) 165-215 Hz sco
0.2-6 micron earth albedo on 230-280 Hz sco
8-30 micron total emitted thermal radiation (time ref on TIROS-4) on 295-345 Hz sco
0.55-0.75 micron visible (vidicon comparison) on 360-410 Hz sco
chopper 550 Hz reference am'd on sco
1: 30 record:replay ratio - 3' 20" minutes replay time to CDA

IRP – 2 channel low resolution
Non-scanning Radiometer, Passive IR

Time-multiplex on 427-437 Hz sco of
Black cone (0.2-50 micron), White cone (5-50 micron) 50° FOV and Housing temps.
And later, HB and IP (Radiometer temp, Electronics temp, 3 reference resistors)

HB
Heat Budget, omni-directional IR by V. E. Suomi of University of Wisconsin
Black and white cone mounted Parallel to spin axis

IP
Electron Temperature ion probe – University of Michigan

IR tape recorder ad transmitter

IR and IRP recorded on 100 minute long endless tape, replayed to CDA (3.3') on a separate IR FM transmitter on 237.8 MHz

APT Automatic Picture Transmission – direct local readout on TIROS-VIII only (ESSA prototype)
single 25mm Vidicon 108° FOV f/1.8 5.7mm focal length
1200 x 1200 km 4km resolution
208 sec readout period, 240 rpm, 3s start, 5s phase, 200s pix
800 lines,
developed from Nimbus
central cross and 24 fiducial marks
136.95 MHz 5W linear polarization, ΔF ±10 kHz, direct readout

TIROS II and onwards, had magnetic attitude control – a 250 turn electromagnetic coil to interact with the Earth's magnetic field to control the spin axis attitude.
IR Horizon attitude sensor – one sensor mounted 90° to spin axis, 7-30 micron, 1°x 1° FOV
Sun or North sensors – 9 sensors, 40°intervals around periphery of s/c, 7° FOV

Telemetry, Tracking and Command sub-system

Beacon transmitters -

2, 108 MHz (136 MHz from TIROS-IV) 30 milliwatt, 50 milliwatt from TIROS-XI, NASA Minitrack beacons, permanently on from launch
each modulated with output from a 1200±100 Hz sub-carrier oscillator
amplitude modulated with Spin Axis Horizon sensor (approx 100ms burst of 3KHz).
sends 40 channel telemetry switch in 30 seconds on 1300 Hz sco on either Direct 1 or 2 , Playback 1 or 2 commands, during CDA interrogations.

30s used for TV tx valve heater warm-up
Also used as positive indication of 3rd stage separation during launch (Beacon tx 2 sco goes from 1200 to 1300 Hz)
TIROS VI and onwards, had 1 year ± 30 days timer to "kill" beacon transmitter

Command

TIROS Command receivers operated in the 148-150 MHz (148.56 MHz ?) amplitude modulated with 8 tones, in combinations
TIROS VIII and onwards, had addressable command decoders.

NIMBUS series

Parameter	**NIMBUS-1**	**NIMBUS-2**		**NIMBUS-3**	**NIMBUS-4**	**NIMBUS-5**	**NIMBUS-6**	**NIMBUS-7**
Launch Date	28/08/1964	15/05/1966	18/05/1968	14/04/1969	08/04/1970	12/12/1972	12/6/1975	24/10/1978
End of Life	24 days	978 days	FTO	1028 days		29/3/1983	29/3/1983	1993
Pre-launch	NIMBUS-A	NIMBUS-C	NIMBUS-B	NIMBUS-B2	NIMBUS-D	NIMBUS-E	NIMBUS-F	NIMBUS-G
Designation	1964-52A	1966-40A		1969-37A	1970-25A	1972-97A	1975-52A	1978-98A
Catalog no	872	2173		3890	4362	6305	7924	11080
Apogee	931	1174		1132	11097	1088	1111	956
Perigee	422	1090		1069	1085	1079	1098	944
Inclination	98.7°	100.6°		100°	99.9°	99.8°	99.8°	99.1°
Period	98.4’	108.1’		107.2’	107	107.1’	107.4’	104.15’
Mass	373 kg			576	621 kg	718 kg	909 kg	965 kg
	1707.5 5W	1702.5 5W 137.20 1.5W MRIR		1702.5 5W 1707.5 5W	1702.5, 10 W	1702.5 4W 1707.5 4W 2208.5 SCMR	1702.5 4W (2) 2253.0 2/4/8W 2062.85 ATS-6	2211.0 4W WB
APT	136.95 5W	136.95 5W		136.95 5W	136.95 5W			
Bcn/Tlm	136.50 350 mW	136.50 350 mW		136.50 300 mW	136.50, 500 mW	136.50 500 mW	136.50 500mW	2273.5 1.5W
Cmd	149.52	149.52		149.52	149.52	149.52	149.52	2093.514583

NIMBUS-1 3 AVCS 1 APT HRIR 1st three axis stabilization
NIMBUS-2 3 AVCS HRIR MRIR
NIMBUS-3 IDCS HRIR MRIR SIRS-A IRIS MUSE IRLS
NIMBUS-4 IDCS THIR SIRS-B IRIS MUSE IRLS SCR BUV FWS

AVCS Advanced Vidicon Camera System - flight test for APT and AVCS on TIROS and ESSA
Automatic and manual vi commands F-stop (aperture) adjustment
APT
HRIR

NIMBUS-1 (NIMUS-A) 1964-052A

- Launched 0852Z 28/8/1964 on Thor-Agena from WTR
- Agena fuel leak caused short 2nd stage burn and elliptic orbit 423x 933 km

- Solar paddle drive failed 23/9/1964, 26 days after launch
- 1st 3 axis stabilized to 1°
- 2 IR horizon scanners on roll axis 90°FOV IFOV 3x10°
- s/c active during orbits 1 to 199 and 380 to 1231
- 199 orbits of HRIR played back
- AVCS (3 cameras) and recorder
    - Each with 37°FOV, spaced 35° apart giving 2° overlap
    - 6.75 sec/pix (0.25s blank video, 6.5 s video, 0.25 s blank
    - 833 video lines
    - 91 seconds between pictures
    - recorded and played back over CDA via S-band tx
    - 70 KHz video sco
    - 80 KHz F&W sco with 36bit TC PDM
- APT
- HRIR
    - night-time IR 3.48 to 4.17 μm
    - 7.9 mr IFOV approx 0.5°
    - 7.5 km ground resolution at 930 km orbit height
    - 1.3418 seconds per scanline, 44.715 rpm (exact ratio 5500/123)
    - built by ITT
    - Lead Selenide (PbSe) photoconductive cell
    - Radiatively cooled to –75°C
    - 1500 Hz chopper at the focus of a 4” f/1 modified Cassegrainian telescope
    - linear-log amp produces 0 (space, cold) to –6V (earth,warm) output with video bandwidth of 286 Hz
    - 7 sync pulses
    - frequency modulator output - 10KHz (0v) to 8.25 KHz (-6v)
    - 2 track tape recorder at 3.75ips
    - 4 track replay at 30 ips. ie x8 record speed in 7.25’
    - record capacity 57’ in each direction, 114’ total
    - during replay, the 4 tracks are translated by 4 specific local oscillators and multiplexed
    - Stored data transmitted by S-band
    - 45 s S-band tx warmup time
    - Nimbus –1 s/c night-time is 49’

- 136.95 MHz APT

    - 110° FOV
    - 800 lines
    - 240 rpm
    - 208 s readout time
    - DRID Direct Readout Image Dissector
- 136.50 MHz beacon
    - 2 PCM systems, 3 modes, telemetry transmitted real-time and stored
    - telemetry ADC 7 bits
    - 'A Real Time' ART 500 bps to beacon tx and recorder
    - ART format 1024 words Master Frame, 16 sub-frames,64 words/subframe, 8 bit words,
    - Sub-frame format 'ff' sync word, '00' to '3f' subframe Id, 62 data, 1.024 s/subframe, 16.384 s/master frame(1024 x 8/500)
    - 'A Stored' transmitted on command at 30 times record rate by 15 KHz sco, 15,000 bps, 220' tape, 120' capacity, 4' replay time
    - 'B Real Time' s/c emergency mode, 62 key parameters, 10 bps,2 samples/104 s,128 slots
- 1702.5 MHz 5W FM composite sub-carriers for AVCS & HRIR

NIMBUS-2 (NIMBUS-C) 1966-040A

- launched 15/5/1966 on TAT/Agena B from WTR
- sun sync orbit 600 nm 12 noon ± 32 min LST NASN
- AVCS (3) and recorder failed 31/8/1966
- APT with Data Code Experiment – failed April 1968
- HRIR and recorder
    - 44.715 rpm
    - Real time data called DRIR
    - failed 15/11/1966
- MRIR
    - 5 channel radiometer and recorder
    - 5.4 to 6.9 microns
    - 10-11 microns
    - 14-16 microns
    - 5-30 microns
    - 0.2 to 0.4 microns
    - 2.85° IFOV
    - 7.9 rpm
    - 33.3 samples/sec by 9 bit ADC
    - recorded at 0.45 ips

  - playback at 1:26 ratio via VHF 137.2 MHz 1.75 W ΔF ±25 KHz 66.6 Kbps FSK MI = 0.8
  - 30 nm GFOV
  - failed 2/9/1966
- 136.50 MHz beacon
  - PCM/AM
  - 350 mW
  - either stored loop data or RT data
  - Low rate emergency data
  - S/c TC on 10KHZ sco
  -
- 136.95 MHz APT & DRIR
- 1702.5 MHZ 5W AVCS replay
  - CDA diagram shows FM demodulators for 0-750KHz
    - AVCS TC Time code
    - AVCS LC Left Camera
    - AVCS CC Centre Camera
    - AVCS RC Right Camera
    - HRIR video forward direction (Mode 1)
    - HRIR F&W forward direction
    - HRIR video reverse direction (Mode 2)
    - HRIR F&W reverse direction

- ceased operations 18/1/1969

NIMBUS C Mission Operations Plan, NASA GSFC, March 1966

1702.5 Mhz AVCS and HRIR Stored WideBand Data
3 MHZ IF bandwidth
FM modulator
Single tx and ant
8 subcarriers
AVCS Time Code Mode 2
AVCS Left Camera Mode 2
AVCS Central Camera Mode 2

AVCS Right Camera Mode 2
AVCS Real time Timecode mode 1
HRIR video mode 1 or 2
HRIR time mode 1 or 2

137.2 MHz
MRIR stored data
1.75 W
300 KHZ IF bandwidth
66.6 Kbps PCM (Biphase-C)/FM
FM $\Delta F \pm 25$ KHz, MI = 0.8,
4 mins replay time

136.95 MHz FM 5W Real Time Narrow Band (30 KHz) APT (day) and DRIR (night)

136.50 MHz
PCM/AM
2 350 mw transmitters
Right hand circular polarization
100 KHZ IF Bandwidth
30 KHZ IF bandwidth for “A realtime”
A realtime telemetry on from launch
spacecraft status and command verification
stored data from endless tape recorder
real time data
low rate emergency data
spacecraft timecode PDM/AM/AM
Telemetry A PCM (NRZ-C)/AM 15 kbps stored and realtime
Telemetry A 500 bps
Telemetry B PCM (NRZ-M)/PSK/AM 5 Kbps realtime (backup)

149.52 MHz Command

AVCS
HRIR & DRIR
APT

MRIR

NIMBUS-B

- 18/5/1968 mid flight abort due Agena 2nd stage failure

NIMBUS-3 (NIMBUS-B2) 1969-037A

- launched 14/4/1969 on Thorad-AGE
- IDCS
  - Replaced AVCS and APT
  - No fiducial marks
  - 7 sync bars instead of black blanking pulse
  - failed 25/1/1970
  - DRID - Direct Readout Image Dissector
- HRIR
  - single channel 0.695 x 0.672 mm Lead Selenide photoconductor
  - 3.4 – 4.2 μm night IR
  - 0.7 – 1.3 μm day IR
  - 6.72 mr IFOV
  - 4 nm ground resolution
  - 7 sync pulses
  - 7 step grey wedge
  - 48 rpm
  - DRIR – Direct Readout Infrared Radiometer
  - Failed 31/1/1970
- MRIR
  - 5.4 to 6.9
  - 10 to 11
  - 14 to 16
  - 20 to 33
  - 0.2 to 0.4
  - failed 4/2/1970
- IRIS failed 22/7/1969
- SIRS
- MUSE
- IRLS
- Beacon –136.5 MHz 300 mW (2)

- RTTS – Real Time Transmission System, 136.95 MHz 5W Day time DRID, Night time DRIR
- 1702.5 MHz 10W (2) – Stored data play back on command

NIMBUS-4 (NIMBUS-D) 1970-025A

- launched 8/4/1970 into 590 ± 3 nm orbit on Thorad-Agena D
- IDCS Image Dissector Camera System
    - 108° FOV, 240 rpm, 800 line/200 sec, 4 km res, 208 second repeat
    - no fiducial marks
    - 7 sync pulses in blanking
    - No Data Code Experiment
- RTTS Real Time Transmission System
    - IDCS or THIR, AM on 2400 Hz sub-carrier, FM on 136.95 MHz, 5W
- IRIS Infrared Interferometer Spectrometer
    - Realtime on beacon
    - Stored on HDRSS
- MUSE Monitor of Ultraviolet Solar Energy
- IRLS Interrogation, Recording, Location System
- SIRS Satellite Infrared Spectrometer
- THIR Temperature-Humidity Infrared Radiometer
    - replaced HRIR and MRIR,
    - 48 rpm
    - 11.5 μm 8km res day/night and 6.7 μm 22 km res night only
- FWS Filter Wedge Spectrometer
- BUV Backscatter Ultraviolet Spectrometer
- SCR Selective Chopper Radiometer
- HDRSS High Data Rata Storage System
    - 5 channel tape recorder (2)
    - 134’ capacity
    - Two 4 W S-band (1702.5 MHz) and antennas
    - THIR, IDCS, IRIS, VIP & Timecode am on 10KHZ sco (F&W comp)
- VIP Versatile Information Processor
- 136.5 MHz 500mW beacon 2 transmitters and recorders
    - VIP 1000 sensor, 4kbps bi-phase
    - 10 KHz Time Code Format 100 bps PDM LSB Standard NASA timecode
    - IRIS 3.75kbps

- 136.95 MHz 5W RTTS
- 1702.5 MHz 10W (2) stored data playback over CDASs
    - x 32 replay in reverse
    - THIR 657.8 to 602.8 KHz
    - IRIS data recorder at 3.75 Kbps, replayed at 120 kbps
    - VIP ? KHz SCO at 4 Kbps
    - Timecode 10 Kbps ?

NIMBUS-5 (NIMBUS-E)

- launched 11/12/1975
- SCMR
- ITPR
- NEMS
- ESMR
- THIR
- No RT data
- Solar cells and 2 SNAP-19 RTGs
- 136.5 MHz beacon
- 1702.5 MHz 4W
- 2208.5 MHz 4W

NIMBUS-6 (NIMBUS-F)

- launched 12/6/1975
- ERB
- ESMR
- HIRS
- LRIR
- T&DR
- SCAMS
- TWERLE
- PMR
- 136.5 MHz beacon VIP (2)
- 149.52 MHz command
- 1702.5 MHZ 4W (2) HDRSS A & B SD PB

- 2253.0 MHz 2, 4 or 8 W telemetry and HDRSS science data transmit to ATS-6
- 2062.85 MHz command receive from ATS-6

NIMBUS-7 (NIMBUS-G)

- launched 24/10/1978
- LIMS
- SAMS
- SAM-II
- SBUV/TOMS
- ERB
- SMMR
- THIR
- CZCS
- Two USB TC&C transponders
- USB Commandc, 2093.51458333 MHz, PCM PSK/FM/PM
- USB Telemetry, 2273.5 MHz, 1.5 W, PCM/PM
    - 4 kbps RT VIP PCM, 80 x 80 10-bit words/16 sec. (ERB, SAMS, SAM II, SBUV/TOMS, 576 Analog, 16 Digital A, 320 Digital B)
    - 25 kbps RT DIP (Digital Information Processor) PCM (VIP + THIR, SMMR, LIMS)
    - Ranging tones (PM), phase coherent ranging PM , 240/211 turn around ratio
- Wide Band transponder (2), PCM/FM 2211.0 MHz, 5 W
    - 800 kbps DIP PB
    - 800 kbps ZIP PB (Stored CZCS data, 9.5 mins max)
    - 800 kbps ZIP (RT CZCS data)
- Three 450 Mbyte capacity GSTRs

ESSA - TOS (TIROS Operational System) series

Parameter	**ESSA-1**	**ESSA-2**	**ESSA-3**	**ESSA-4**	**ESSA-5**	**ESSA-6**	**ESSA-7**	**ESSA-8**	**ESSA-9**
Launch Date	03/02/1966	28/02/1996	02/10/1966	26/01/1967	20/04/1967	10/11/1967	16/08/1968	15/12/1968	26/02/1969
End of Life	12/06/1968	16/10/1970	02/12/1968	05/05/1968	20/02/1970	03/12/1969	10/03/1970	12/03/1976	29/11/1973
Pre-launch	OT-3	OT-2	TOS-A	TOS-B	TOS-C	TOS-D	TOS-E	TOS-F	TOS-G
Launcher	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta
Site	ETR	ETR	WTR	WTR	WTR	ETR	WTR	WTR	ETR
Designation	1966-8A	1966-16A	1966-87A	1967-6A	1967-36A	1967-114A	1968-69A	1968-114A	1969-16A
Catalog No	1982	2091	2435	2657	2757	3035	3345	3615	3764
Apogee	965	1639	1709	1656	1635	1713	1691	1682	1730
Perigee	800	1561	1593	1522	1556	1622	1646	1622	1637
Inclination	97.5	101.0	101.0	102.0	101.9	102.1	101.7	101.8	101.9
Period	100.2	113.3	114.5	113.4	113.5	114.8	114.9	114.7	115.3
Mass	144 kg	132 kg							
Camera 1	TV-WA	APT	AVCS	APT	AVCS	APT	AVCS	APT	AVCS
Camera 2	TV-WA	APT	AVCS	APT	AVCS		AVCS	APT	AVCS
LRIR (FPR)			•		•		•		•
BCN TX 1	136.23	136.77	136.77	136.77	136.77	136.77	136.77	136.77 0.25 W	136.77
BCN TX 2	136.92	136.77	136.77	136.77	136.77	136.77	136.77	136.77	136.77
TX 1	235.0	**137.5**	235.0	**137.5**	235.0	**137.5**	235.0	**137.62 5W**	1697.5
TX 2	235.0	137.5	235.0	137.5	235.0	137.5	1697.0	137.62	1697.5

TOS-H stored
LRIR also know as Flat Plate Radiometer (FPR)

ESSA - Environmental Science Services Administration (1965- 1970)
ESSA-1 same as TIROS-9 with 2 TV-WA & ½" vidicons
ESSA-2, 4, 6,and 8 - redundant APT TV and transmitters
ESSA-3, 5, 7 and 9 - redundant AVCS, 100 feet tape recorders and transmitters and LRIR (aka FPM)
Redundant command receivers and addressable decoders
Redundant telemetry beacon transmitters
Same design as TIROS - 136 kg 107 cm diameter x 57 cm high with approx 9000 solar cells
Nominal circular, near polar, cartwheel mode, Sun synchronous, 1450 Km, 114 minute orbit
Spin axis perpendicular (orthogonal) to orbit plane
Spin rate 5.5 sec/rev – 10.91 rpm (APT), 6.5 sec/rev – 9.225 rpm (AVCS), maintained by Magnetic Attitude Spin Coil (MASC) and 5 solid thrusters
Equator crossing time (at launch) APT – 0900 LST Southbound, AVCS – 1500 LST Northbound

APT Automatic Picture Transmission
2 Tegea kinoptic 1 inch vidicons mounted 180° apart, 90° to spin axis
5.7 mm focal length
1.8 f-stop
focal plane shutter, 1.5 milliseconds
107.8° FOV
3200 km square coverage , 3.8 km res at centre, 7.4km at edge
Fiducial marks in image
8 pictures, 352 seconds (64 spins) with 35% overlap during sunlit part of orbit
800 scanlines per frame
200 seconds/frame, proceeded by 3 sec start and 5 sec phase signal (total 208 sec)
240 lines/min (4 lps)
direct transmission via redundant 137.5 MHz AM/FM, nominal 5 watts FM $\Delta F \pm 10$ KHz

AVCS Advanced Vidicon Camera System
2 Tegea kinoptic 1 inch vidicons mounted 180° apart, 90° to spin axis
5.7 mm focal length
1.8 f-stop
focal plane shutter, 1.5 milliseconds
107.8° FOV
3200 km square coverage , 3.8 km res at centre, 7.4km at edge
Fiducial marks in image
12 pictures, 260 seconds (40 spins) with 50 % overlap during sunlit part of orbit
833 scanlines per frame

6.75 seconds/frame
12 frames of stored data (1.9-2') transmitted to CDA on redundant 235.0 MHz, 2 watts nominal, replaced on ESSA-7 & 9 by 1697.5 MHz, 5W nom.
Recorder track 1 AVCS video – Replay 87.5 KHz SCO
Recorder track 2 F&W – Replay 12.5 KHz SCO
Recorder track 3 20 bit binary time reference of picture-taking time. Replay 3.9KHz SCO

LRIR Low Resolution Infrared Radiometer
Short wave solar radiation below 3 microns and long wave radiant energy from the earth (7-30 microns white, 0.4-30 for black) 3 disc assembly
Data (25, 12-bit words) is recorded on an incremental tape recorder with 90,000 bit capacity, at 2 bps, replayed at x bps and modulates a FM subcarrier oscillator (IRIG E (17 KHz)) on the AVCS transmitter
See reference NESC-42

Beacon transmitters (2) 250 milliwatt nominal

On command, 90 HK TLM points proceeded by 20 bps time reference on AVCS s/c or 1.2 seconds of single level voltage for APT s/c, modulate a IRIG 9 (3.9 KHz) sco. IR (8 to 18 micron) horizon crossing sensors are mounted on each side of the s/c, tilted at 43°. Each is differentiated and modulates a sco (IRIG 7 (2.3 KHz) and 8 (3.0 KHz)) on the beacon transmitter

ITOS - Improved TOS series

Parameter	**ITOS-1**	**NOAA-1**			**NOAA-2**		**NOAA-3**	**NOAA-4**	**NOAA-5**
Launch Date	23/1/1970	11/12/1970	21/10/1971		15/10/1972	16/7/1973	6/11/1973	15/11/1974	29/7/1976
End of Life	18/6/1971	19/8/1971	FTO	Stored	30/1/1975	FTO	31/8/1976	18/11/1978	16/7/1979
Pre-launch	TIROS-M	ITOS-A	ITOS-B	ITOS-C	ITOS-D	ITOS-E	ITOS-F	ITOS-G	ITOS-H(E2)
Designation	1970 8A	1970 106A	1971-91A		1972 82A		1973-86A	1974 89A	1976 77A
Catalog No	4320	4793	5565		6235		6920	7529	9057
Apogee	1700 km	1472			1458		1512	1461	1518
Perigee	1648 km	1422			1491		1508	1447	1504
Inclination	102.0°	102.0°			102.0°		101.9°	101.6°	102.1°
Period	115.1'	114.8'			114.9’		116.1’	114.9’	116.2’
Mass	310 kg				340 kg				
AVCS	2	2							
VHRR					2		2	2	2
SR	2	2			2		2	2	2
APT	2	2			2		2	2	2
VREC	1	1					1	1	1
SRR	3	3			3		3	3	3
ITR	1	1							
FPR	1	1							
SPM	1	1			1		1	1	1
ITPR					2		2	2	2
DDP					1		1	1	1
S-band 1	1695.0	1695.0			1697.5		1697.5	1697.5	1697.5
S-band 2					1697.5		1697.5	1697.5	1697.5
VHF 1	**137.5**	**137.62**			**137.5**		**137.62**	**137.5**	**137.62**
VHF 2	137.62	137.5			137.62		137.5	137.62	137.5
Beacon 1	**136.77**	136.77			**136.77**		136.77	**136.77**	136.77
Beacon 2	136.77	**136.77**			136.77		**137.14**	137.14	**137.14**

All launched on Delta boosters from WTR (VAFB, Ca)
S/C lifetime and orbital parameters from Rao (corrected)

ITOS Improved TOS

Spacecraft

Box-like 102x102x122 cm, 284 kg plus 3 200-400 W solar panels, 91x160cm
3 axis stabilized via fly-wheel rotating at 150 rpm
Sun synchronous, near polar orbit

Instruments

APT Automatic Picture Transmission
90 ° FOV, 1800 nm wide at 790 nm height 2 nm res
600 lines/frame ,3s start, 5s phase plus 150 s/frame 158 s total), 4 lpm, 260 sec repeat, followed by 102s of no signal or 94s SR and 8s no signal
vs ESSA TOS 800 lines and 352 sec repeat
realtime transmission only

AVCS Advanced Vidicon Camera System
Same as on TOS (ESSA) and Nimbus 1 and 2
1800 nm wide, 2-4 nm res
recorded and replayed to CDA
1' vidicon
833 lines/frame, 10 gray shades, 133 lps in 6.25 sec/frame
90° FOV
11 pictures at 260 sec intervals during s/c day with sun elevation > 15°
50% overlap

SR Scanning Radiometer
48 rpm
IR 10.4-12.5 microns, 5.3 mr IFOV, 4 nm res NEΔT 1°K at 350°K, 4°K at 185°K
VIS 0.52-0.73 microns 2.7 mr FOV 2 nm res
Stored on 1 of 3 onboard SRRs and realtime – for 70' of s/c night and 94s between APT in s/c day

FPR Flat Plate Radiometer for atmospheric heat balance measurement
0.3-30 microns black, 7-30 micron white
32 sec/frame, 60 8 bit words
recorded on ITR

SPM Solar Proton Monitor for solar proton flux measurement

Protons 10.30 and 60 Mev
Electrons 100-750 Kev
12.5 sec/frame, 20 9 bit words
recorded on ITR & real time on beacon – 2300Hz sco return to bias format, NESCTM 7 p.A-2.3, NESS 49 p.4, NESS 79
- 3900 Hz is horizon detector, differentiated analog signal
ITOS-1 SPM real time data used during Apollo-13 mission

ITR

3 track, 15 bps record of SPM, FPR and sync
300 bpi, 90' tape, 324 kbit/track
2000 bps playback rate in 2.7 '

SRR

3 of 209’ capacity cf 115’/orbit
replay time – 5’/full orbit time multiplexed VIS and IR
CDAS to DDHS at ¼ speed

Communications

CDA (S-band)

1695.0 MHz RHCP, 2 W, 30.2 - 34 dBm EIRP FM composite subcarriers

Multiplexer frequency band	Data from Tape Recorders
12±1.5 KHz	AVCS F&W
25 to 150 KHz (f_o=88 KHz)	AVCS video
200±1.5 KHz	SR-A F&W
230 to 280 KHz (f_o=255.5 KHz)	SR-A video
300±0.1 KHz	Pilot xtal controled
320 to 370 KHz (f_o=355.5 KHz)	SR-B video
400±1.5 KHz	SR-B F&W
444±4 KHz	FPR and TLM \
460±4 KHz	Digital bit reference |- from ITR
476±4 KHz	SPM /

Real-time

SR 137.5 MHz, 5 W, 31.7 dBm EIRP linear, FM ΔF ±9±1 KHz, 2400 Hz AM subcarrier

Beacon 136.77 MHz, 250 mW, 10 dBm EIRP, linear polarized,
FM composite sub-carriers
Channel 1 IRIG-7 2300 Hz SPM "return to bias" when s/c is away from CDA
Channel 3 IRIG-9 3900 Hz 150 rpm IR horizon scanner "differentiated" pulses

Modifed ITOS (ITOS-D to G)

Reference: NESS-35 and NESS-60

Box-like structure, 102x102x145 cm with 3 163x91 cm solar panels
±½° pitch axis control by momentum wheel, spinning at 150 rpm
yaw and roll control by coils
Sun synchronous, near polar 1464 ± 46 km, 101.7°, 115.14' orbit
67' day/35' night

Sensing instruments
- 2 VHRR
- 2 SR
- 2 VTPR
- 1 SEM

thermal, vehicle dynamics, power command and communications sub systems

VHRR Very High Resolution Radiometer, 2 channel
- 400 rpm
- 0.6 mr IFOV (0.8 km SSP) both channels
- 0.6-0.7 microns VIS, silicon photodiode detector
- 10.5-12.5 micron IR HgCdTe detector cooled to 105°K by radiant cooler.
- Prime mode VHRR 1, ir channel followed by VHRR 2 vis channel , time multiplexed by operating VHRR 1 and VHRR 2 180° out of phase.
- Backup mode 1. IR only from selected VHRR on one 99 KHz subcarrier
- Backup mode 2, IR and VIS from selected VHRR on separate 99 and 249 KHz subcarriers

VREC VHRR Recorder
- 8.5 minute record capacity, RD:PB is 1:1
- records prime mode or IR only mode (99 KHZ FM) and F&W

SR Scanning Radiometer
- 48 rpm
- 0.5-0.7 micron VIS, silicon photovoltaic detector, 2.8 mrad IFOV, 4 km SSP
- 0.4-1.1 microns from NOAA-3
- 10.5-12.5 micron IR, thermistor bolometer detector, 5.3 mrad IFOV, 7.5 km SSP

SRR Scanning Radiometer Recorder (3) NESS-52
3 unit each with 209'minute record time
RD:PB ratio is 1:20.83 (5.5')
SR 1 time multiplexed IR & VIS video sco deviation 3.58-4.86 KHz
SR 1 F&W 6.25 KHz
SR 2 time multiplexed IR & VIS video
SR 2 F&W
DDP output at 512 bps, replay at 10.667 kbps rate

VTPR Vertical Temperature Profile Radiometer NESS-65
8 bands between 11 and 19 microns, 6 in 15 micron CO2 band, 11 microns and 18 micron water Vapor band
single optical system with pyroelectric detector and a filter wheel with 8 spectral defining filters (120 rpm/62.5 ms per filter) 0.5s dwell time, 23 steps 2.235°x2.235° FOV
data processed by DDP and recorded by SRR
NOAA-3, 4 & 5 transmitted VTPR on the 137.14 MHz beacon transmitter, 512 bps PCM/PM

SEM Solar Environment Monitor NESS-29, NESS-49 and NESS-73
Protons – 10, 30 and 60 Mev
Electrons – 100 to 750 Kev
Data processed by DDP and recorded on a SRR and transmitted real-time at 16 bps 'return to bias' (20 9-bit words over 12.5 sec) over the BCN

DDP Digital Data Processor
Formats various data into 512 bps data stream for SRR or real-time transmission on BCN
Analog VTPR
Attitude data
Command verification
Accelerometer vibration data during launch phase
Digital Solar Aspect Sensor (DSAS)
S/c time reference code (time increment since last reset)

APT Automatic Picture Transmitter
IR transmitted directly, VIS tape delayed by 625 ms
7 pulses of 300 Hz sync added before IR and VIS scans, IR tlm is 6 steps, VIS tlm is 11 lines of tlm then 14 lines of steps
Redundant VHF transmitters and antennas, 137.5 and 137.62 MHz , 5W, linear, ΔF ±9 KHz, 2400 HZ am sub-carrier, antenna coupler provides quadrature feed to 2 ½λ dipoles mounted on the ends of the solar panels

HRPT High Resolution Picture Transmission
Redundant 99 & 249 Khz FM subcarriers oscillators cross-strped to redundant S-band transmitters, 1697.5 MHz, 5W, and crossed dipole over ground plane RHCP antenna, also used over CDA for playback

Operate/playback modes
A. VHRR RT prime
B. VHRR RT prime or backup
C. VHRR RT prime, VREC PB, VREC F&W, SRR-B video, SRR-B F&W, Digital-B
D. VHRR RT prime, SRR-A video, SRR-A F&W, SRR-B video, SRR-B F&W, Digital-A, Digital-B
Mode C and D use 2 sco (99 and 249 KHz) with reduced carrier deviation (55 KHz)

BCN Beacon aka Direct Sounder Broadcast (DSB)
Redundant dual sco and dual frequency transmitters via filter network to monopole antenna
NOAA-2 both 136.77 MHz
NOAA-3 onwards, 136.77 with 2 sco and 137.14 MHz with 2 sco and phase modulated Direct Broadcast DDP data (MI= 0.24 rad) at 512 bps RF bw 8.5 Khz, video bw 50-770 Hz (DDP = VTPR, SPM, telemetry and time code)
3.9 KHz sco SPM data or PAM HK TLM from DDP, Sun angle, Command Verification when over CDA
2.3 KHz sco attitude data from dual IR pitch sensors in momentum wheel

CMD 148.56 MHz , Single monopole antenna via filter network to redundant command receivers, redundant command decoders ach with different 5.35 s enable tones, 12 bit s/c address (2 1s and 10 0s format) FSK return to bias data, Decoder maintained on by FSK tone. Direct commands 2 of 12 with 13th bit, remote commands 2 of 12 plus 28 bit timer program or attitude data, 6.5 s up date rate.

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TIROS-N series

Parameter	TIROS-N	NOAA-6		NOAA-7	NOAA-8	NOAA-9	NOAA-10	NOAA-11	NOAA-12	NOAA-13	NOAA-14
Launch	13/10/1978	27/6/1979	29/5/1980	23/6/1981	28/3/1983	12/12/1984	17/9/1986	24/9/1988	14/5/1991	9/8/1993	30/12/1994
End of Life	27/2/1979	31/3/1987	FTO	7/6/1986	9/1/1986	22/5/1996	22/3/1995	10/4/1995	10/8/2007	21/8/1993	14/5/2007
Pre-launch	TIROS-N	NOAA-A	NOAA-B	NOAA-C	NOAA-E	NOAA-F	NOAA-G	NOAA-H	NOAA-D	NOAA-I	NOAA-J
Designation	1978-96A	1979-57A		1981-59A	1983-22A	1984-123A	1986-73A	1988-89A	1991-32A	1993-50A	1994-89A
Catalog no	11060	11416	11819	12553	13923	15427	16969	19531	21263	22739	23455
Launcher	Atlas-F	Atlas-F	Atlas-F	Atlas-F	Atlas-E	Atlas-E	Atlas-E	Atlas-E	Atlas-E	Atlas-E	Atlas-E
Apogee	864	823		869	801	841	824	863	819	863	858
Perigee	849	807.5		852	826	862	803	845	812	850	848
Inclination	98.92’	98.74		98.9	98.2	98.9	98.66	98.91	98.5	98.91	99
Period	102.3	101.26		101.92	101.2	102.0	101.277	101.9	101.2	102.07	101.2
Mass	1405	1405	1405	1405	1712	1712	1712	1712	1405	1712 kg	1712.3 kg
AVHRR	2	2			2		2				
AVHRR/2				2		2		2	2	2	2
SSU				2	Dummy	2					
MSU	2	2		2	2	2	2	2	2	2	2
HIRS/2	2	2		2	2	2	2	2	2	2	2
SEM	1	1		1	Dummy	1	1				
DCS	1	1		1	1	1	1	1	1	1	1
SBUV						Ballast		1		1	
ERBE						Ballast	1				
SAR					1	1	1	1	1	1	1
HRPT	1707	1698		1707	1698	1707	1698	1707	1698	1707	1707
APT	137.62	137.5		137.62	137.5	137.62	137.5	137.62	137.5	137.62	137.62
Telemetry	137.77	136.77		137.77	136.77	137.77	136.77	137.77	136.77	137.77	137.77
Command	148.56	148.56	148.56	148.56	148.56	148.56	148.56	148.56	148.56	148.56	148.56

FTO Failed To Orbit
S/C Lifetime & Orbital parameter for TIROS-N to NOAA-9 from Rao (corrected) and for NOAA-10 to NOAA-14 from NOAASIS
NOAA-13 suffered power supply short circuit within 2 weeks of launch. See rescue attempts and Failure Report
NOAA-14 APT off since 14 August 2002

Summary of Meteorological Satellites

Refer NOAASIS www URL http://noaasis.noaa.gov/NOAASIS/ml/status.html for current status

Revision of 1 March, 2009

AVHRR - Advanced Very High Resolution Radiometer, 4 channel, 360 rpm
All channels are 1.3mr IFOV with 1.1km ssp

Channel 1 0.55-.68 micron, silicon detector, (was 0.55 – 0.90 µm TIROS-N)
Channel 2 0.725-1.0 micron, silicon detector
Channel 3 3.55-3.93 micron, InSb detector
Channel 4 10.5-11.5 micron, HgCdTe detector

AVHRR/2 - Advanced Very High Resolution Radiometer, 5 channel, 360 rpm
All channels are 1.3mr IFOV with 1.1km ssp

Channel 1 0.55-.68 micron, silicon detector
Channel 2 0.725-1.0 micron, silicon detector
Channel 3 3.55-3.93 micron, InSb detector
Channel 4 10.5-11.5 micron, HgCdTe detector
Channel 5 11.4-12.4 micron, HgCdTe detector

HRPT – High Resolution Picture Transmission, 6 line/sec, 11090 10-bit words/line, 5 channel x 2048 pixel + TIP PCM, 665.4 kbps Bi Ø-L, ±67° PM, 1698, 1702.5, 1707 MHz, 5W, RHCP
APT – Automatic Picture Transmission, 120 line/minute 2 channel analog video amplitude modulates a 2400 Hz sub-carrier that then frequency modulates either 137.50 or 137.62 MHz, 5 W, RHCP, ΔF ± 17 KHz
Telemetry – Direct Sounder Broadcast (DSB), 8320 bps PCM Bi Ø-L, ±67° PM, 136.77 or 137.77 MHz, 250 mW, Linear Polarization, 104 8-bit words/minor frame
Command – 148.56 MHz, 1000 bps Ternary FSK/AM (8, 10 & 12 kHz)

ATN - Advanced TIROS N

Parameter	NOAA-15	NOAA-16	NOAA-17	NOAA-18	NOAA-19
Launch	13/5/1998	21/9/2000	24/6/2002	20/5/2005	6/2/2009
End of Life	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
Pre-launch	NOAA-K	NOAA-L	NOAA-M	NOAA-N	NOAA-N'
Designation	1998-30A	2000-55A	2002-32A	2005-018A	2009-005A
Catalog No	25338	26536	27453	28654	33591
Launch Vehicle	Titan-23G	Titan-II	Titan-II	Delta-II	Delta-II
Apogee	802	860	822	865	866
Perigee	818	844	804	846	845
Inclination	98.5	98.9	98.7	98.9	98.7
Period	101.09	101.98	101.16	102.04	102.06
Mass	2231 kg	2231 kg	2231 kg	1420 kg	1420 kg
AVHRR/3	1	1	1	1	1
HIRS/3	1	1	1		
HIRS/4				1	1
AMSU-A	1	1	1	1	1
AMSU-B	1	1	1		
MHS				1	1
SEM/2	1	1	1	1	1
SBUV/2	1	1	1	1	1
DCS/2	1	1	1	1	
A-DCS					1
SARR	1	1	1	1	1
SARP/2	1	1	1	1	
SARP/3					1
HRPT	1702.5	1698	1707	1698	1707
APT	137.5	Failed	137.62	137.10	137.9125
Beacon	137.35	137.35	137.77	137.35	137.77
A-DCS TXU					465.9875
Telemetry	2247.5	2247.5	2247.5	2247.5	2247.5
Command	2026.0	2026.0	2026.0	2026.0	2026.0

NOAA-16 APT failed 15 November 2000
NOAA-N' damaged in manufacturing incident 6 September 2003.

AVHRR/3 – Advanced Very High Resolution Radiometer, 6 Channels, 360 RPM
All channels are 1.3mr IFOV with 1.1 km resolution at satellite sub-point

Channel 1	0.580 – 0.68 μm
Channel 2	0.725 – 1.00 μm
Channel 3A	1.580 – 1.64 μm
Channel 3B	3.550 – 3.93 μm
Channel 4	10.30 – 11.3 μm
Channel 5	11.50 – 12.5 μm

Beacon – now 1W, RHCP.
Telemetry – 16.64 kbps Boost mode (during launch), 8.32 kbps TIP mode on orbit
Command – 2000 bps NRZ-M BPSK on 16KHz sub-carrier, ±1 radian PM on USB carrier.

A-DCS TXU – 400 bps PCM (HDLC)/Bi-Phase-L/PM. Command and Interrogation Downlink to ARGOS-3 Platform Message Transceivers, PMT.

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